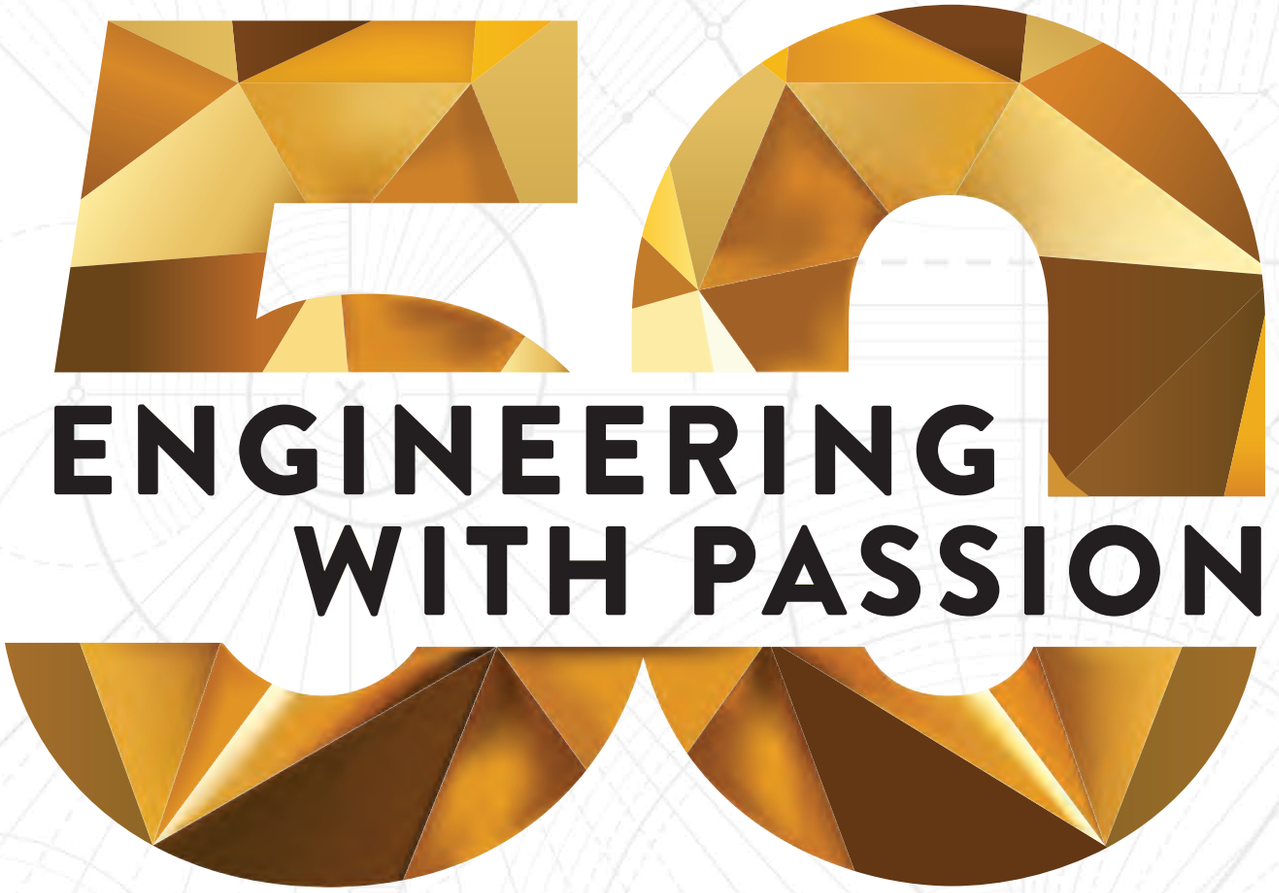
ST Engineering



ENGINEERING WITH PASSION

SINCE 1967

CELEBRATING 50 YEARS OF INNOVATIVE ENGINEERING

GREETINGS FROM
ST ENGINEERING
EMPLOYEES ACROSS
THE WORLD

E N G I N E E R I N G

WITH PASSION

OVERVIEW

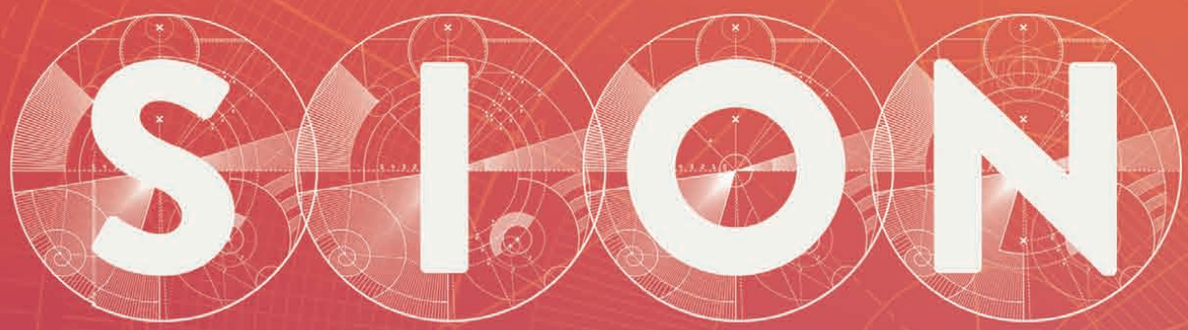
WE DEDICATE THIS BOOK TO OUR CUSTOMERS AND PARTNERS FOR THEIR TRUST, OUR FOUNDING FATHERS FOR THEIR VISION, OUR SHAREHOLDERS FOR THEIR FAITH, OUR PIONEERS AND STAFF FOR THEIR COMMITMENT AND PASSION.

PREFACE

PEOPLE AND PURPOSE

ASPIRATIONS AND AMBITIONS

SOLUTIONS AND SERVICES



Prime Minister's Foreword

The story of Singapore would be incomplete without recognising the contributions of ST Engineering. As part of the defence eco-system, it has played a critical role supporting our security and defence. As a commercial concern, it has matured into one of our home-grown multinationals.

Likewise, the story of ST Engineering would be inconceivable without the bold and enterprising spirit of the pioneer defence engineering companies, led by visionary leaders and supported by industrious people. Many of them spent their entire careers with the Group.

ST Engineering began as the Chartered Industries of Singapore (CIS). At the behest of Singapore's first Minister for Defence, Dr Goh Keng Swee, CIS was run as a commercial enterprise independent of the government. It was a model that all subsequent defence companies would follow. This hard-nosed approach, with no guaranteed safety net, made their jobs much tougher. The team had to innovate and work hard to stay profitable. But the experience produced a generation of determined managers and inventive engineers whose sheer grit and ingenuity overcame all odds and kept the pioneer companies operating and thriving. They forged a strong work ethos based on quality and excellence that continues till today.

Like its previous incarnations, ST Engineering is a strategic partner supporting the Singapore Armed Forces. It plays an indispensable role in Total Defence, keeping Singapore safe and secure.

ST Engineering has done equally well applying its engineering capabilities commercially. Today, it is the world's largest independent airframe maintenance, repair and overhaul service provider, and biggest enterprise Very Small Aperture Terminal systems manufacturer. It develops innovative software and systems that enable the Internet-of-Things, cyber security and smart cities. Its public transport solutions are deployed in many metropolises. It makes smart masks that fit the smaller faces of children, and energy-efficient outdoor cooling systems suited for tropical climates. It has built Singapore's first commercial satellite that now orbits the earth, with a second one on its way.

The type of engineering challenges might have changed over time but their relevance has not. Singapore will always need engineers who are intensely curious, with a passion to solve real-world problems and improve our lives. As one of the largest private sector employers of engineers in Singapore, ST Engineering has built a strong foundation of engineering capabilities crucial to Singapore's future economy and its efforts to become a smart nation.

This book honours the accomplishments of the pioneers and celebrates the passions of its people. It offers an insight into the thinking that has shaped the course of ST Engineering's history, and the perspective that will guide its path forward.

Congratulations on your 50th Anniversary, and may you engineer another successful 50 years!

Lee Hsien Loong
Prime Minister
Singapore

Message from Deputy Prime Minister & Coordinating Minister for National Security

ST Engineering traces its roots to the pressing need to build up our industrial capacity to support the needs of the fledgling Singapore Armed Forces (SAF) in the 1960s. From the outset, the companies that were later to come together as ST Engineering not only had to provide high quality products and services, but were also required to be commercially run.

The pioneers of ST Engineering rose to this demanding challenge, and built efficient and reliable companies that supported the SAF cost-effectively.

ST Engineering made significant strides through the decades, as the SAF moved from just requiring maintenance and support, to wanting equipment that was tailored to its operational requirements in a cost-effective way. ST Engineering successfully carried out programmes such as the A4 Super Skyhawk upgrade, new Bionix Infantry Fighting Vehicle, and the highly-flexible Endurance-class Landing Platform Dock. ST Engineering also moved to meet the needs of the networked Third-Generation SAF, developing various command and control and communications systems.

These programmes not only met the needs of the SAF but also catalysed the build up of a core of highly capable engineers in ST Engineering. They were able to draw on this spectrum of deep engineering expertise to develop home-grown and dual-use products and services for commercial applications beyond Singapore.

After five decades of progress, ST Engineering is now a company known for its innovative technology products and services for both military and commercial applications. It has found success in international markets as a leading Maintenance, Repair and Overhaul provider for commercial aircraft, providing systems for mass transit trains, supplying armoured vehicles, unmanned systems and warships to discerning customers, and connecting people through satellite communications. As a technology leader with a global network, ST Engineering has a distinct advantage to be a significant player in providing solutions for smart cities and the digital economy.

This book is a testament to the engineering capabilities and enterprising spirit of the people in ST Engineering through these five decades as they constantly seek out new frontiers and break new ground in making the Group a trailblazer in technology, defence and engineering globally. This is an achievement that every member of the ST Engineering team can be proud of.

I am proud to have been a partner in the progress of ST Engineering over the years, and to have known and worked with many of the people who have made ST Engineering what it is today.

Congratulations on your Golden Jubilee, and I wish you many more years of progress and success.

Teo Chee Hean

Deputy Prime Minister &
Coordinating Minister for National Security
Singapore

Chairman's Message

Our 50th anniversary is a major milestone, considering how far ST Engineering has come from its humble beginnings. We have much to be proud of. Over the last five decades, ST Engineering has stayed true to its role, making significant contributions to the security of Singapore together with the Defence Technology Community. We have established good business fundamentals, found success with our commercial operations and extended ourselves as a global company. Today, we are a leading engineering group with 22,000 employees across 22 countries.

These accomplishments stem from the visionary leaders of Singapore and the contributions of everyone at ST Engineering, past and present, and that of our customers, collaborators and business partners.

As we celebrate our Golden Jubilee, we are standing at the crossroads of exciting changes. Artificial intelligence, robotics and the information age are no longer distant ideals. Smart cities and communities of the future depend on reliable technologies and engineering to solve problems and existential challenges. Our philosophy is to build on our capabilities and knowledge to come up with more technology 'unicorns' – not just profitable businesses, but iconic innovations that can make a difference to societies and mankind.

As a global technology, defence and engineering group, we are uniquely placed to develop cutting-edge solutions and forge long-term partnerships by channelling our strengths to achieve a multiplier effect for our stakeholders. It is an earnest goal that has seen us through the last 50 years.

The next 50 years will be even more exciting for ST Engineering. We must be prepared to think differently, and to take greater leaps of faith in technology and innovation. We have competent people who have proven their tenacity and commitment to this cause, and a capable leadership that is ready to run the next lap.

ST Engineering is more than ready for its new challenges. Our hard-earned achievements and the testament to our pioneering spirit and engineering passion will drive us to accomplish more and create greater value for all who have a stake in the Group's success.

Happy 50th birthday, ST Engineering!

Kwa Chong Seng
Chairman
ST Engineering

President & CEO's Preface

The history of ST Engineering's development, 50 years in the making alongside Singapore's growth as a nation, is well documented. I am sure many readers are familiar with the founding of Chartered Industries of Singapore, the formation of Sheng-Li Holdings and Singapore Technologies, and the evolution of ST Engineering after that. It was the early interest of our pioneer companies in technology and engineering that supported the initial decades of nation building and our growth as a Group.

Less known, perhaps, are the people stories that underlie ST Engineering's success: the anecdotes of our pioneers during the formation years; the thinking behind the strategic decisions of our past and present leaders as they expanded their operations and transformed the Group; as well as interesting and highly relatable tales of triumphs and setbacks in engineering, remembered by those whose knowledge, skills and careers have shaped our achievements in the Aerospace, Electronics, Land Systems and Marine sectors.

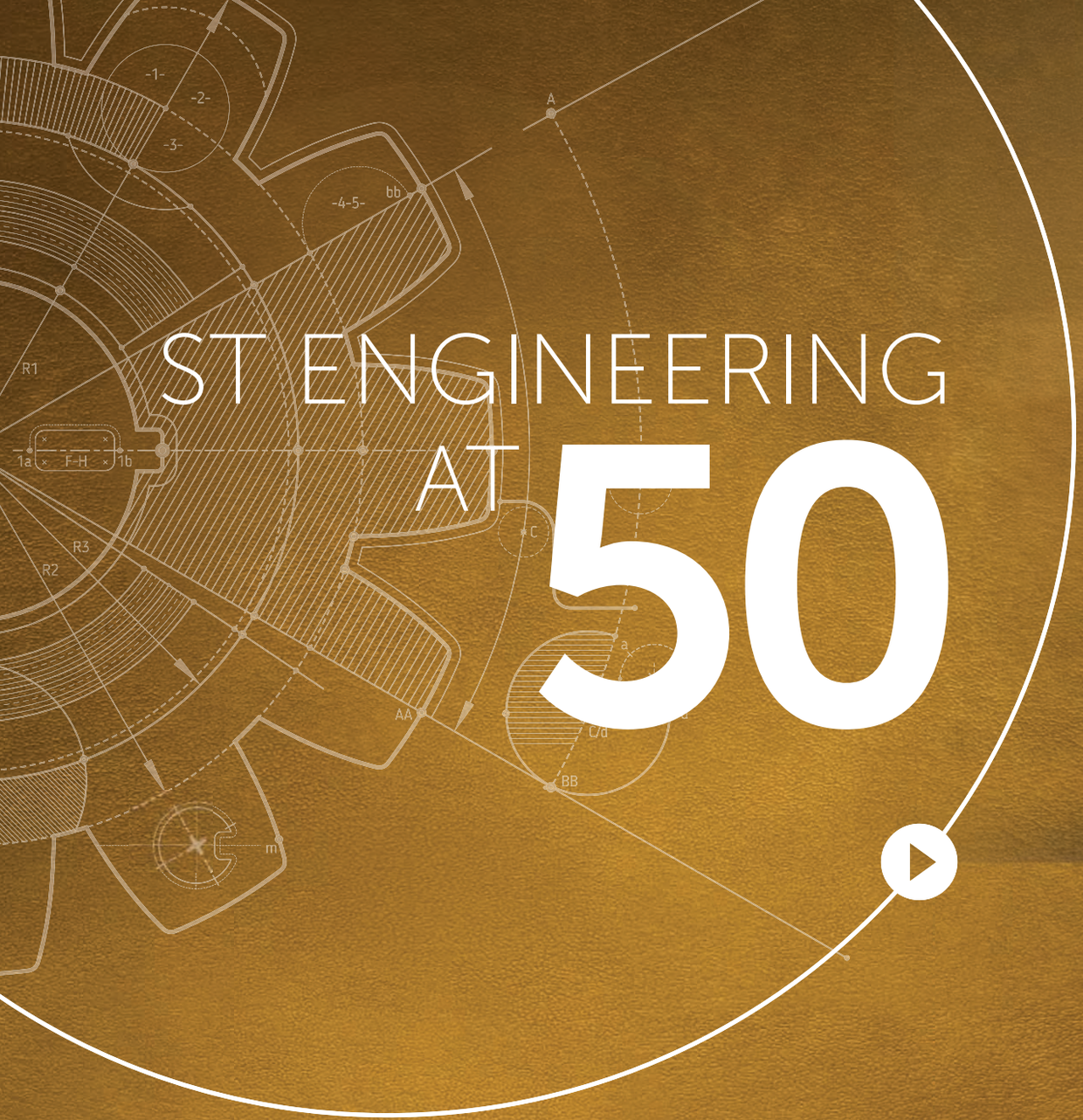
This book is an attempt to curate some of the stories that define ST Engineering at 50. It captures many fond memories as well as vivid lessons in our journey and is a continuation of earlier chronicles, "Towards Tomorrow" and "Under One Sun", published to celebrate Singapore Technologies' 30th anniversary and ST Engineering's 40th anniversary respectively. There are many more people and contributions that make up the ST Engineering story. We are not able to feature them all.

The stories in this commemorative book are organised into seven chapters detailing the drive of our **People and Purpose**; the conviction of our **Ambitions and Aspirations**; the breadth of our **Solutions and Services**; the rigour of our **Standards and Systems**; the thoroughness of our **Ideas and Innovations**; the lessons from our **Opportunities and Outcomes**; and our commitment to **Nature and Nurture**. These titles form the acronym PASSION, which is the essence of our theme for the Golden Jubilee, Engineering with Passion.

Today, ST Engineering is a global technology, defence and engineering Group because of our visionary pioneers, the unwavering support of our loyal customers and business partners, and the hard work of generations of staff who have upheld our core values.

Sir Isaac Newton once said, "If I have seen further, it is by standing on the shoulders of giants." We have been similarly inspired to dream and create by standing on the shoulders of our pioneers and predecessors who have shown that we can make a big difference in the lives of people that we serve. Beyond the Golden Jubilee, this book celebrates the stories of the giants in our midst – ordinary people with extraordinary passion.

Vincent Chong
President & CEO
ST Engineering



ST ENGINEERING AT 50

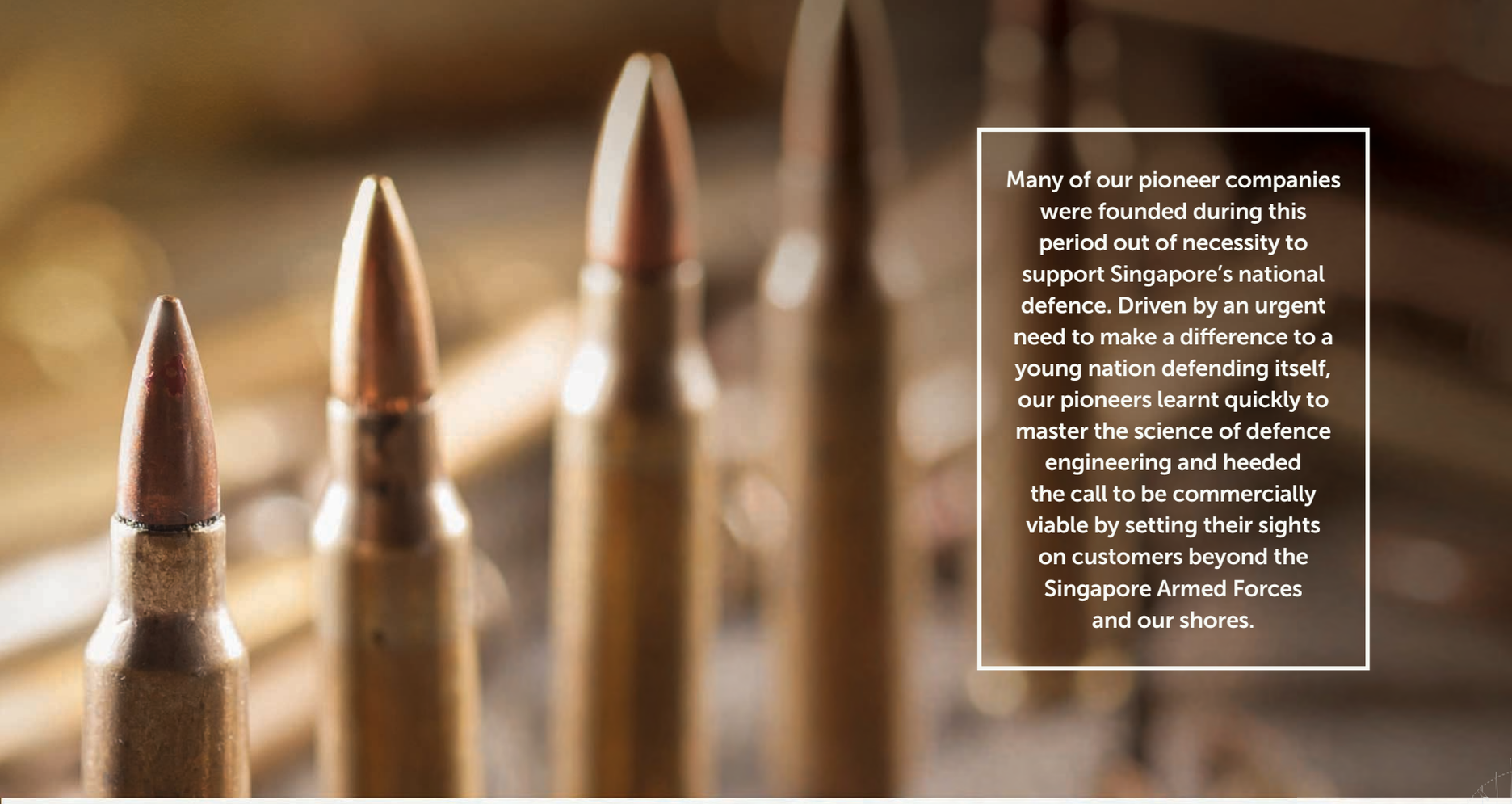
ST Engineering's history began in 1967 as an ammunition manufacturer and subsequently as a military platforms service provider.

The birth of our pioneer companies in shipbuilding, electronics, engineering, automotive and aerospace gave rise to our formation and set us on course for expansion. With foresight, perseverance and the determination to succeed, we overcame challenges, forged partnerships and broke new ground with our innovative solutions for customers around the world.

The amalgamation of the various companies under the Singapore Technologies group to form ST Engineering in 1997 sparked our transformation. It was a period when the Group grew in size and stature, expanding in geographies and customer base towards a vision of being a global defence and engineering group.

The Group's footprint now stretches across four continents and our products are into the depths of the oceans and up to the vastness of space. ST Engineering is what it is today because of our unity in strength and because we dared to dream. We aspire to make a difference; we are and will remain passion-driven to engineer the future.

The milestones of our illustrious journey are reflected in the formation, expansion, transformation and aspiration of the Group over the last 50 years.



Many of our pioneer companies were founded during this period out of necessity to support Singapore's national defence. Driven by an urgent need to make a difference to a young nation defending itself, our pioneers learnt quickly to master the science of defence engineering and heeded the call to be commercially viable by setting their sights on customers beyond the Singapore Armed Forces and our shores.

FORMATION

1970

1979

1967
- Formation of Chartered Industries of Singapore to manufacture 5.56mm ammunition for the M16 rifle.

1968
- Formation of Singapore Shipbuilding and Engineering (precursor of ST Marine) to provide local capability to build and repair naval vessels.

1969
- Formation of Singapore Electronic & Engineering (precursor of ST Electronics) to provide Singapore Armed Forces with electronic and electrical services.
- Won contract to design and build four Missile Gun Boats for the Singapore Maritime Command in collaboration with Fr Lurssen Werft GmbH of Germany.

1970
- Maiden ship construction project, a 25m ferry boat named 'Kuala Batee'.

1971
- Formation of Singapore Automotive Engineering (precursor of ST Kinetics) to perform high echelon maintenance and refurbishment of heavy military vehicles for MINDEF.

1975
- Formation of Singapore Aerospace Maintenance Co. (precursor of ST Aerospace) to take over the services hitherto provided for the Republic of Singapore Air Force by Lockheed Aircraft Services Company.

1978
- Won contract for Building Automation System for Changi International Airport.

1979
- Launched Ultimax 100, which is still the world's lightest and lowest recoil light machine gun.

EXPANSION

1990


1994

1984
- Obtained Air Operator Certificate to start air charter business.
- Awarded 1st rail electronics contract to support the supervisory control and communication system for Singapore's 1st MRT line.

1988
- Commissioned to upgrade the AMX-13 SM1 Tank that significantly boosted engineering capability.
- FH-88 155mm howitzer guns, Singapore's 1st indigenous howitzer, entered into service.

1990-1991
- Start of the Singapore Technologies era, when most business units in the group carried the Singapore Technologies family name and used the new sunburst logo.
- In 1990 and 1991, defence-related subsidiaries of Singapore Technologies were publicly listed, shedding their image of a wholly government-owned group.
- Diversified into commercial aviation segment with set up of 1st commercial airframe MRO facilities in Singapore in 1990 and Alabama, US in 1991.

1992
- First shipyard in Singapore to acquire the knowledge to outfit and repair vessels made from glass-reinforced plastic.

1993
- Contracted by the Republic of Singapore Navy to design and build 12 Fearless class Patrol Vessels.
- Rolled out test-bed tracked armoured vehicles that would lead to the Bionix Infantry Fighting Vehicle and subsequent families of armoured vehicles.

1994
- Expanded marine operations with 2nd shipyard in Tuas, Singapore.

1995
- Set world record with fastest turnaround time for Boeing 747 forward-fuselage (Section 41) modifications.
- FH-2000, the world's 1st military-fielded 155mm 52 calibre howitzer, was commissioned into service.

The pioneer companies steadily ascended the technology ladder and built a reputation for quality and reliability in both commercial and military businesses. Their track record of successes went beyond Singapore and gradually gained international respect and recognition.

Three decades of relentless growth produced a diverse collection of core competencies across aerospace, electronics, land systems and marine sectors. These pioneer companies were amalgamated as one ST Engineering in 1997.

TRANSFORMATION

2001

2003

1997
- ST Aerospace, ST Electronics, ST Automotive and ST Marine merged to form ST Engineering, a listed company with market capitalisation of S$2 billion.

1998
- Installed Intelligent Building Management Systems for Jin Mao Building in Shanghai, China.

1999
- Singapore-made SAR21 assault rifles sold to more than 10 countries since its launch.
- The Bionix Infantry Carrier Vehicle shortlisted as one of the finalists of the US Army's Interim Armoured Vehicle Programme.

2000
- ST Automotive acquired Chartered Industries of Singapore and renamed as ST Kinetics, effectively consolidating all defence-related pioneer companies within ST Engineering.
- Completed the 1st DC-10 Passenger-to-Freighter conversion for Boeing.
- Set up ST Dynamics as the Group's Advanced Engineering Centre to develop a broader portfolio of future technologies and capabilities.

2001
- Bronco, the All Terrain Tracked Carrier with the world's highest payload, was commissioned into service.

2002
- Set up VT Systems in Virginia as US headquarters. It has since acquired more than 10 companies including businesses in aerospace, marine, specialty vehicles and satellite-based communications.
- Set up 2nd commercial aircraft MRO facility based in San Antonio, US.
- Attained top placing in Aviation Week's biennial Top Airframe MRO provider ranking survey and continues to hold top position today.

2003
- SARS hit; developed Infrared Fever Screening System which was named TIME Magazine's Coolest Invention of the Year.

2004
- Delivered the 1st Singapore-built stealth frigate to the Republic of Singapore Navy.
- Entered China with the 1st airframe MRO facility in Shanghai.

While focusing on our core defence business, the Group pushes the frontiers of technology and engineers possibilities from the depths of the oceans and to the vastness of space.

TRANSFORMATION


2008

2009

2005
- Secured contract from US Navy to design and construct Fast Missile Craft for the Egyptian Navy.

2006
- The Group's quarterly turnover crossed the billion-dollar mark, with a three-fold growth compared to its debut listing in 1997.

2007
- First public listed company to be awarded the inaugural Singapore Quality Award with Special Commendation.
- Secured the single largest Passenger-to-Freighter conversion contract to convert 87 Boeing 757-200 aircraft.
- Launched Terrex, the world's most advanced 8x8 wheeled Infantry Fighting Vehicle.
- Awarded by MINDEF to design, build and operate a Submarine Support Rescue Vessel (SSRV), first privately-owned SSRV to be operating in the region.
- Established ST Aerospace Academy to venture into commercial pilot training business with a focus on Multi-Crew Pilot Licence.

2008
- Implemented a Traffic Control Centre for Beijing 2008 Summer Olympics.
- Started engine MRO facility in Xiamen, China.
- Contracted by DOF Subsea to build a Diving Support Vessel, first of its kind to be constructed in a Singapore shipyard.
- Awarded by Royal Thai Navy to design and build a Landing Platform Dock, the first contract with a regional navy.

2009
- First shipyard to design, build and deliver Roll-on/Roll-off vessels in Singapore.

2010
- Diversified into environmental engineering market with waste management and water treatment projects in Brunei and China.
- Set up office in Sao Paulo, Brazil.

2011
- Awarded US Government-approved Proxy Agreement to pursue classified government and military contracts.

2012

2013

2012

- Secured naval export contract to design and build four patrol vessels for the Royal Navy of Oman.
- First in the world to launch A330 Passenger-to-Freighter conversion programme, in partnership with Airbus.
- Penetrated US and Malaysia markets for rail electronics solutions.
- Launched AERIA, a new VIP aircraft interior completion brand to tap the growth opportunities in aircraft interior design and engineering.
- US shipyard expanded and added shiprepair capability to its offerings.
- Aerospace sector restructured its Scandinavian operations following a business review.

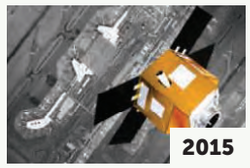
2013

- Contracted to build eight Littoral Mission Vessels for the Republic of Singapore Navy.
- Added a new airframe MRO hangar at the Changi facility and an aviation centre at the Seletar facility in Singapore.

2014

- Only Singaporean company named in the Forbes' list of The World's Most Innovative Companies.
- Set up aircraft MRO facility in Guangzhou, China.
- iDirect became the world's largest VSAT systems manufacturer by enterprise hardware sales, according to the 13th edition of COMSYS VSAT Report.
- Opened the ST Electronics Satellite Systems Centre for the design and manufacturing of satellite systems.

TRANSFORMATION


2015


2016

2015

- Launched AIR+ Smart Mask, the world's 1st protective mask with an attachable Micro Ventilator.
- Contracted to supply Terrex 2 prototypes to US Marine Corps for evaluation phase of their Amphibious Combat Vehicle 1.1 programme.
- Set up the ST Engineering-NTU Corporate Laboratory jointly with Nanyang Technological University to focus on advanced robotics and autonomous systems.
- Collaborated with The Singapore Centre for 3D Printing to develop disruptive 3D printing applications.
- Launched TeLEOS-1, Singapore's 1st commercial Earth Observation satellite, which now orbits 550km above us in a Near Equatorial Orbit.

2016

- Increased stake in Elbe Flugzeugwerke to 55% and to develop and launch the A320/A321 Passenger-to-Freighter conversion programme.
- Deployed Asia's 1st fully-operational autonomous vehicle at Singapore's Gardens by the Bay.
- Unveiled Airbitat Smart Cooler, the world's 1st evaporative cooler that reduces temperatures by up to 10°C in warm and humid climates.
- Jointly set up a Cyber Security Laboratory with the Singapore University of Technology and Design.
- Opened new VIP aircraft interiors completion centre at the Seletar Aerospace Park in Singapore.
- Implemented Smart Street Lighting Control and Management in Canada, New Zealand, the UK and the US.

2017

- Launched year-round celebration of 50th anniversary.
- Retained first placing in Aviation Week Network's Top 10 Airframe MRO service provider for the seventh consecutive biennial ranking.
- Partnered DSTA to develop TeLEOS-2 with Synthetic Aperture Radar capable of capturing all-weather imagery 24x7.
- Launched the Singapore Autonomous Vehicles (AV) Consortium with industry partners and institutes of higher learning to develop AV standards and technologies for applications and adoption in Singapore.

ASPIRATION

ST Engineering has come a long way with a rich history of delivering innovative engineering solutions. We will forge ahead and retain our leading position among our competitors in the world.
We will further spark employee passion so that our people build meaningful connections with ST Engineering as a global technology, defence and engineering powerhouse.

PEOPLE AND PURPOSE

ST Engineering's success is fuelled by the passion of its people. From illustrious pioneers to industrious individuals, we have been enriched by the achievements of our past and present employees, whose resourcefulness and commitment have made ST Engineering the organisation it is today.

As the Group turns 50, we look back at the vignettes that have defined our history. Together, we celebrate our common purpose – to create value for our customers, partners and people. It has given all 22,000 of us the impetus to work as one team.

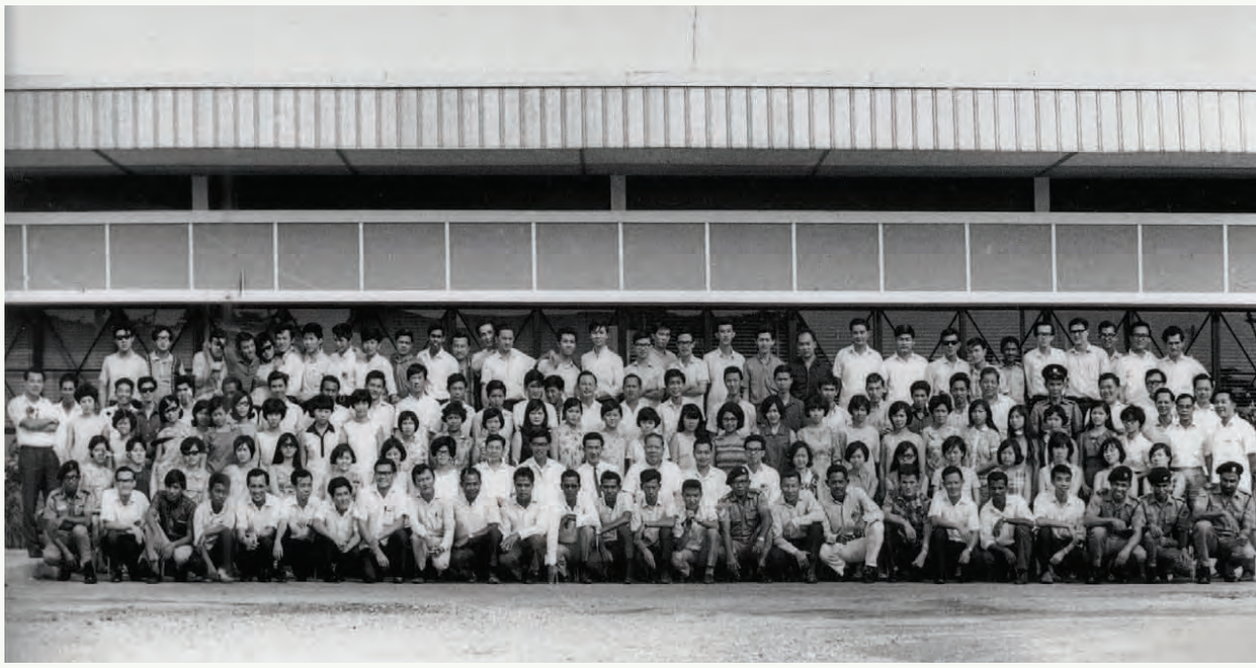
PIONEERING SPIRIT

In the Beginning

Dr Goh Keng Swee

Minister for the Interior and Defence (1965 - 1967)
Minister for Defence (1970 - 1979)
Deputy Prime Minister (1973-1984)

Photo courtesy of Ministry of Information and the Arts



CIS' employees in 1968.

The story of ST Engineering began in 1967 with the formation of Chartered Industries of Singapore (CIS). It was the idea of Dr Goh Keng Swee, the then Minister for the Interior and Defence and a founding father of independent Singapore. CIS was the first of several defence-related companies set up by Dr Goh to support the newly established Singapore Armed Forces (SAF). In 1974, Dr Goh set up Sheng-Li Holdings as an umbrella organisation to rationalise the budding defence industry, monitor their growth and coordinate activities. He picked the name Sheng-Li himself, which means 'victory' in Chinese.

By then, the defence industry had expanded with seven other defence pioneer companies, namely Singapore Shipbuilding & Engineering (SSE) to support the Republic of Singapore Navy (RSN); Singapore Electronic & Engineering Ltd (SEEL) to repair weapons and electronic equipment for the RSN; Singapore Automotive Engineering (SAE) to repair military trucks and AMX-13 tanks for the SAF; Allied Ordnance of Singapore (AOS) to assemble and repair naval guns; Ordnance Development & Engineering Company of Singapore (ODE) to produce rifle bayonets and mortars for the artillery units; SAF Enterprise (SAFE) to provide retail services to SAF personnel; and Singapore Food Industries (SFI) to buy and supply food to the SAF. These defence pioneer companies, except SAFE and SFI, would become part of today's ST Engineering.

> "CIS, when it started, formed the core of the government's industrial effort... We were confident national service would be successful, but at the beginning we were not confident about CIS... The arms market is heavily regulated. But in spite of this, CIS scored several remarkable successes. The ability of CIS to expand continuously in the face of limited support, a small home market, is due to its ability to compete worldwide.
>
> **Dr Goh Keng Swee**
> *Interview for Towards Tomorrow Singapore Technologies' 30th Anniversary Book, 1997*

Henry Cheong (far left) and Lai Chun Loong (right) accompanying President Wee Kim Wee (1984-1993) during his visit to CIS in 1986.

Photo courtesy of Ministry of Information and the Arts

"In 1967, Dr Goh planted the seed of CIS and gave it the charter for licensed manufacturing of the American M16 rifle and its 5.56mm ammunition, for use by the SAF. Concurrently, CIS minted circulation coins for the Board of Commissioners of Currency of Singapore. The Singapore Mint within CIS shared the tool and die workshop with the 5.56mm ammunition production line. Thus, CIS began by serving both military and civilian markets.

Philip Yeo
Board Member (from 1980) and Chairman of the Executive Committee of Singapore Technologies Holdings (1987 to 1993)

"I remember Dr Goh asking me over dinner after one of the technology showcases we organised for him whether CIS could make a gun that could shoot around a corner. It would have provided our soldiers a distinct advantage in urban warfare. The technology failed us at that time, and such a gun was only marketed by a foreign company in the early 2000s, a good thirty years later. The incident always reminds me of Dr Goh's foresight and how some of his ideas were truly ahead of their time.

Lai Chun Loong
General Manager (1980-1982), Managing Director (1983-1989) and President (1989-1993) of CIS

"I was appointed, along with a few others, as a member of the Sheng-Li Board by Dr Goh at the first meeting in 1973. Mr Ong Kah Kok, who just retired as Director Logistics, Ministry of Defence (MINDEF), was the Chairman. It was done matter-of-factly, without any of the formal process we have today.

At that first Sheng-Li Board meeting, Dr Goh made it very clear that profit was an important measure of success in managing a project or a business. And that every business decision the company makes is a potential to either create or destroy value. There were no qualms about moving anyone out of the way if that person was unable to perform. Dr Goh promptly sacked the General Manager of SSE when it was found out that he was making sales of S$5 million at a cost of S$7 million. The same happened to CIS and Mr Lai Chun Loong was quickly promoted to General Manager to make it profitable.

Mr Kua Hong Pak, then the newly appointed Managing Director of Sheng-Li, was asked by Dr Goh to come up with management procedures to help the various Sheng-Li entities manage their businesses better. And as the Director Logistics in MINDEF, I would be held responsible if Hong Pak did not do his job. I was lucky that Hong Pak performed and my neck was saved."

Prof Lui Pao Chuen
Director Logistics, MINDEF and Director, Sheng-Li Holdings (1973 – 1974) and Chief Defence Scientist of MINDEF (1986-2008)

A CIS employee inspecting 5.56mm rounds coming off the production line in 1968.

Photo courtesy of The National Archives of Singapore

In Service to the Nation

Prof Lui (left), Quek Poh Huat (middle) and Tan Pheng Hock (right) at the 'Remembering Portsdown' event in 2011. Operations at 5 Portsdown Road were closed after 40 years and consolidated at 249 Jalan Boon Lay in 2011.

In 1971, a young Major hustled to the Registrar of Companies. He was instructed by the then Minister for Defence Dr Goh Keng Swee to register for the incorporation of SAE. That young officer was Major Lui Pao Chuen, who had just been posted to the Office of Second Permanent Secretary as his Deputy to set up the Science and Management Group that would undertake projects considered by the Minister to be critical to the SAF. He forked out S$2 of his own money to register the company under his name. The new setup would provide depot level maintenance support for the V200 Armoured Personnel Carrier, and would evolve to become ST Kinetics, the land systems arm of ST Engineering.

Prof Lui, as he is known now, became the Chief Defence Scientist, and served on several Boards relating to ST Engineering and its subsidiaries at different periods, carrying with him, along with Mr Lim Ming Seong, the distinction of serving on the most number of Boards of the Group and its preceding entities. He is a firm believer in building up strong local capabilities to support the defence needs of Singapore and has advocated for the local development of landmark programmes like the Bronco All Terrain Tracked Carrier, command and control systems and more recently, the Next Generation Armoured Fighting Vehicle to provide leading-edge capabilities to the SAF.

Date	Company
1973-1974	Director, Sheng-Li Holdings
1974-1975	Chairman, Singapore Automotive Engineering
1981-1988	Director, Singapore Electronic & Engineering Limited (Chairman 1984-1987)
1981-1993	Director, Singapore Aircraft Industries
1982-1986	Chairman, Chartered Engineering
1986-1990	Director, Singapore Engineering Software (Chairman 1986 - 1987)
1994-1997	Director, Chartered Industries of Singapore
1997-2008	Director, ST Engineering
2004 onwards	Chairman, ST Dynamics
2004 onwards	Director, ST Electronics
2006-2009	Chairman, Advanced Technology Research Centre
2008 onwards	Director, ST Kinetics

Prof Lui planting a 'Happiness' tree at 249 Jalan Boon Lay in 2011.

"MINDEF knew from the start that defence would be an expensive business and importing technologies would make Singapore dependent on external sources over time. We needed our own local capabilities in strategic areas that could adequately support Singapore's defence needs.

It was also clear to Dr Goh that only those tasks requiring uniformed personnel would be performed by the SAF. All support functions that did not need uniformed personnel were done by civilians and anything that did not need to be done by the government were farmed out to the industries. This philosophy would guide the establishment of the defence industry, beginning with the formation of the CIS in 1967.

In the late 1960s, the focus was mainly on equipping the Army. The British Forces were expected to remain in Singapore until 1975, which would give us time to grow the Air Force and the Navy later on. To our horror, the British suddenly decided in 1967 to totally withdraw its forces by 1971. There was a mad rush to equip the three Services and to set up an industrial base capable of supporting the new SAF.

A number of defence pioneer companies were formed in quick succession after CIS to take over the operations left behind by the British, from shipbuilding and electronics to ordnance and aviation. Although these companies would operate based on Dr Goh's philosophy of profitability and national defence priority, they had to compete for SAF contracts at arm's length.

I have the pleasure of serving on the Boards of many of these companies till today, and can still see this pioneering spirit in ST Engineering. The Group is constantly leveraging its capabilities and international presence for new opportunities, while continuing to support the SAF as a strategic element of the local defence ecosystem.

ST Engineering has, in fact, gone way beyond our initial expectations with the success of its commercial operations. We have always thought it would be good if ST Engineering could meet the military requirements, better yet if it could sell some of the defence products overseas. We could never have anticipated that the flow of military technology into the commercial sector would become an important contributor to Singapore's economy, and that MINDEF would likewise benefit from the infusion of commercial technology in defence applications.

Prof Lui Pao Chuen
Chief Defence Scientist
(1986 to 2008)

Lai Chun Loong with CIS team in 1983.
Photo courtesy of Lai Chun Loong

Ground Zero

The CIS Administrative Building with its iconic watch tower, circa 1968.

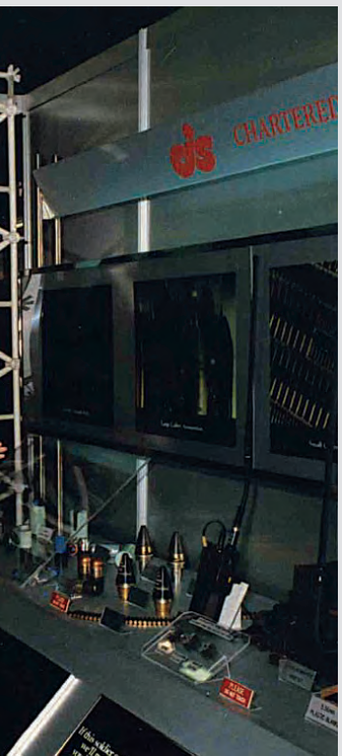
Somewhere in the mudflats of Jurong, a 24-hectare site had been earmarked for the construction of an ammunition factory. Opened in 1968 by Dr Goh Keng Swee, the premises became home to CIS, the first government-owned company to set up shop in the Jurong industrial estate. There were 10 employees and just one product – the 5.56mm round. 50 years on, the address, 249 Jalan Boon Lay, remains synonymous with the birthplace of Singapore's defence industry – the original manufacturing buildings where ST Kinetics' products are still being produced today. ST Kinetics itself came about in 2000 when the then ST Automotive, three years after merging into ST Engineering, acquired its previous parent company CIS. This brought all of the land systems pioneer companies back into one fold after years of organisational changes.

GUNNING FOR EXCELLENCE

Between 1977 and 1981, CIS would host annual technology showcases for the Defence Minister, Dr Goh Keng Swee. These were opportunities for the engineering department to demonstrate its latest products and innovations, ranging from hand grenades and fuses to telecommunication equipment and guns.

Teo Ming Kian (left) and Lai Chun Loong (middle) with Dr Goh Keng Swee (right) at Singapore Technologies 30th Anniversary Dinner in 1997.

Photo courtesy of Lai Chun Loong



Lai Chun Loong showing 2nd Minister for Defence, Mr Lee Hsien Loong (1987-1990) Chartered Electronics' proximity fuses and telecommunications equipment at Asian Aerospace 1988.

Photo courtesy of Lai Chun Loong

"These technology showcases are well remembered by many of us as casual get-togethers. We would chat over dinner on what worked and what didn't so as to develop ideas for future products. Dr Goh was a highly curious man who showed great interest in the new products displayed. He would quiz the engineers with all kinds of probing questions. So, we had to be constantly on our toes and know our work inside out.

The engineering department came up with the mock-up of a new rifle at one of these showcases. The display piece was quite heavy and this did not go unnoticed by Dr Goh. He was concerned that it would be unwieldy for the soldiers in the battlefield. The project was aborted and we jokingly called the rifle 'the elephant gun' after that.

Dr Goh was always a sharp observer. It forced us to pay greater attention to details, and to have a better understanding of customers' thinking. Working with Dr Goh, we all learned to become more persistent with our experimentation. These traits would eventually set the stage for CIS and later ST Kinetics to develop some of the most advanced weapon systems in the world."

Lai Chun Loong *worked in CIS from 1968 to 1993 in a variety of roles, with the last being President, CIS and Chairman, ST Automotive.*

PIONEERING SPIRIT

Henry Cheong (left) in the Netherlands for a fire control system evaluation exercise in 1968.
Photo courtesy of Prof Lui Pao Chuen

THE ROUND THAT MADE THE TANK

Mr Henry Cheong joined CIS Product Development in 1977 and became Director of Engineering in 1983. That was the year Mr Lai Chun Loong was appointed Managing Director. While CIS was known for its guns and bullets, few would appreciate the sheer amount of innovation and product development that went on behind its protected walls.

Henry Cheong (left) and Lai Chun Loong (right) at ST Engineering 50th Anniversary commemorative event on 26 January 2017.

"CIS was producing all kinds of rounds and thinking of new ways to make munitions work better in the hot and humid equatorial climate. Right across the 'longkang' (canal), the ODE chaps at Chin Bee Drive were making guns to fire these rounds. Despite being so close to one another, we didn't know what each of us was doing. Our work was shrouded in great secrecy.

One of my favourite projects was the armour-piercing projectile for the AMX-13's 75mm gun. We called it the Spider round because its technical name 'armour-piercing fin-stabilised discarding-sabot projectile' was a mouthful. We did a lot of fine-tuning on the projectile to make it work, like slowing down the spin and thickening the fins to clear the muzzle brake at the end of the gun. The Spider round became the world's most powerful 75mm round of its generation. With the cartridge filled to the brim with propellant to get the biggest bang for the buck, it was a potent tank killer.

This project was a case of the tail wagging the dog. Had we failed to make a working projectile that would give the Army a critical capability, they would have axed the AMX SM1 upgrade programme. Without the expertise and confidence from the AMX upgrade, we would not have pushed to make our own tanks later on and there would have been no Bionix!

Henry Cheong *worked in CIS from 1977 to 1996. He was CIS' first Engineering Director and fondly referred to as the "original mad scientist" by Ms Ho Ching, the founding Chairman of ST Engineering.*

MISTER WHY-NOT

"Philip Yeo was Chairman of CIS when I was the Engineering Director. Whenever we presented ideas for R&D projects to him, his typical response would be 'Why not?' No idea was too far-fetched for him. So, we started calling him 'Mister Why-Not' behind his back. With Philip's confidence and full backing, we had plenty of room to stretch our imagination and attempt the impossible.

Henry Cheong
Director of Engineering, CIS

THE ARMOURED VEHICLE THAT WAS ALMOST NEVER BUILT

"We may have designed and upgraded the AMX-13 tank to SM1, making it much more capable than it was originally designed for, and localised the upgrade kits for the M113 Ultra, but we did not have any track record in designing or building a complete armoured vehicle," said Mr Wu Tzu Chien, who was General Manager of ST Automotive from 1993 to 1997. "All we needed was an opportunity to show that we could achieve."

He recalled that Mr Lye Fei, his predecessor at ST Automotive and General Manager of SAE before that, had played a significant role to convince the SAF and MINDEF. "We relied heavily on the deep level of trust Lye Fei had built up with our local customer over the years. It was instrumental in securing the opportunity for us to build a full-size demonstrator. We did it in less than four months. It looked like the real thing and it worked! Most importantly, the whole endeavour demonstrated not just our capability – it also showed our commitment," Tzu Chien added.

Lye Fei reflected, "In those days before the Internet, reputation was everything. Trust and commitment in relationships were especially important and valuable, and had to be earned. Down the line, we needed to act as one to secure the customer's confidence. That made it important for us to get our culture and values right."

Lye Fei (left), Chairman of ST Automotive and Wu Tzu Chien (right), General Manager of ST Automotive in 1995.

In fact, Lye Fei is often credited for starting the 'family culture' at ST Automotive. The team was known for its 'pak si buay chow' (undaunting) spirit in conquering one challenge after another. Tzu Chien would perpetuate this spirit of steadfastness when he assumed the role of President, ST Automotive in 1997, after ST Engineering was formed. He left ST Automotive in 1998 to serve as President of ODE and a year later concurrently as President of CIS, before returning to become President of ST Kinetics from 2000 to 2006.

"During the course of the Bionix programme, the team composed a Triumph Poem and concocted a Funby Drink as a motivation to overcome the seemingly insurmountable challenges. I remember the cocktail started off bitter and ended on a sweet after-note," Tzu Chien laughed.

Senior management team of SSE in 1993. From left, Gan Chee Yen, Tan Pheng Hock, See Leong Teck, Boon Swan Foo, Wong Kin Hoong, Han Yew Kwang, Teh Yew Shyan, Tan Ching Eng & Tan Siew Teck.

Setting Sail

Singapore Shipbuilding and Engineering (SSE) was founded in 1968 by three Singaporean businessmen – Mr Tan Soen Swan, Mr Baey Lian Peck and Mr Whang Tar Liang – tasked by Minister for Finance Dr Goh (1967-1970) to set up a shipbuilding and marine engineering facility for a fledgling island state. Thus began the story of ST Marine as a private venture with a minority government stake, whose first yard was a humble structure with a zinc roof at the mouth of Benoi River. The fledgling company started off as a builder of tugs and barges, an assembler of these vessels. Early projects that set the company in motion included ferry boats, landing craft, oil barges, bulk carriers and harbour launches.

In 1969, SSE entered into a technical co-operation agreement with Fr Lurssen Werft, a German shipbuilder for transfer of technology in patrol craft design and construction. The same year, MINDEF awarded the contract to build a series of four 45-metre Missile Gun Boats.

The following year, SSE built its first boat, a 25-metre ferry boat named Kuala Batee.

By 1978, an impressive 133 vessels had been built and delivered to local and international customers. Amongst these were 10 multi-purpose Cargo Container Vessels for a consortium of European owners. At that time it was one of the largest contracts ever awarded to a local ship builder. However, there were losses from this contract and together with the global oil crisis and slump in the shipbuilding industry in the late 1970s, put SSE on the verge of a financial collapse.

A restructuring exercise followed, coupled with the injection of fresh funds by Sheng-Li Holdings, SSE's parent company at the time, to keep the company going. Mr Kua Hong Pak, Sheng-Li's Managing Director and an accountant by training, was made Managing Director of SSE to turn the company around.

SSE's first boat, a 25m ferry named Kuala Batee.

SAVING ST MARINE

"SSE was nearly bankrupt when I joined in 1980. I remember accompanying Mr Kua Hong Pak to re-negotiate that notorious container ship contract with the fleet owner – I was then a young naval architect. We were already more than halfway through with the deliveries at that point, and Mr Kua was prepared to close the yard and walk away if the negotiations failed – it would have been a loss to both sides to write-off the deal. In the end, we managed to settle on a good price for the remaining ships. We knew then and there that we must toughen up to avoid putting the yard and our workers through similar difficulties in future.

It was around that time that we secured the RSN contract for 12 coastal patrol craft. We also managed to sell a larger version of the container vessel to another customer. These contracts helped to turn the yard around. All of us received our first annual bonus of half a month in 1981, a meagre quantum in today's context, but a remarkable bounty given what the yard's been through.

When I became SSE's General Manager in 1990 and later, as President in 1994, one of my goals was to make sure we controlled the designs of our vessels. ST Marine would never have become a global turnkey solutions provider for shipbuilding, repair and conversion had we been content to manufacture from other companies' designs. See Leong Teck was one of my strongest naval design managers back in the day. Thanks to his competency in ship design, we identified capabilities that were lacking, and acquired or developed the right ones in order to roll out many highly customised vessels for our customers, including the RSN. As such, the technical designs of many of the made-in-Singapore naval vessels were kept within our shores.

The marine staff used to call me 'the communist' during my shipyard days. That's because I awarded flat bonuses to everyone, regardless of rank or seniority. My prime motivation was to make sure every yard worker received a fair share of the company profits.

The yard employees also remember me for another scheme, which was quite unorthodox at that time: I gave everyone a free computer and for workers with children, two places for a computer course – one for the child, one for either parent. The HR people and the union were apprehensive at first, but they did not object after I got them on board. People remember these things for a long time afterwards, even their spouses and children, because you have helped to make life a little better for the employees and their families.

Boon Swan Foo
President, SSE (1994 to 1995)

Kua Hong Pak pictured in 1982, three years after successfully making SSE profitable again. Also pictured are Dr Tony Tan (2nd from right) and Cheong Quee Wah (far right).

PIONEERING SPIRIT

MODERNISING THE SHIPYARD

A team of highly trained professionals bringing life to a customer's concept using a CAD/CAM system put in place in 1986.

"I remember when Mr Philip Yeo became our Chairman in 1984. He transformed SSE from a slow-paced shipyard with an average performance into an organisation that was dynamic, more technologically advanced and diversified. That was a key turning point for many of us. Mr Yeo's vision was to globalise SSE. He also revamped our design and production processes by acquiring a Computer-Aided-Design and Computer-Aided-Manufacturing (CAD/CAM) system. This allowed us to design and detail a ship in full perspective. As a result, we could explore a wider range of design ideas to suit customers' specific requirements and to provide them with a high standard of engineering services. Mr Yeo's twin strategy of international marketing and investments in advanced state-of-the-art computer systems continued to pay dividends in the years to come.

Mr Boon Swan Foo was an up-and-coming naval architect at the time. He rose through the ranks to become General Manager in 1990, General Manager and Director in 1992, Managing Director in 1993 and finally, President of SSE from 1994 to 1995. He was the one who pushed SSE to become, in 1991, the first shipyard outside Western Europe and one of few in the world to be ISO 9001 certified.

The ISO certification came at the time we were designing and building two 400 Twenty-Foot Equivalent Unit Roll-on/Roll-off and Lift-on/Lift-off vessels, the Tropic Sun and Tropic Tide, for the US-based Tropical Shipping and Construction. Mr Boon had impressed the customer that these vessels were not only designed by SSE, they were built to high standards of quality assured by an internationally recognised quality assurance system.

I remember the two vessels were completed a month ahead of schedule. It prompted the owner to proclaim both vessels to be 'unique in the world, moulded from imagination to reality by exceptionally creative and capable talents of the SSE team and their advanced CAD/CAM facility'. The design team was led by Mr See Leong Teck, another brilliant naval architect and the Senior Manager (Design) at the time. It was Leong Teck who led in the building of the first indigenous series of Fearless class Patrol Vessels, Fast Landing Craft and Endurance class Landing Ship Tanks for the RSN.

Leong Teck eventually became General Manager before taking over from Mr Boon as President SSE. He was a hands-on engineer with a strong passion in engineering, and was personally involved in the design and engineering of all the ships. Wanting the company to be a leading medium-sized shipyard in the industry, he strengthened SSE's design and engineering capabilities, improved the performance of existing products, developed new products, sought out new markets and business opportunities, and invested in staff training and facility upgrades.

Tropic Sun and its sister vessel alongside the fitting out jetty.

State-of-the-art underwater-plasma cutting machine installed in 1986.

Leong Teck was instrumental in many of the innovation and infrastructure initiatives that enabled the yard to take on complex and challenging projects like the Formidable class Frigates programme for the RSN. When we acquired the know-how to build Frigates from our French partner, DCNS, in the late 2000s, we had only designed and built fast combatant ships of up to 62m. The 114m Frigate is almost twice the length, five times more in displacement, and a stealth ship – we had no experience with this capability at the time. DCNS was naturally doubtful whether we could construct the five Frigates. They became deeply convinced of our engineering capabilities after we delivered the first Frigate to the RSN.

The investment in a new yard sited at Tuas was another turning point for the company. The opening was officiated by Rear-Admiral (NS) Teo Chee Hean in 1996, when he was Environment Minister and Second Defence Minister. I had the privilege of working with Mr Tan Pheng Hock, who was then in charge of developing and operationalising the yard, and later became President & CEO of ST Engineering.

The 1990s was also a time when the company accelerated its build-up of talent and engineering skills. Two to three employees were offered the Overseas Training Award (OTA) each year to study overseas and I was offered an OTA to study Mechanical Engineering at City University in London from 1992 to 1994.

Twoon Kok Yam
Senior Vice President (Benoi Yard), ST Marine

Tuas Yard completed in early 1996 at a cost of S$80 million.

GAINING DEPTH

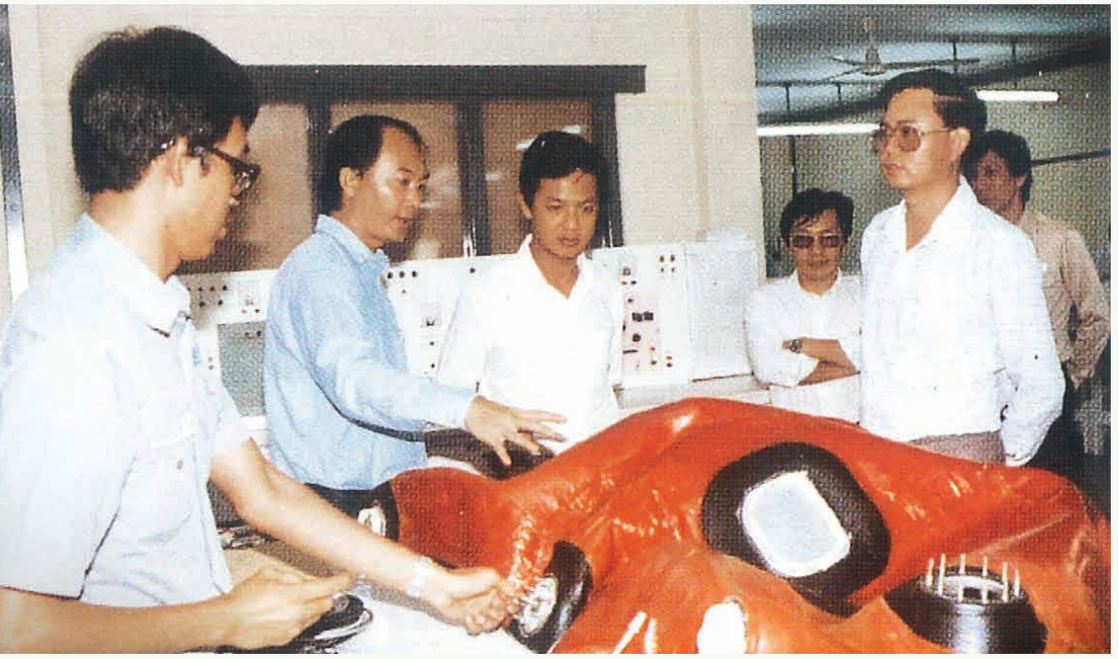
In 2000, ST Marine decided to build up a submarine maintenance workforce to support the RSN's submarine fleet. It was considered a bold move given that ST Marine had no prior experience in this field. Astute leadership and a dedicated team would be required for the yard to enter this highly complex and often risky business of maintaining underwater vehicles.

"Mr See Leong Teck, who was President of ST Marine at that time, was instrumental in establishing the plan to train a maintenance team and a submarine safety programme (SubSafe) in three years to ensure the submarines could operate safely after its refit," recalled Mr Tan Kim Hock, Vice President of Operations (Benoi Yard). He was the first Submarine Maintenance Safety Programme Manager at ST Marine.

The SubSafe programme is about providing safety assurance to the RSN, the submarine crew and their families. "As a member of the maintenance team, we imagined the RSN submariners as our next-of-kin. We would strive to do everything to make sure they set out and return safely," Kim Hock added.

The success of the SubSafe programme eventually paved the way for RSN to enlarge its submarine squadron with more sophisticated submarines in later years.

Challenger submarine.
Photo courtesy of cyberpioneer



From top left:
- Chong Kok Pan (right) shaking hands with Union President Peter Vincent (left), circa 1980.
- Employees of SEEL under the original 'Guiding Compass Sign' logo.
- Chong Kok Pan (right) hosting a visit by Dr Yeo Ning Hong (centre), then Senior Minister of State for Defence with Foo Hee Liat (2nd from left) in 1981.

Getting Wired

ST Electronics started out as SEEL, which was formed in 1969 to take over the staff and workshops left behind by the British forces at Sembawang Naval Base. At the founding of SEEL, the company's first Chairman Mr Hon Sui Sen commented that it "will be of unique importance not only to Singapore but to the whole of Southeast Asia."

His words would prove prescient as SEEL expanded its operations from naval systems to large-scale automation systems and enterprise software engineering, and grew to become a leading Information and Communications Technology (ICT) service provider in Southeast Asia. Today, ST Electronics delivers a wide spectrum of products and services that are essential to the productivity and security of economies, and that serve to improve the quality of everyday life.

THE GROWING YEARS

"I was seconded from MINDEF to SAE in 1970, and worked there for eight years before taking over from Mr Lim Ming Seong as SEEL's General Manager. He was the first Singaporean who took over the company from expatriate management in 1975 and turned it around.

Back then, SEEL had a mechanical workshop in Sembawang Shipyard that serviced 20mm Oerlikon turrets and fire control units for the RSN. The same workshop also maintained and overhauled aircraft instruments for the RSAF. There was another workshop in Seletar Airport that serviced radio and communication equipment.

Business flourished and sales turnover tripled between 1979 and 1981 to about S$50 million. Mr Kua Hong Pak, who was then SEEL's Chairman, initiated a large-scale build-up of engineering capabilities and the move to a custom-built complex in Ang Mo Kio. We were also one of the earliest local companies to computerise our operations and financial reporting.

In 1981, SEEL came under Singapore Aircraft Industries (SAI) with the government's push to make Singapore a regional aerospace maintenance hub. SEEL's Aviation Division, which accounted for some 40% of the sales and profit, was further hived off in 1983, and merged with Singapore Aircraft Maintenance Company's Mechanical Components Division to form Singapore Aero-Components Overhaul.

SEEL was left with a Mechanical Workshop for naval guns, a Calibration Centre and a System Division involved in the design and engineering of large-scale systems, like building automation systems and rail supervisory control and communication systems. We had to make the most of what we could out from these units, which would become the foundation of today's ST Electronics."

Chong Kok Pan
General Manager SEEL (1978 to 1984). Kok Pan is one of the few pioneers who had the opportunity to serve in three business sectors.

HARDWIRED FOR SUCCESS

"I joined SEEL in 1984 as the Divisional Manager of the newly created Engineering Software Division. Mr Lye Hoeng Fai had just taken over from Mr Chong Kok Pan as General Manager, and his focus was on scaling up product and software development capabilities to support the increasing use of software in engineering and electronic systems. I remember it well as a period of intensive recruitment for software engineers and specialists as well as heavy investment in hardware and development facilities.

The mid-1980s to early 1990s was a period that saw SEEL transformed from a system maintenance house into a Systems Integrator (SI) with both hardware and software capabilities, backed by strong system development expertise.

SEEL remained as an SAI subsidiary up until 1989, when it became clear that the company should develop outside the aerospace sector with the growing importance of ICT. In 1991, SEEL became the third Singapore Technologies entity to be listed on the Singapore Stock Exchange. It was renamed ST Electronics & Engineering (STEE) in 1995 and I became its General Manager in the same year.

In 1996, Singapore Technologies initiated Project Tornado in an effort to regroup its electronics and software capabilities. I led STEE to acquire Agilis Communication Technologies (Agilis), CET Technologies (CET), ST Simulation Systems (STSS), Singapore Engineering Software (SES) and the Command and Control (C2) Software Division from Singapore Computer Systems (SCS). Following these acquisitions, the capabilities were reorganised. STEE's Communication Systems Division was moved to CET, its Simulation Division to STSS and SCS' C2 Software Division to SES. The Industrial Systems Division remained with STEE.

One of STEE's successes was in realising the importance of intellectual properties early in the game. Without the C2 know-how from SES, for instance, we would end up purchasing C2 solutions from overseas, which would no doubt cost us an arm and a leg. Another success factor was the decision to develop in-house software capabilities to complement the hardware expertise. It enabled STEE to become an SI capable of delivering value-added services. The solid push came from the consolidation of electronics pioneer companies in 1997, which created the critical mass and breadth of capabilities STEE needed to become a leading ICT player in Southeast Asia.

Yap Eng Lip
General Manager, STEE (1995), and Managing Director, ST Electronics (1997).

PIONEERING SPIRIT

IN COMMAND AND IN CONTROL

In 1986, after the SAF had acquired some experience in real-time C2 systems with the Air Force Development System, it was ready to develop C2 systems for the RSAF, Naval Command Post and missile corvettes. This presented a golden opportunity for the local defence eco-system to build up C2 capabilities. I brought together two interested parties, Ericsson from Sweden and SEEL, and they formed SES. I became its founding Chairman and stayed on for four years to ensure SES was able to gain a sure footing in the industry. The strategy for Singapore to be self-reliant in the development of Command and Control Systems succeeded through the tight integration of operational and technical staff of the SAF, MINDEF and ST Electronics.

Prof Lui Pao Chuen
SEEL's Board Director (1981 to 1988) and Chairman (1984 to 1987)

Prof Lui and team taking a breather in Sweden to negotiate the SES joint venture with Ericsson.

ELECT TO WIN

ST Electronics crossed the S$1 billion revenue mark in 2007.

CET Technologies (CET) was formed in 1994 when the Defence Products Division of Chartered Electronics Industries was merged with CIS' Electronics Warfare Group to create a larger company capable of meeting the SAF's growing demand for defence electronics.

The first thing I did when I joined CET as its General Manager was to create a strong corporate identity, raise its profile and relocate the office to Jurong East to give the staff a stronger sense of pride and belonging. Next, I implemented an 'Action-Oriented and Customer-Oriented' culture to encourage staff to work as a team and proactively engage and win more customers for the company.

CET was initially involved in making and maintaining electronic fuses, military radios and tactical communications devices for the SAF. I decided to take a dual-use approach and apply military technologies to systems for the para-military and transportation markets. We developed an engineering road map for the transportation business and secured S$20m funding from the National Science and Technology Board to develop indigenous products and capabilities.

As an ICT company, CET needed regular technological breakthroughs in product development to stay competitive. The first one was the development of a DigiSAFE ultra-high frequency radio encryptor in 1995. Then, we went on to create a despatch algorithm for a Taxi Fleet Management System; a patented Radio Frequency Identification Library Books Management System that made me the first patent holder in ST Electronics; and a family of SuperneT Internet Protocol Communications Systems. As these products were ahead of the industry, we were able to establish CET firmly in the markets before the competition was able to catch up.

Seah Moon Ming (right) at a signing ceremony with Thales in 2007, as part of ST Electronics' efforts to build up capabilities through partnerships with international companies.

I succeeded Eng Lip as STEE's Managing Director in July 1997. Later that year, STEE was regrouped under ST Engineering and renamed ST Electronics. With the enlarged ST Electronics coming from erstwhile six distinct business units, I saw the importance of establishing an integral culture to align the different practices and expectations across the entities. A centralised organisational structure was created to manage and support the decentralised business development and project execution activities. I also told each entity to 'chiong' (charge forward) in a collective and guided manner to ensure ST Electronics achieves accelerated growth in the highly competitive ICT industry.

To support the aggressive expansion strategy, we established a collaborative eco-system of local enterprises, institutes of higher learning, technology companies and original equipment manufacturers. More R&D funding was also provided to develop a suite of core products and SI capabilities to secure ST Electronics' credibility and standing as a regional ICT powerhouse.

In 2005, all wholly-owned subsidiaries were renamed to consolidate ST Electronics' branding. Agilis changed its name to ST Electronics (Satcom & Sensor Systems), CET to ST Electronics (Info-Comm Systems), SES to ST Electronics (Info-Software Systems) and STSS to ST Electronics (Training & Simulation Systems).

I felt a tremendous sense of pride when ST Electronics achieved its first S$1 billion in revenue in 2007. Although the company was consistently achieving double-digit growth every year, and established a strong track record for integrating complex systems like the Shanghai Jin Mao Intelligent Building Management System and Changi Airport Terminal Building Automation System, many in the company thought it would be tough for a local ICT firm to hit the billion-dollar revenue mark.

We did it through clear goal-setting, a team of empowered employees, a suite of strong capabilities and a drive for international expansion. We sharpened our competitive edge with practical innovations and exercised effective control over our key intellectual properties. In my mind, being able to productise dual-use technologies and to offer our own system products and solutions in multiple markets was the critical success factor for ensuring continued business growth.

These advantages would eventually place ST Electronics at the forefront of technological advancements and enable it to develop effective solutions that solve real-world problems, address customers' needs and secure more business deals.

Seah Moon Ming
General Manager of CET (1994 to 1997), Managing Director of STEE (1997) and President of ST Electronics (1997 to 2009)

ST Electronics successfully entered the China market and secured multiple MRT and related contracts, including the Traffic Control Centre for Beijing MRT Network. Seen here is Seah Moon Ming (2nd from left) at the contract award ceremony.

PIONEERING
SPIRIT

ST Aerospace started as SAMCO in 1975, then evolved into Singapore Aircraft Industries in 1981 before changing its name to Singapore Aerospace in the late 1980s and finally its current name in 1994.

Taking Flight

Shortly after the British forces pulled out of Singapore, a group of officers from the Singapore Air Defence Command (SADC), renamed the Republic of Singapore Airforce (RSAF) in 1975, was given the mandate to set up an industrial facility that could undertake aviation maintenance beyond the SADC's operational scope. Unknown to all at the time, the humble operation established in 1975 at Seletar Air Base would one day grow to become the world's largest commercial airframe Maintenance, Repair and Overhaul (MRO) service provider.

FINDING OUR FEET

When Singapore Aerospace Maintenance Company (SAMCO) started in 1975, I was seconded from the RSAF to be the Production Manager in charge of operations. We started out in the unattended hangars of the Royal Air Force (RAF) in Seletar. The lights, wires, and in fact, everything, weren't working. We had to buy, rent and even borrow equipment from the RSAF to set up the workshop. However, the most difficult part was in getting the right people. There were just the few of us under Mr Patrick Wong Yeok Yeok, the first Managing Director, whose job was to set up the depot and take over the heavy maintenance of RSAF aircraft previously carried out by Lockheed Aircraft Services (LAS). Contracts from the US Navy came about a couple of years later.

We recruited our first batch of technicians comprising ex-RAF, RSAF and LAS personnel as well as our first foreign talents from India and the Philippines, all of them highly skilled. Later on, we hired Taiwanese technicians as well, who brought with them deep experience with US military aircraft. We started an apprenticeship scheme soon after, to make sure our technicians were adequately trained for our future needs.

By the 1980s, we had military jobs coming from Oman, Bahrain and Venezuela. Later on, we established joint ventures with original equipment manufacturers, like Eurocopter and Messier-Bugatti, to expand into commercial aviation and build up the MRO capabilities. Had we not taken steps to nurture an eco-system, ST Aerospace wouldn't have gone far as a maintenance company.

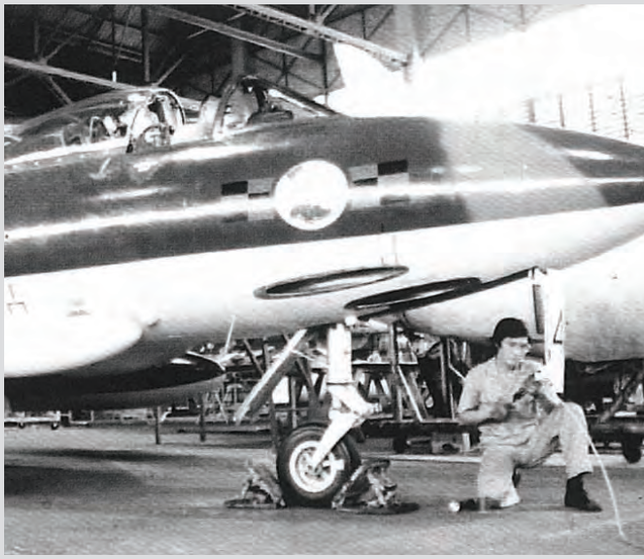
I think the most memorable part of my career would have to be the A-4 Skyhawk re-engineering programme for the RSAF – it was our biggest and most challenging. Our people managed to overcome their initial technical difficulties with expertise and assistance from third parties and we did well in the end. The experience contributed greatly towards SAMCO's engineering capabilities and boosted our confidence for other RSAF upgrades, as well as work for foreign air forces in subsequent years. The engineering capability helped to differentiate us from other MRO companies. It laid the groundwork for commercial aircraft modification work, including our Passenger-to-Freighter programmes.

An experience like this forced us to learn to swim in the deep end. We had to have the structural and engineering knowledge to make design changes. That's why I've always believed that there must be two parts to engineering passion. Firstly, we must be prepared to work from first principles and go the extra mile to deliver to the customers' expectations. In the early days, there were so many challenges falling outside our areas of expertise, and we would have failed had we drawn lines and relied on only what we knew. Secondly, we must learn to keep up with a changing world by learning and exploring new business to stay ahead of the competition. Had ST Aerospace been stuck with doing just heavy maintenance work, we would never have become number one in airframe MRO today.

Lim Lu Hock in 1994 as Senior Vice President, International Business.

Lim Lu Hock
An ST Aerospace pioneer who retired from the Group in 2012 after serving 35 years in various capacities, including Senior Vice President, Business Development.

Aerial view of SAMCO at Seletar Air Base.



SAMCO technicians servicing a Hawker Hunter fighter.

PIONEERING SPIRIT

FOUNDING THE MRO INDUSTRY

SAMCO was one of three aviation companies grouped under SAI, when the latter was established in 1981. The others were SEEL and SAEOL. SAEOL was initially a joint venture between Singapore Airlines (SIA) and Sheng-Li Holdings. It became a wholly owned SAI subsidiary in 1982, the same year SEEL's Aviation Division and SAMCO's Mechanical Components Division merged to form Singapore Aero-Components Overhaul (SACO). Between 1983 and 1985, SAI's capabilities were further strengthened with the formation of two other subsidiaries: Singapore Aerospace Manufacturing (SAM) and Singapore Aero-Warehousing and Supplies (SAWS).

SEEL left the SAI group in 1989 to become the foundation for today's ST Electronics. SAI was renamed Singapore Aerospace in the late 1980s and listed on the Stock Exchange of Singapore in 1990. SAM became part of the Precision Engineering Group of Singapore Technologies in 1994. SAMCO, SACO, SAEOL and SAWS have respectively evolved into today's ST Aerospace Engineering, ST Aerospace Systems, ST Aerospace Engines and ST Aerospace Supplies.

Quek Poh Huat receiving plague of commendation in 1991 from then Deputy Prime Minister and Secretary-General of NTUC, Ong Teng Cheong, in recognition of cordial Management-Union relations.

Quek Poh Huat (left) and Francis Yuen (right), then GM SASCO in ceremony marking the opening of SASCO's 2nd hangar at Paya Lebar in 1992.

"It was clear in the late 1980s that we would have to diversify into commercial work to be cost-competitive by spreading overheads and to venture overseas to grow. I remember four initiatives that were started in quick succession.

In 1990, we set up a commercial airframe facility named Singapore Aviation Services Company (SASCO) in Changi, Singapore. Next, we opened a marketing office in London to explore business opportunities in Europe. This was on top of our Los Angeles office which was set up much earlier in 1981. At the same time, we started a small joint venture, Airline Rotables Limited, in Stansted, UK to offer what was one of the world's first 'power-by-the-hour' programmes for aircraft components. Our 4th initiative was to venture into North America with the setup of Mobile Aerospace Engineering in 1991, smack in the middle of the first Gulf War. We could have postponed or scaled down our launch because Operation Desert Storm had just begun, but we pushed on, struggled a few years and managed to secure FedEx as a key long-term customer.

ST Aerospace became number one in airframe MRO because we took pride in our work. This meant ensuring quality workmanship, on-time delivery and a fair price. That's how we kept customers happy, and we were fortunate to have very good people to deliver just that.

We also took pride in being Singaporean. The Singapore brand stands for quality, and you can attribute the success of the Singapore Airshow to that. I hope our future leaders recognise this advantage, and will continue to use the Airshow as a strategic opportunity to market ST Engineering's services and capabilities."

Quek Poh Huat
Managing Director, SAI (1981 to 1990) and President, Singapore Aerospace (1990 to 1995)

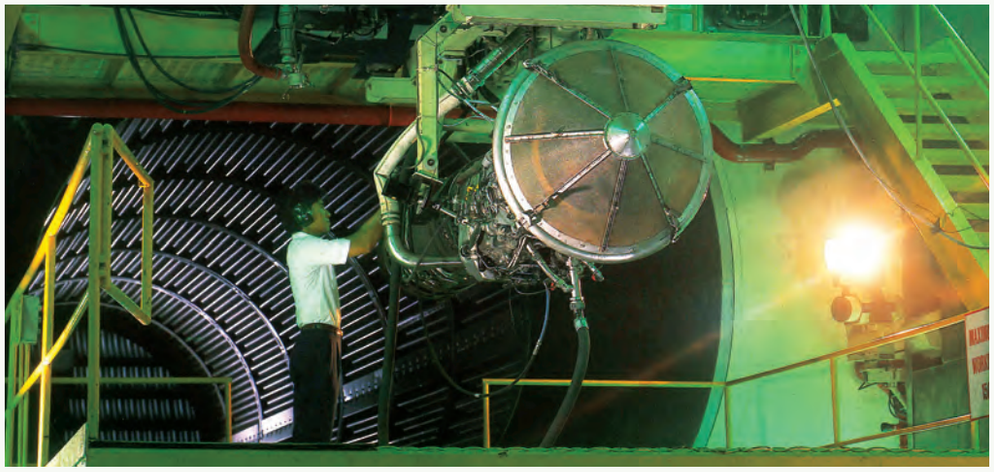
FUELLING OUR GROWTH ENGINES

When I became the General Manager of SAEOL in 1985, SAEOL was still supporting the JT8D engines on SIA's Boeing 727s and 737s, as well as several engine types for RSAF fighter aircraft. We started to make inroads into the Middle East and Africa where older Boeing aircraft were still in operation. Concurrently, we built up our military engines capabilities for the RSAF. These efforts allowed SAEOL to win new contracts, like the maintenance of the C-130 T56 engines for the Royal Saudi Air Force.

SAEOL's relentless push to expand internationally also enabled it to land a multi-year T56 contract with the US Air Force, amongst others. We knew the Boeing 727 and early generations of 737 fleets would be phased out by the 1990s, and began to expand our capabilities to the modern CFM56 family of engines used in narrow-body aircraft. SAEOL was renamed Singapore Aerospace Engines and then subsequently STA Engines in 1997 to align with the naming convention of ST Aerospace.

Chong Kok Pan
General Manager, SAEOL / STA Engines (1985 to 1999)

Re-engined A-4 Skyhawk at Asian Aerospace 1988; Quek Poh Huat was instrumental in making Singapore a major aviation exhibition site with the initiation of Asian Aerospace with a British partner in 1981.



Rigging of a GE J85 engine for testing in the fully computerised test cell of Singapore Aerospace Engines, circa 1990.

GEARING FOR LIFT-OFF

There was a global over-capacity in the aircraft maintenance industry when I became President, ST Aerospace, in 1995. Most of our sales were denominated in US dollar, which had weakened at that time, and ST Aerospace was on its way to losing S$48m that year. Key to me was to turn SASCO around and this we did by adopting a twinning concept, offering services for narrow-body aircraft in the US and wide-body aircraft in Singapore to the same customers. Another thing we did was to invest in engineering and development, especially in the development of our own Supplemental Type Certificate for the Boeing 757 PTF conversion at the behest of Tay Kok Khiang, then Executive Vice President, Military Business Group. These initiatives helped to invigorate ST Aerospace.

We also scrutinised our own strengths and weaknesses and did a few things to strengthen the company's culture. I remember appointing Pauline Ng and Jenny Lee, two engineers from the Engineering and Development Centre, to come up with a peer appraisal system and a boss appraisal system respectively. The two 'internal consultants' roped in their colleagues and the Human Resource Department and rolled out their appraisal systems across ST Aerospace in 1997. I volunteered myself for the first vertical appraisal exercise – and as it turns out, I was quite popular among the junior staff. ST Aerospace continued to use the 360-degree appraisal for many years after that.

A customer-centric work ethic was another area I wanted to ingrain. I stopped fellow colleagues from calling me 'Sir' and we kept all the covered car park lots in front of the office building for customers. I told the marketers that I should be the one to call on the customer, not the other way around. To walk the talk, I spent long hours on the road marketing our services. I even negotiated the payment of aged debts personally, as I often reminded marketers that their job was not done until and unless monies had been collected!

Boon Swan Foo
President, ST Aerospace (1995 to 1997)

Sailing Steadfastly Forward with Passion

VT Halter Marine yard at Pascagoula, Mississippi, US.

Ng Sing Chan
President, ST Marine

ST Marine has accomplished much in 50 years. It has developed the designs of an impressive array of sophisticated vessels, and constructed and delivered most of them with a high degree of engineering content. In ship conversion and ship repair, it has kept an excellent reputation with fast turnaround times and efficient programme management. It continues to play a vital role as a strategic partner in Singapore's maritime security and defence.

Its latest milestone is the construction of eight Littoral Mission Vessels (LMVs) designed in partnership with Saab Kockums for the Republic of Singapore Navy (RSN). The first LMV was delivered in 2016. Other important achievements in the recent decade include the delivery of a Landing Platform Dock for the Royal Thai Navy, the first major naval export contract for ST Marine; an S$880 million deal for four Patrol Vessels for the Royal Navy of Oman, the biggest defence export contract awarded to an ST Engineering unit to date; and the order for four Fast Missile Craft for the Egyptian Navy delivered by the Group's US shipyard, VT Halter Marine (VTHM).

Aside from naval projects, the commodities boom, which started in 2003, created opportunities for the design and construction of highly customised support vessels for the oil and gas sector. The breakthrough came with a contract from Swire Pacific Offshore Operations (SPO) to design and deliver a Seismic Survey Vessel.

This was followed by orders from Lewek Shipping Pte Ltd, a wholly-owned subsidiary of Ezra Holdings Limited for a Anchor Handling Tug Supply (AHTS) vessel and DOF Subsea in 2008 for a Diving Support Vessel.

Subsequently, SPO awarded two additional contracts in 2011 and 2012 totaling the orders of six AHTS vessels.

The ability to take on turnkey technically complex orders for newbuilds was further demonstrated when ST Marine was awarded a contract to design and construct two large Roll-on/Roll-off (RoRo) vessels for the transportation of large A380 sections, including the fuselage and wings. "With the two RoRo vessels, one of them called the City of Hamburg and the other,

the Ciudad de Cadiz, ST Marine has become an aircraft carrier builder of sorts!" laughed Mr Ng Sing Chan, President of ST Marine.

Sing Chan credits these successes to the people, "It's not about how many products or contracts we win. Were it not for the passion and capabilities of our people, none of these engineering feats would have been possible."

> "The fleet of eight new LMVs will replace the current Fearless-class Patrol Vessels. These new ships will be faster and more versatile in operations than their predecessors. As RSN completes its 3rd Generation transformation, the LMV will become the flagship of our future Navy to better safeguard our waters and protect our Nation.
>
> **RADM Lai Chung Han**
> *Chief of Navy, RSN (2014 to 2017)*

ACHIEVING TEAM EXCELLENCE

Sing Chan chairs the ST Engineering People Excellence and Learning Organisation (PELO) Committee, with an aim to distinguish the Group as a preferred employer. PELO pursues the well-being and development of employees through staff engagement and other activities such as the annual ST Engineering Team Excellence Convention to recognise and encourage creativity, use of technology, innovation and continuous improvement tools to enhance the Group's processes, products, services and work environment.

LEARNING AS AN ORGANISATION

ST Marine prides itself as a learning organisation. It has a framework for imparting know-how and good practices at the workplace through a combination of on-the-job training, coaching and instructor-led training at a rough ratio of 7:2:1. This, according to Mr Bryan Ee, Vice President of Human Resource, has helped ST Marine to execute its PELO objectives. "The 7:2:1 learning model is embedded into the annual Learning Needs Analysis. We are fully committed to staff learning and development. Skilled employees are not only more productive and successful at their work, they are able to improve safety and organisational excellence."

A Talent Development Committee at the marine sector level helps to review talent movement and development plans, and to ensure employee development processes are integrated. Other learning forums include the Research & Design Committee Review Meetings, Business Excellence Seminars and Work Plan Reviews where employee participation is highly encouraged. In addition to the biannual Group-wide Employee Opinion Survey, ST Marine also conducts an annual staff dialogue, and has implemented a Staff Suggestion System since the 1990s. Through these platforms, ST Marine is able to maintain regular communication with the employees and provide better working conditions for them. "It's all part of continual learning at all levels and functions throughout ST Marine," Bryan added.

ST Marine's engineers sharing good practices at the shipyard workshop.

Sailing Steadfastly Forward with Passion

Ng Sing Chan (middle), Chairman, PELO Committee shaking hands with Lin Yong Wee (right) of ST Aerospace at the Business Excellence Seminar 2017.

To build new capacity for growth, ST Marine has been looking for infrastructure that would support its pursuit for high-value and heavily customised solutions in the marine and environmental engineering industry. Sing Chan said, "A significant development was the expansion into ship repair by VTHM in 2013. We added a 12,000MT lifting capacity floating dry dock that can accommodate handy-sized vessels belonging to ship owners operating in the US Gulf Coast as well as other ST Marine customers with ships plying the waters near our US facility. With our Singapore and US operations now equipped with both newbuild and repair capabilities, we are able to synergise our design, marketing and integrated logistics support efforts, and provide better and more comprehensive after-sales services."

ST Marine also expects to gear up on environmental engineering solutions to tackle waste and water management in the region. "We have completed the integrated waste management facility at Brunei's Sungai Paku and Akar, as well as the Pneumatic Waste Collection System in China's Tianjin Eco-city. Our people managed the design, build, operate and transfer contents, and clearly demonstrated our abilities to provide reliable and cost-effective eco-solutions," Sing Chan said.

While growth strategies are important, Sing Chan believes that the real enablers reside in an organisation's culture. "An open culture enables passion and innovation to thrive. That's why we've invested in both training and employee engagement."

During these sessions, he would share with the staff lessons from maritime incidents like the Costa Concordia and Sewol disasters as well as feedback and accolades from customers to improve service standards, business operations and ship design.

Sing Chan would also highlight humanitarian missions and major projects that involved vessels built by ST Marine, like the deployment of the submarine search and rescue vessel by the RSN in the search and recovery of AirAsia Flight 8501 in 2015. "We have every reason to be proud, knowing that the ships we've built are contributing directly to economies and people's lives," he said.

"ST Marine has made significant strides in the last 10 years rebranding itself as an employer of choice in the maritime industry. We recognise that our people are not only the anchor during tumultuous times, they are the great sail carrying the company steadfastly forward," Sing Chan said assuredly.

"Regardless of the sea of change the world is going through, maritime transport will continue to be the backbone of the global logistics network," he continued. "The demand for specialised vessels, overhaul, repair and maintenance will always be there, but so will the competition. While we have good hands on deck and great leaders at the helm, we will still need to do more in terms of innovation and productivity to stay ahead."

He cited 3D printing as an example. It is a potential technology where common and obsolete parts could be replicated, and in doing so, improve the inventory management and customer service for the company. Other areas that ST Marine is looking into include the use of lightweight materials, like aluminium, for building fast craft; data analytics for predictive maintenance; and robotics for the automation of risky and mundane work, like ship blasting and painting.

However, Sing Chan believes the shipyard of tomorrow would require more than just advanced technology. It would need greater efficiency to improve business competitiveness. Technology and processes should be tightly integrated to enable seamless information exchange and streamlined workflow. We also need to take advantage of Big Data for predictive analytics and make the yards smarter. After all, as Sing Chan pointed out, "Technology is useful only if it can support us to do our everyday work safer and better."

NO IDEA TOO SMALL

In the marine and offshore industry, the removal, servicing and reinstallation of propeller shafts is a labour-intensive and time-consuming process. A propeller shaft weighs between 12 to 22 tonnes, and requires a crew of six able-bodied men to move it. In 2014, a team of engineers from the Tuas Yard came up with an idea of using a jig to remove and reinstall the propeller shaft. They designed the jig in-house and built the support equipment in 10 weeks. A new handling procedure for the propeller shaft that required only half the crew and two-thirds the usual processing time was developed. The jig also improved workplace safety by reducing worker fatigue and injuries.

Mr Chen Zhi Ru, Engineer from the Machinery Department and the project's Team Leader, said, "The jig was a very simple idea that led to great results. Not only did we win accolades from customers for turning around the repair work faster, the jig also won a STAR Award at the ST Engineering Team Excellence Convention for Innovation and Quality Circle 2014."

Propeller shaft removal in progress using jigs (yellow) designed by ST Marine engineers.

Going the Long Haul

Whether supervisor or seasoned engineer, secretary or head of department, there are many amongst us who have dedicated their entire working lives to ST Engineering. We pay tribute to all long-service staff who have weathered the formation years, supported the Group's expansion, took part in its transformation and continue to contribute as loyal members of our family.

"I joined ST Electronics in 1973 when it was still called Singapore Electronics and Engineering Limited. We were maintaining electronics equipment at that time, and operating from the Royal Navy dockyard at Sembawang. This is my first and only job and I've had no regrets staying with such a progressive company that has invested so much in its people. I consider myself an innovator and I once assembled a 3-in-1 device that was not available in the market. The customer was delighted and I won an innovation award for it in 2007. That's why I love my job and being in the info-communication industry!

Lim See Tew (pictured 1st from left)
Engineer, ST Electronics (Info-Comm Systems)
44 years of service

"I joined Singapore Aerospace Maintenance Company (SAMCO) in 1976 as a Personal Assistant. Lockheed Aircraft Servicing had just vacated the Seletar premises, and we were trying to get SAMCO up and running. Over the years, while ST Aerospace transformed from a MINDEF start-up to a global organisation, I got to work under 10 different bosses! I had my first taste of investment when ST Aerospace became public-listed in 1990. That feeling of owning a stake in the company was particularly memorable, aside from the life-long friendships and professional opportunities I've been given during my years with ST Engineering.

Susanna Mok (pictured 2nd from left)
Confidential Secretary, ST Engineering
41 years of service

"I've held so many roles and appointments since coming in as an aircraft engineer, but I would say it was passion for the industry and satisfaction from tackling various project challenges that inspired me to stay on. I like that ST Engineering takes care of its staff and gives them room to excel. I am thankful for the mentors who guided me in my early years. The most gratifying moments came when I got to learn from their experience and pass on their legacy when I worked with young engineers, many of whom have become senior managers at ST Aerospace.

R Balakrishnan (pictured 3rd from left)
Vice President (Engineering),
ST Aerospace Engineering
41 years of service

"I was just 16 when I joined CIS in 1972 as a Production Operator for M16 rifles. Everything was new to me and I learned as much as I could with the help of many caring bosses. I'm very grateful to one particular supervisor who taught me about documentation and store processes – he was extra patient with me as my English was weak. In 2002, the company went through a right-sizing exercise and although I was not affected, it was no less emotional – it taught me not to take my job for granted. I belong to a generation that believes in loyalty to good employers. Considering I was almost illiterate when I first started work, I've gained so much personally even though I'm just a junior staff in this big organisation.

Chia Teng Sim (pictured right)
Senior Store Specialist, ST Synthesis
45 years of service

“I was hired when KDS was known as Silvatech and we were building log skidders at that time. Being part of the ST Engineering Group has allowed me to collaborate with dynamic teams providing high-value products. As an engineer, I’ve had the opportunity to develop a core competency area, lead in product development and be part of senior management. My proudest moment was when we got the HMX 1100, a hydro-mechanical transmission to work in an ST Kinetics’ armoured vehicle that was subsequently rolled out to the world.

Paul Dries
Vice President of Engineering, Kinetics Drive Solutions (KDS)
22 years of service

CELEBRATING
OUR PEOPLE

Going the Long Haul

"Benoi Yard was a vacant piece of land when I started as a welder in 1970. After becoming a supervisor, I was sent to Sweden in 1998 to be qualified as a Certified Welding Inspector for submarines. In 2001, I was transferred to SSG at Changi Naval Base to help set up a Hull Department. I cannot imagine that I will be celebrating my golden jubilee with ST Marine soon. The reason I've chosen to spend my entire career here is the comradeship with my fellow colleagues, including many who have served with me since day one at Benoi Yard. There's always a great sense of pride when we deliver our ships to satisfied customers – their positive feedback always spur me on to work even harder.

Ng Siew Heng
Department Head, Submarine Support Group (SSG), ST Marine
47 years of service

"I remember my first day in 1976 as an apprentice working on various types of engines. The environment and processes felt so unfamiliar, and I was eager to learn more about the aviation industry. This learning phase, which I went through with a group of peers, was most memorable. Colleagues became friends, and that motivated me to stay on for more than 40 years. The company and my bosses have given me lots of opportunities to develop highly specialised and valuable skills. I've also attended supervisory courses, which have broadened my perspectives as a senior service engineer.

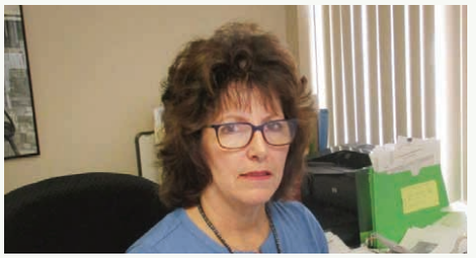
See Chiang Young
Senior Service Engineer,
ST Aerospace Engines
41 years of service

"We used to cycle to work with the shipyard workers back in 1977 when we were in Sembawang. I was a technician then, and one of my first tasks was to fix the communications equipment on a vessel at the Eastern Anchorage, which required a boat ride from Clifford Pier. It felt like a day out at sea complete with a western lunch! The customer was very satisfied when the repair was done. I switched to sales in 1990 after delivering a naval communications project to an overseas navy. I'm proud to work for a company that develops indigenous products to keep our nation safe and secure.

Gurusamy Selvaraj
Deputy Sales & Marketing Director,
ST Electronics (Info-Comm Systems)
40 years of service

“It was in 1973 when I joined CIS as a General Operator handling the heat and chemical treatment process and cutting machines. It wasn't easy finding a job during that time, and so I stayed on. But before I knew it, 40 years had passed. I never thought I would gain so much in exposure and production experience – including working on an overseas project for a year. My time with ST Engineering has made me a more confident and responsible person.

Sueff Bin Yusop
Technical Specialist, Advanced Material Engineering, ST Kinetics
44 years of service



“I was a clerk when I joined the company in 1990. The company was brand new and there were few employees. I also had to double-up working in Finance. We were so excited when the first plane rolled into the hangar for maintenance. I even brought my family to see the plane sitting on the tarmac. I can hardly believe we have redelivered close to 5,000 planes since. I've enjoyed the aerospace environment and getting to know my colleagues. My accounting skills have been sharpened and challenged over my years here, and I have learned so much.

Debbie Phillips
Finance Manager,
VT Mobile Aerospace Engineering
26 years of service

“I was a Principal Engineer in 2001 when iDirect Technologies was still new to the Very Small Aperture Terminal (VSAT) market. My job was to develop the next generation modem and during this time, I worked with some of the most talented, knowledgeable and passionate engineers. I appreciated the empowerment to set my own directions, but what I relished most was the challenge of meeting and exceeding customers' expectations. The best part of my career was when my colleague and I were awarded our first patent for an innovative algorithm. It taught me to approach all technical issues with perseverance and teamwork!

Conor Foley
Vice President of Engineering,
VT iDirect
16 years of service

Minister Ong Ye Kung (middle) with Lim Serh Ghee (left) and Tan Pheng Hock (right) at ST Aerospace National Day Observance Ceremony 2016.

In Partnership with Trade Unions

ST Engineering's relationships with the workers' unions date back to the late 1960s. Through working closely with the Singapore Industrial & Services Employees' Union (SISEU), Singapore Manual & Mercantile Workers' Union (SMMWU), Shipbuilding and Marine Engineering Employees' Union (SMEEU) and ST Electronics Employees' Union (STEEU), ST Engineering strives to build a fair and inclusive workplace for our employees.

Over the years, many of our union leaders have been awarded May Day Comrade and Veteran of Labour Awards by the National Trades Union Congress (NTUC) for their contributions to the labour movement. ST Engineering's management members have also been conferred NTUC's May Day Medals of Commendation for their contributions in strengthening labour-management relations and providing strong support to labour movement's initiatives. Today, the Group's rapport with the unions extends beyond collective agreements to wider issues ranging from environmental health and safety, to staff re-training to stay relevant and jobs re-design to support an aging workforce.

> "I served as the Executive Secretary of SISEU from 2011 to 2012. During that time, I saw how the management of ST Aerospace worked closely with the union, taking in its views on matters concerning workers, and being open and transparent in handling labour-management relations, even when difficult issues were involved. This cooperation extends to union-management support for various NTUC initiatives like the Inclusive Growth Programme, job redesign to make the workplace more age friendly, and Place and Train programme. I hope future generations of union leaders and management representatives continue to uphold that mutual trust. This is what matters most to harmonious industrial relations in Singapore.
>
> **Ong Ye Kung**
> *Minister of Education*
> *(Higher Education and Skills) &*
> *Second Minister for Defence*

Union leaders and management of ST Kinetics with John De Payva (front row, 4th from left), Secretary-General Emeritus of SMMWU.

WORKING HAND IN HAND

"STEEU was established in 1969. Unlike the industrial unions, we are an in-house union started by workers who have a direct stake in the company's success. In many ways, this sets the stage for the close-knit relationship we have with the ST Electronics management. I still recall, when I became STEEU chief in 1995, job security was a key concern. The management has always paid close attention to workers' issues, and we in turn listen and try to understand their challenges. The mutual trust and support have been strong all these years because we've each made the effort to work hand in hand to help the company grow. It's no coincidence why we have so many long-serving staff in our midst. My aspiration is that we continue to uphold this spirit of cooperation to prosper together with the company even further!

Michael Low
ST Electronics Union Leader
Senior Engineer

MUTUALLY SUPPORTIVE RELATIONSHIP

"As a union leader, I work closely with the management to communicate important messages to our workers, such as skills upgrading and workplace productivity. This can be challenging because not everyone is interested to upgrade or become more productive. We try to convince them using programmes like Kaizen to show how productivity can improve their work and performance. Worker safety is another important area for the union. We have representatives in the Work Safety, Health and Environment Committee to encourage workers to play an active part in workplace safety. We have maintained a good relationship with ST Kinetics' management over the years. They have been supportive of our activities – ranging from giving us a recruitment booth at the annual staff briefing, to giving us time off to support the NTUC U Games, which we have won for the last six consecutive rounds.

Koh Ching Chuan
ST Kinetics Union Leader
Senior Foreman

CELEBRATING
OUR PEOPLE

Vincent Chong (right) receiving a token of appreciation from NTUC Secretary-General Chan Chun Sing (middle) with NTUC President Mary Liew (left) for donating S$1 million to the NTUC Education and Training Fund on May Day 2017.

COLLECTIVE COLLABORATION

My most memorable milestone as a union leader was negotiating the Collective Agreement in 2015. Some of our members had issues with their salaries and leave entitlement. I represented the workers and led a team to work out a new set of terms with ST Marine's management. The negotiation went on for six months before we finally reached a fair and satisfactory agreement for both sides. The workplace environment has definitely improved over the years due to the collaborative efforts between the ST Marine management and the union. We are represented in key committees, such as the one on Environment Health & Safety, which allow our collective voice to be heard. We came up with interesting ways to enhance safety consciousness in the shipyard. As a result, during the employee opinion survey, safety consciousness received the highest score in terms of satisfaction and engagement level.

Shio Kumar
ST Marine Union Leader
Executive

SERVING A COMMON INTEREST

The role of the union leaders is to serve our members' workplace interest and to bridge the relationship between workers and the management. Besides making sure our workers are fairly treated, we also work with the management to create greater value for the company because when the company does well, the employees will benefit as well. I remember during the 2008 global financial crisis, I worked very closely with the management to save as many jobs as possible and helped those who were retrenched to find new jobs. To enhance employability, we brought workers to the Employment & Employability Institute to be re-skilled for other job options. We managed to overcome the recession and come out stronger than before, with many of us gaining new and relevant skills. The challenges we are facing today are very different from the past. As union leaders, we must learn to constantly adapt to change, remain focused on our objectives and stay close to workers on the ground.

Lim Kuang Beng
ST Aerospace Union Leader
Senior Licensed Aircraft Engineer

Recognising our NS Warriors

National Service is a cornerstone of Singapore's national security that has kept the island-nation safe and secure since 1967. The SAF Operationally-Ready National Serviceman Award (NSman Award) was introduced in 1994 to acknowledge NSmen who have made significant contributions to national defence. Award winners are known to possess exemplary attitude towards the National Service, demonstrate high standards in military training and contribute positively to the units.

ST Engineering has been a strong supporter of National Service over the years and is proud to have many NSman Award recipients, including former Deputy Chairman, President and CEO, LTC Boon Swan Foo who was the 1996 SAF NSman of the Year and former President ST Marine, Captain (RET) See Leong Teck who was the 1997 SAF NSman of the Year.

"If an employee is committed towards serving National Service, you can be rest assured that he can be counted on to have commitment in his work too. ST Electronics understands this and has supported me in going for in-camp trainings. I remember in 2014, while in the midst of taking over my colleague's role in a project, my unit called me up to participate in a three-week long biennial multinational overseas exercise. My supervisor approved the NS leave without hesitation and arranged for my work to be covered during my absence.

SAF NSman of the Year (2016)
ME2(NS) Loh Soon Beng
Engineer, Training & Simulation Systems, ST Electronics (2nd from left with daughter)

"I am greatly honoured to be given the opportunity to serve in National Service, where I've learnt to lead by example and motivate fellow NSmen to give their best during training, among other things. These are valuable skills that have become invaluable in my life and career.

SAF NSman of the Year (1996)
COL (RET) Alex Teo
Senior Vice President, Defence Business and Head Security, ST Engineering (2nd from right)

"I remember I was putting my 13-year old son Ashton to bed the night before I had to leave for a battalion exercise. Ashton, who had grown to be quite attached to me, found out that I would be gone for a week and asked me why I couldn't come home to play with him every night, and I told him, 'So that you, mei mei (younger sister) and mummy can sleep peacefully every night.'

SAF NSman of the Year (2013)
SLTC(NS) Ace Low
Head, Defence Engagement, Kinetics Integrated Services, ST Kinetics

"I was a project manager for the Bronco at ST Kinetics and a NSman Officer Commanding of a Bronco Reconnaissance company with the SAF. This puts me in a unique position where I can understand the ground issues first-hand as a Bronco operator and propose refinements to the Bronco family to overcome these challenges to improve usability and reliability.

SAF NSman of the Year (2014)
CPT(NS) Pierre Chew
Senior Manager, Head Operations Control, Kinetics Integrated Services, ST Kinetics (with wife Jane Neo)

Cheering from the Sidelines

ST Engineering actively promotes a balanced and healthy lifestyle through annual events and during staff forums. Besides sporting activities organised by the business units, ST Engineering regularly organises group-level competitions for popular sports, like soccer, bowling, badminton and golf. Within ST Engineering, there are many sportsmen who have not only brought glory to the nation, their determination and triumph also served as an inspiration for the rest of us in the company. ST Engineering salutes and supports these sportsmen in their pursuit of sporting excellence.

"I sail competitively in local regattas and also represented Singapore at the Southeast Asia (SEA) Games in 1993 and the International Sailing Federation Cup Final in Dubai in 1998. The company has supported me by giving me time off from work to concentrate on the preparation for the competitions. I remember many encouraging words from my supervisors, and the one that I will always draw upon for strength was 'to stay focused and do your best, not just for the company, but for Singapore'.

Loh Kwan Boh
Senior Manager, Security, ST Aerospace
Represented Singapore in Sailing
1993 SEA Games, Bronze
(Middle of trio in red and white jersey)

"After the 2015 SEA Games, I received an invitation to have lunch, together with two other ST Engineering athletes, with Mr Tan Pheng Hock, then President & CEO. He was appreciative of our efforts in representing Singapore, and juggling the demands of work and sports. This simple gesture inspired us to give our best at work, knowing that our company is fully supportive of our aspirations as athletes.

Jenmark Binay Sorreda
Senior Associate Engineer, ST Kinetics
Represented Singapore in Floorball
2013 SEA Games, Gold
2014 SEA Championship Cup, Gold
2015 SEA Games, Gold
2016 World Floorball Championship Qualifiers (2nd place)

"I joined ST Aerospace in end-2006, and was selected to represent Singapore in the SEA Games in 2007. I was worried at that time whether I would be able to compete as I was new and in my first job. I was deeply encouraged when my supervisors not only supported my training regime leading up to the Games, Mr Jeffrey Lam, ST Aerospace's COO, also congratulated me personally after the competition and promised the company's continual support in my sporting pursuits.

Eugene Chiew
Head of Mechanical Engineering, ST Aerospace
Represented Singapore in Shooting
2007 SEA Games, Bronze (Individual)
2007 SEA Games, Bronze (Team)
2015 SEA Games, Silver (Team)

"ST Engineering has been extremely supportive of my sports activities. As an intern at ST Kinetics, my supervisor has accommodated my training with a flexible work schedule. The extra time was vital in making the long trips from my training area in Kallang to my work place in the west side of Singapore.

Mervyn Toh
ST Engineering Scholar and final year NUS Mechanical Engineering student (in foreground)
Represented Singapore in Flatwater Kayaking
2015 SEA Games, Gold (K1 200m)
2015 SEA Games, Silver (K2 200m)
2015 Asian Canoe Championships, Bronze (K1 200m)
2016 Singapore Meritorious Sportsman Award (Individual)
2016 Asian Canoe Cup, Bronze (K1 200m)
2016 ASEAN University Games, Gold (K1 200m)
2016 ASEAN University Games, Gold (K2 200m)
2016 ASEAN University Games, Gold (K4 200m)
2016 ASEAN University Games, Gold (K1 500m)
2016 ASEAN University Games, Gold (K4 500m)

ST Aerospace Coastal Run 2005.

Celebrating ST Automotive's 25th Anniversary with 1,091 km jog and walk.

ASPIRATIONS AND AMBITIONS

Growing up, we all had ambitions to achieve great things, and ST Engineering is no different. From a humble ammunition manufacturer five decades ago to support the needs of a fledging nation, the Group has worked relentlessly to expand and enhance its products and services to become a leading global defence and engineering Group with world-class aerospace, electronics, land systems and marine solutions.

ST Engineering is what it is today because of our unity in strength and because we dared to dream – challenging ourselves to deliver exceptional value for our stakeholders. Our aspirations and ambitions will continue to take us further as we build upon the capabilities honed by the generations before us to scale new heights. With renewed strength and confidence, we are ready to embark on our next lap of growth.

PARTICIPATION IN SINGAPORE NATIONAL DAY PARADES OVER THE GROUP'S TRANSFORMATIONAL YEARS

Photos courtesy of Ministry of Information and the Arts

Singapore Technologies in 1993

Sheng-Li Group in 1980


ST Engineering in 2001

Singapore Technologies in 1990

From Sheng-Li to ST Engineering

By the late 1970s, there were more than 16 defence pioneer companies under Sheng-Li Holdings. In 1981, the Government reorganised them into four sectors. Under Aerospace were Singapore Aerospace Manufacturing Company (SAMCO), Singapore Aero-Engine Overhaul (SAEOL) and Singapore Electronic and Engineering (SEEL). Under Ordnance were Chartered Industries of Singapore (CIS), Singapore Automotive Engineering (SAE), Ordnance Development and Engineering (ODE), Allied Ordnance Company of Singapore (AOS) and Unicorn International (UI). The Marine sector had Singapore Shipbuilding and Engineering (SSE); while SAF Enterprise (SAFE) and Singapore Food Industries (SFI) came under General Services.

A year later, Singapore Aircraft Industries (SAI) was formed to be the holding company for the Aerospace sector, in line with the Economic Development Board's intention to position Singapore as a regional aerospace hub. Similarly, Singapore Technology Corporation (STC) was formed in 1983 as the holding company for the Ordnance sector, less AOS.

In 1987, Ministry of Defence (MINDEF) drew up the Singapore Defence Industries Charter, defining the roles of the defence industries, its relationship with MINDEF and its strategic thrust. The Charter was announced by BG Lee Hsien Loong, then Second Minister for Defence, to the Sheng-Li executives, reiterating the need for the defence industries to stay commercially viable beyond their roles in Singapore's defence. This was consistent with the direction Dr Goh Keng Swee had set out for the pioneer defence companies when they were established.

Anticipating a slowdown in the Singapore Armed Forces' (SAF) demand in the 1990s, Sheng-Li carried out another review to leverage the core competences of its subsidiaries to diversify into commercial products and services for global markets. To promote a consistent and coherent corporate identity for internationalisation, the sunburst logo was launched in 1989 and Sheng-Li was renamed Singapore Technologies (ST) Holdings a year later. ST Aerospace and ST Marine listed on the Stock Exchange of Singapore in 1990 to be followed by ST Electronics and ST Automotive in 1991. ST maintained management control of these companies.

In 1994, the ST group came under the Singapore investment company, Temasek Holdings, and in 1995 ST Pte Ltd (STPL) was formed as the group's operational headquarters. Ms Ho Ching became STPL's first Managing Director. In 1996, several ST business units involved in information communications technologies were consolidated under ST Electronics.

In 1997, ST Aerospace, ST Electronics, ST Automotive and ST Marine were amalgamated to form ST Engineering. Ms Ho Ching, who took on the appointment of President & CEO of STPL that year, served as ST Engineering's founding Chairman and Mr Boon Swan Foo, its founding President & CEO.

In the final step of the consolidation of pioneer defence companies, ST Automotive acquired CIS in late 1999 and was renamed ST Kinetics in 2000 to reflect its enlarged portfolio. In 2004, ST Engineering came directly under Temasek Holdings when STPL was absorbed by Temasek Holdings.

PUBLIC LISTING OF PIONEER DEFENCE COMPANIES IN 1990 AND 1991

Singapore Aerospace was the first to be publicly listed followed by Singapore Shipbuilding & Engineering, Singapore Electronic & Engineering and Singapore Automotive Engineering.

Ho Ching with Kwa Chong Seng and Vincent Chong at ST Engineering's 50th Anniversary commemorative event.

Engineering Technology for Singapore

Many would recognise Ms Ho Ching for her contributions in Temasek Holdings but few might know her as a veteran of the Singapore defence community.

Ho Ching started her career in 1976 as a defence engineer in what is now part of DSO National Laboratories (DSO). In 1983, she became the Director of Materials Management Organisation, the procurement arm of the Ministry of Defence, and concurrently the Deputy Director of DSO.

In 1987, Ho Ching joined the Chartered Industries of Singapore (CIS) as the Director II of Engineering. She spent the next 10 years working to expand and reposition the group of companies before becoming the President & CEO of Singapore Technologies (ST) in 1997. That year, ST Engineering was formed as a result of Ho Ching's initiative to build depth and scale for the defence-related companies under ST. She served as its founding Chairman until 2003.

From her first project to develop an artillery radar trainer, to the development of the FH88, Singapore's first indigenous 155mm field howitzer, her mantra has been for defence technology to be a force multiplier in support of the Singapore Armed Forces (SAF).

A strong proponent for R&D capability, she seeded then Singapore Automotive Engineering, now ST Kinetics, with a S$5m grant from CIS to develop its own automotive platforms. It was an act of confidence in the young engineers, which kick-started the company's transformation from a maintenance and upgrade engineering shop to become an innovative solutions provider. Today, ST Kinetics stands proud of its suite of modern fighting platforms, from the early Bionix Infantry Fighting Vehicles for the SAF to the new-generation Terrex Infantry Fighting Vehicles shortlisted for trial by the US Marine Corps in 2016.

Little known too were Ho Ching's behind-the-scene involvements in several non-defence programmes, like the Infrared Fever Screening System (IFSS), and more recently, the Air+ Smart Mask for schoolchildren.

Mr Seah Moon Ming, former President of ST Electronics and Deputy CEO of ST Engineering, recalled Ho Ching's involvement

Ho Ching

Founding Chairman of ST Engineering,
and Executive Director and CEO of Temasek Holdings

Photo courtesy of Temasek Holdings

in the development of the IFSS. "During the start of the SARS epidemic, Ho Ching gave her personal input on improvements needed for the prototype thermal imager. This guided the eventual packaging design, system accuracy and product certification of the IFSS. At the height of the SARS crisis, she sent units of the IFSS to regional airports and immigration checkpoints, as gifts of Temasek, to help screen for fevers. She even brought some units personally with her to Beijing for their airport screening," he said.

Similarly, after a spell of severe haze coming from massive forest fires in Indonesia in 2013, Ho Ching turned to her trusted former colleagues at ST Engineering to find a solution to protect the school children from the unhealthy haze. Thus, was born the AIR+ Smart Mask, with its detachable micro-ventilator, the first N95-certified masks in the world fit tested for children to protect them from airborne hazards.

Whether in defence engineering or commercial systems, Ho Ching is a stickler for making lives better and products safer for the users, be they children or National Servicemen.

Ho Ching seeded the capability buildup that led to the Bionix, Bronco and other armoured vehicles of ST Engineering.

"At CIS, I worked alongside dedicated pioneers like Henry Cheong, Loh Chuk Yam, Chia Pak Chong, Lai Chun Loong, and many others. They were exceptional leaders who set the firm foundation for ST Engineering today.

CIS itself was reflective of a young Singapore's collective will to overcome the odds and to survive as a new nation. We succeeded, and ST Engineering is today one of Asia's leading technology, defence and engineering groups.

Beyond Asia, ST Engineering has earned its reputation with products like the Warthog all-terrain vehicles, which saved the lives of several British soldiers; the TeLEOS-1 imaging satellite, which has affirmed Singapore's space aspirations; and the patrol vessels for the Royal Navy of Oman, the largest defence export contract in ST Engineering's history.

The years of roughing it out have polished the edges of ST Engineering, and given the Group its shine. It has the breadth, depth and heft of hard-earned experience under its belt to take on new opportunities in the world.

Yet, its goal must remain unchanged. ST Engineering is still very much a part of Singapore' collective determination to overcome the odds and thrive in a fast-changing, globalised and connected world. Its core purpose must still be to make a difference in the lives of its fellow citizens and soldiers of the SAF.

It is important that when we look to the future, we remember the predecessors who have cleared the grounds and sweated the course before us. We must never dismiss their actions casually but try to understand why decisions were made that way. Only then will we be able to gain the wisdom to build upon and improve the remarkable heritage the pioneers had provided us.

To me, the mission of ST Engineering is already encapsulated in its name.

Singapore *is the core of what we are, who we are, and what we stand for, be it good governance, discipline in delivery or integrity in all that we do. While we expand globally, we have to stay rooted to Singapore as our headquarters.*

Technologies *are the lifeblood of what we must master and deliver to make lives better for our citizens and soldiers, and for ST Engineering's customers in Singapore and abroad.*

Engineering *is a calling, always looking to make things better, to design more efficient processes or to build better systems to make lives better.*

Everyone in ST Engineering, past and present, local and overseas, should stand proud of the numerous innovations and immense contributions over the last five decades. All of you have made a real difference whether it is in the area of defence or in helping to make lives better, in Singapore and other parts of the world.

Ho Ching
Founding Chairman of ST Engineering, and Executive Director and CEO of Temasek Holdings

A Boon to the Group

Swan Foo hosting the late President of the Republic of Venezuela at ST Aerospace in 1999.
Photo courtesy of Ministry of Information and the Arts

Boon Swan Foo
Founding President & CEO, ST Engineering (1997 to 2000), Deputy Chairman & CEO, ST Engineering (2000 to 2001)

Mr Boon Swan Foo is a man of many talents. He is an experienced skydiver, licensed scuba diver, naval architect, chartered accountant and outstanding CEO award winner. Swan Foo's tour of duty with ST Engineering began in 1980 with ST Marine, then known as SSE. He worked his way up at SSE to become its President in 1994 and from 1995 to 1997, was the President of Singapore Aerospace.

Most of all, Swan Foo is remembered as ST Engineering's founding President & CEO, the role he assumed in 1997. He was Deputy Chairman & CEO when he stepped down in 2001. During this time, he had a hand in amalgamating four listed STPL entities to form ST Engineering, grew the Group's market capitalisation from S$2 billion to about S$7.6 billion, and set it on a trajectory for global expansion as a top-performing company.

According to Swan Foo, the decision to merge the aerospace, electronics, automotive, and marine businesses in 1997 in what was known as 'Project Armour', was prompted by market forces, convergence of military and commercial technologies, as well as rationalisation by STPL. MINDEF too, had been supportive of the arrangement, which would strengthen the local defence capabilities. It would also provide ST Engineering with considerable opportunities

for sustainable long-term growth, the critical mass to compete and forge strategic alliances globally, and business possibilities beyond the resources of any one single sector. The final step in the consolidation masterplan would take place in 2000, when CIS came into the ST Engineering fold.

"Naturally, the convergence of four completely different businesses created plenty of excitement for everyone," Swan Foo recollected. "From the market perspective, we became sizeable enough for the large global funds to take an interest. On the technology front, there was good potential from the emergence of electronics and Internet connectivity to transform our hardware offerings and make them smarter for both defence and commercial customers. At that juncture too, many staff got to convert their stock options from the de-listed companies into ST Engineering shares. I'm sure they all made a tidy windfall!" he added cheekily.

As the boss-man, Swan Foo was known for his quick wit and no-nonsense business approach. "The yes-man is a big no-no for me. One must learn to stand up for what they believe in, otherwise ST Engineering would never have improved or become what it is today," he said. Although Swan Foo did not suffer fools gladly, he was a big-hearted leader who believed that action spoke louder than words.

Till today, many remember the generous IT grants he rolled out around the turn of the millennium so that all ST Engineering employees could own a computer and take advantage of the Internet. "It cost the Group around S$20 million. The junior workers especially were very appreciative of the gesture. Many came to tell me that their children also benefitted from the use of their first-ever home computer. I think companies must be prepared to spend the money if they want to talk about growth and innovation," Swan Foo reflected.

To instil a stronger creative culture, the Group began pushing for the filing of patents and promoting innovation across the ranks. Swan Foo also made it a point to distinguish the look of ST Engineering's annual reports by leveraging creative themes and formats, and starting a trend whereby group photos of the senior management team would be styled in accordance to the themes.

"ST Engineering became the first government-linked company to obtain the highest possible credit rating. I'm proud that despite returning 100% of our profits as dividends annually during my time, ST Engineering has been able to retain this credit rating in spite of the tremendous growth and expansion over the years, thanks to sound financial management by the CFO. For many years, ST Engineering would announce its full-year results in January, ahead of most companies in Singapore. We were among the first listed companies to start filing quarterly financial reports, publishing details down to the sectoral levels and bagging numerous accolades such as the Most Transparent Company Award, as a result," beamed Swan Foo.

Looking back at other sweeping decisions that were made under his watch, Swan Foo admitted, "I don't think everyone agreed with the way I work. But when something was right and if there were fair reasons behind it, I've stuck my neck out to make sure that things got going." He cited major turning points for the Group, such as its high-profile participation in the US Interim Armoured Vehicle programme and the resolution of an intellectual property dispute over the design of a platform. "Without taking such steps, we would have no VT Systems, no defence growth in the US or elsewhere, no future exports for the platform concerned, and no credibility as a big league player," he asserted.

Only the flamboyance and gumption of someone like Swan Foo could warrant an official tribute on US Congressional Record in 2002 for his visionary leadership in advancing a global enterprise, "which he did the old-fashioned way, from ground up, taking care of the assorted details along the way," according to Congressman Solomon Ortiz.

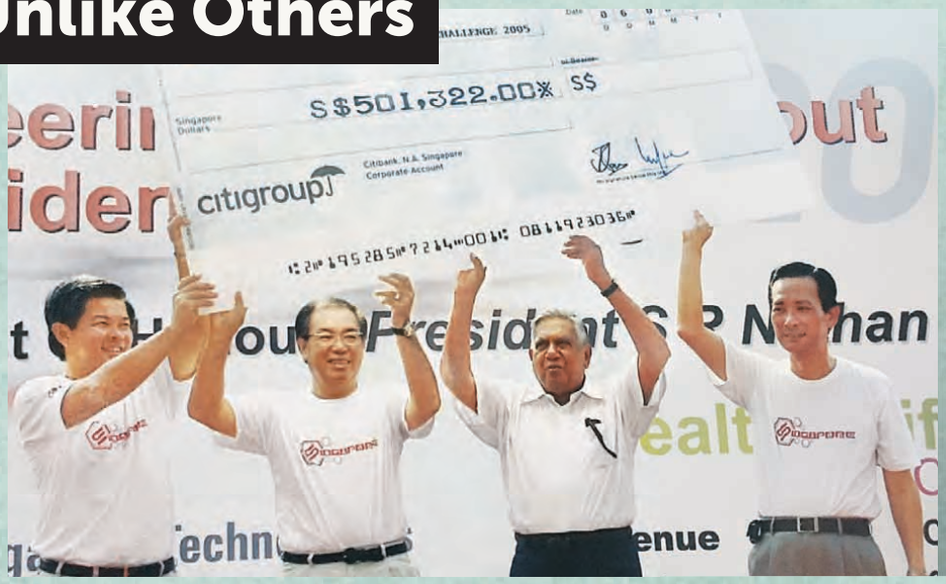
In Swan Foo's mind, one thing has always been clear: Singapore is a small country that has to survive. "This is a calling that requires more than mere passion! If we don't do it right, our company and country are both at stake. ST Engineering must always remember its roots, the defence of Singapore, and hence work hand-in-glove with MINDEF. We have been fortuitous enough to build on the legacy and accomplishments of our pioneers and must be able to do the same for future generations. I hope our engineers have the same hunger for survival," he mused.

Espousing the need for "T-shaped individuals", Swan Foo believed that a good engineering company requires people with breadth of knowledge as well as depth of expertise. "These days, it's easy to rely on the Internet for business or engineering knowledge. My parting shot to all engineers is to dig deep, specialise and make every effort to gain real experience. You'll find that ST Engineering is one organisation where there's plenty of opportunities to put this into practice," he concluded.

Boon Swan Foo receiving his outstanding CEO of the Year 2000 Award.

Source: The Business Times © Singapore Press Holdings Limited. Reprinted with permission.

A Group Unlike Others



Peter Seah (2nd from left) presenting ST Engineering's collective contribution towards President's Challenge 2005 to late Singapore President, S R Nathan.

Photo courtesy of DBS Bank Ltd

Peter Seah
Chairman, ST Engineering (2002 to 2013)

Mr Peter Seah is a seasoned banker and a familiar face on the Boards of many Temasek-linked companies. He was President & CEO of the now-defunct STPL when asked to chair the ST Engineering Board in 2002.

"ST Engineering is unlike other Temasek-linked or STPL companies. Its mission is to help strengthen the defence of Singapore, and so you cannot run it like any other company. My role was to grow this Singapore-centric defence-oriented organisation into a global and commercially viable business and to ensure Singapore's defence needs were fully met," Peter said.

To deliver the mission, Peter had to find a capable CEO. "Ho Ching and I took a chance on a young Pheng Hock. Initially, when I was still STPL's CEO, I played a more active role as mentor and adviser, lending him my experience in areas like leadership renewal, overseas expansion and major investments. However, my Board philosophy is to be a partner to management, and not to get into any direct involvement. I think Pheng Hock's done a spectacular job. Kudos to him for being able to consistently return close to 30% on equity as President & CEO of ST Engineering."

"As ST Engineering's Chairman, I've always felt a different sense of pride when our artillery and armoured platforms roll past at Singapore's National Day Parades. Overriding any other accomplishment as a Group, ST Engineering contributes to the defence of Singapore – that's neither a business nor a job. While we planted flags around the world and grew our revenue stream, our interest was and still is to become the best possible partner to MINDEF, one who is trusted," said Peter.

Under Peter's watch, ST Engineering blossomed as a global group with significant defence and commercial reach. It entrenched its presence in the US and grew its operations in Europe and the Middle East with substantial acquisitions like VT Halter Marine, VT iDirect, Elbe Flugzeugwerke

and Telematics Wireless, while Group revenue grew from about S$2.6 billion in 2002 to S$6.6 billion in 2013.

Back in the day, extracting maximum synergy from the four business sectors was a key item on Peter's agenda, "I created the roles of President, Defence Business, and President, Commercial Business, to make sure the Group's efforts were well coordinated, and that key customers received maximum attention." In retrospect, the integrative effort has served the Group well, given the convergence of MINDEF's air, land and naval operations and the digitisation of things, enabled by rapid advancements in electronics and the information communications technology sphere.

"My other focus was to cultivate 'private-sector thinking' among the top executives," Peter continued. "I decided that no employee should use their military ranks at ST Engineering so as to commercialise their mindsets and inculcate a global outlook.

Peter still finds himself correcting misperceptions of ST Engineering from time to time. "Not everyone realises the engineering depth and R&D capabilities ST Engineering has built up over 50 years together with Singapore's Defence Technology Community. Some are still surprised to learn that state-of-the-art developments, like the Warthogs that were sold to the UK, were designed and built in Singapore.

"Going global, and exporting defence solutions especially, will always be tough for small countries like Singapore. But I believe ST Engineering has turned that to its advantage – by working harder. In achieving its ambitions, ST Engineering has managed to pool resources, establish strong teams and maximise people's skills – leveraging the same factors that have propelled Singapore's global success," he added.

One of a Kind

Mr Lim Neo Chian is the only former ST Engineering Deputy Chairman and CEO who benefitted from the Group's many cutting-edge solutions as a customer, and understood what it took to develop and market them to the SAF and the world. Notably, one of Neo Chian's many roles before taking the helm between 2001 and 2002, was Chief of the Singapore Army from 1992 to 1995.

"What's less known were my roles as Board Director of the Chartered Industries of Singapore and Singapore Aircraft Maintenance Company in the 1980s, and Chairman of ST Automotive between 2000 and 2001. So, my time with ST Engineering had felt like a continuation of my service within the defence ecosystem – from having a hand in defining the operating requirements of key products like the Bionix Infantry Fighting Vehicle, SAR21 Assault Rifle and the FH2000 artillery gun as a user, to being able to help improve and bring these home grown technologies and equipment to countries like the US as the Group's CEO," he described.

Yet, what struck him most when he succeeded Mr Boon Swan Foo was not the sophistication of the Group's technologies, but the sheer number of developments and innovation it was capable of pushing out. "To me, technologically advanced solutions for Singapore's decisive victory are a given. But obsolescence happens quickly, so there's a need to stay 20 to 25 years ahead of time in order to maintain that critical edge."

Speaking from experience, the former Major-General added, "The SAF cannot fight this high-tech battle on its own, and continued investments to build up defence capability and the people who support the technology establishments are a must. ST Engineering will remain relevant so long as it maintains its edge by working hand-in-hand with the SAF."

Neo Chian pointed out another important quality about ST Engineering that left a deep impression – the drive of its people. "In almost every group I got to know, there was that unmistakable dedication to excellence and pushing the company forward – whether in terms of revenue, technical capability or business opportunities. The energy level to keep moving is just amazing, and it was never a case where people had to be pushed. That made it easy for me to focus on the steering of the Group," he shared.

Photo courtesy of Agri-Food and Veterinary Authority of Singapore

Lim Neo Chian

Deputy Chairman & CEO, ST Engineering (2001 to 2002)

Tan Pheng Hock receiving the Outstanding CEO of the Year 2014 Award.

The Former Boss who Never Sleeps*

Ask anyone who has ever worked with Mr Tan Pheng Hock and he or she is likely to mention how ST Engineering's third President & CEO never seems to sleep due to his habit of replying emails at all times of the day. With his trusty BlackBerry by his side, Pheng Hock charted ST Engineering's growth from a S$2.6 billion company in 2002 to becoming one of Forbes' most innovative companies in the world in 2014 and a Group with a revenue size of about S$6.7 billion by the time he retired in 2016.

"Over the years, I've come to realise one thing: that the most important attribute to look for in people is passion. People who're here to do a job, they'll come and go. There's no real commitment, no job enlargement and no personal fulfilment. On the contrary, when you're passionate about what you do, you'll want to make a difference. You're driven to innovate, make products better, and take up more responsibilities.

ST Engineering's biggest strength is the fact that it has good, passionate people – especially in the engineering pool. We put our capability and passion to good use in solving problems or tailoring solutions that the world needs.

The AIR+ Smart Mask is a recent example. Producing a solution that would help those affected by the haze was a new challenge in the market. Passenger-to-freighter conversions are another – not many have the capability, capacity or certification to undertake such a major feat of engineering.

Being passionate means we don't just talk about ideas. We put in time and resources to design and make ideas work. Even if ideas aren't entirely new, we're always challenging ourselves to upgrade, modify and value-add. That's why, for five decades, we're consistently able to churn out innovative solutions for the market.

Whether it's dealing with the SARS crisis, putting a satellite in space, customising the Warthog to keep British soldiers safe, or building Littoral Mission Vessels to enhance Singapore's seaward defence, the Group and its achievements have grown from strength to strength. Today, we are a partner of choice. To me, that's what makes ST Engineering different.

Tan Pheng Hock
President & CEO, ST Engineering (2002 to 2016)

* These days, Pheng Hock has more time to take the MRT: "I makan (means to eat in Bahasa Melayu), relax and tidur (means to sleep in Bahasa Melayu)." So, for the record, Pheng Hock does sleep.

DID YOU KNOW?

HE SPENT OVER 30 YEARS AT ST ENGINEERING, HIS FIRST AND ONLY JOB

Pheng Hock joined ST Marine in 1981 where he rose to the rank of Executive Vice President. He was President, Corporate Affairs at ST Engineering in 1997, President, ST Automotive in 1998, President and Chief Operating Officer of ST Engineering in 2000 and Group President in 2001, before assuming the role of President & CEO in 2002.

HE GARNERED MULTIPLE AWARDS AS ST ENGINEERING'S CEO

He was named Outstanding CEO of the Year in 2014; CNBC's Asia Business Leader of the Year in 2013; Honorary Fellow of the ASEAN Federation of Engineering Organisations in 2013, Best CEO (market cap of S$1 billion and above) in 2012; one of Platinum Circle's Asia Leaders and the Asia Leader for Singapore in 2010; winner of the CNBC Asia Talent Management Award in 2009; and the first Asian Chief Executive to receive the Walter L. Hurd Foundation World Executive Medal in 2007, among other accolades.

HE THRIVED ON HARD WORK

Pheng Hock confesses to working best under tension, and believes that "life is brimming with opportunities to sell if one would only think harder about how to meet customers' needs more creatively." He drummed into staff the need to make the most of every chance and chore that come their way. "If someone recognises you by giving you more work, that means you're good," he said.

HE BELIEVED IN SUPPORTIVE PARTNERSHIPS

In transforming ST Engineering into a capability-driven enterprise, Pheng Hock led the Group to penetrate new markets and forge alliances and partnerships to leverage on competitive strengths and capabilities. To achieve long-term success, however, "one must also learn to treat and respect all customers, colleagues or competitors as partners".

HE ENJOYED CO-OPETITION

Going global was a humbling experience for Pheng Hock, because "you may be big in your home base but elsewhere, you are just an SME (small and medium sized enterprise)." Instead of always competing with the incumbents in a new market, he liked the idea of co-opetition, which is a hybrid of cooperation and competition: "We can compete in some markets and cooperate in others."

HE WAS BIG ON LISTENING

Pheng Hock believed he could learn from anyone by listening. He calls it "a useful skill that has saved him a lot of headache" during his early years at ST Engineering. He still enjoys talking to people with good experiences to share, but advised his younger colleagues that "in order to listen well, try not to talk so much!"

HE WAS A CHAMPION FOR UNION CAUSES

He encouraged the continuous upgrading of skills, and empathised with lower-wage employees by granting a higher percentage of wage increases to this group of workers. Before there were tripartite guidelines, he had advocated the re-hiring of employees beyond their official retirement age, as long as there were positions and they were physically fit for the job.

HE PUSHED FOR DIVERSIFICATION

His main focus areas were geographical diversification – to create a presence beyond the region with operations in the US and Europe; customer diversification – to serve a wider spread of global clients; and industry diversification – to minimise the impact of business cycles on ST Engineering's performance.

HE ENCOURAGED INNOVATION

Innovation to Pheng Hock was more than coming up with new products and services. It was about new and better ways of doing things, creating value-add and improving overall productivity. Knowledge of market and industry trends and what competitors are doing is important. He keeps up by networking and participating in industry events and indulging in his favourite pastime – reading!

HE WAS READY FOR FUTURE-READINESS

Pheng Hock considers a future-ready ST Engineering to be one that is globally effective in operations and meeting market needs; adaptive and well connected in responding to change; and innovative in addressing opportunities and uncertainties. It must be ready to challenge its own mental model and leverage its talent and knowledge capital.

TRANSFORMING
OUR
GROUP

Synergies from Diverse Defence Capabilities

Columns of Primus self-propelled Howitzer parading during Singapore National Day Parade 2010 at the Padang August 09, 2010 in Singapore.

Photo courtesy of Jordan Tan

ST Engineering has an essential role in the total defence of Singapore. In 2002, the Defence Business Group (DBG) was formed to synergise the defence businesses of the aerospace, electronics, land systems and marine sectors – an initiative by former President & CEO, Mr Tan Pheng Hock, to provide better customer support with a single point of contact at the senior management level.

It was a time when the concepts of connectivity and digitised battlefields were still relatively new to conventional armed forces. As an integrated engineering group, ST Engineering could tap into its full spectrum of capabilities to fulfil the growing demand for more integrated solutions. Furthermore, the DBG enabled ST Engineering to avoid duplications in technology development under its different domains.

Mr Wee Siew Kim, who was Deputy CEO of ST Engineering at the time, was appointed the first President of the DBG. The baton was subsequently passed to Mr Seah Moon Ming and Mr Lee Fook Sun, when they became Deputy CEO in 2009 and 2013 respectively. Mr Ravinder Singh took on the President DBG role in 2017.

The DBG is an example of how ST Engineering is able to deliver value that goes beyond the sum of its parts. With the combined focus and expertise of four sectors, the DBG strengthened its efforts to build up key capabilities critical to the success in the Group's defence business.

It led the Group to set up Capability Centres to pursue and pilot emerging technologies in many areas. These ranged from unmanned systems for air, land, sea and underwater operations to soldier systems, maritime platforms, naval combat solution systems, land systems, data link systems and advanced materials relevant to the operational needs of future fighting forces.

The effort advanced the engineering expertise of the Group from that of a proficient systems integrator to one that involved the conceptualisation of smart capabilities and proprietary solutions. The result: a new generation of highly sophisticated solutions involving cross sector collaborations that include the Terrex Infantry Fighting Vehicle, Avionics Upgrades, Battlefield Management Systems, and Littoral Mission Vessels.

While ST Engineering remains fully committed as a strategic technology and engineering partner to MINDEF and the SAF, the build-up of defence expertise over the years has lent itself to numerous overseas successes, such as the Patrol Vessels for the Royal Navy of Oman, Warthog for the British Army, Command, Control and Communications system for the Hong Kong Fire Service, and a major C-130B Retrofit Programme for the Indonesian Air Force, among others.

Ravinder believes that ST Engineering's experiences in export programmes have contributed positively to the Singapore defence eco-system and Singapore at large in terms of technology knowhow, "Defence exports enable us to improve our expertise, lower our costs and tap into the operational experiences of foreign militaries. These allow us to in turn deliver cutting-edge, cost-effective and manpower-efficient solutions to MINDEF and the SAF."

"DBG has come a long way since its inception. Today, our defence business and engineering expertise are better integrated. Our engagements with key customers and related stakeholders have become deeper and stronger. These have helped us to harness our wide spectrum of technologies and multi-faceted engineering capabilities to provide advanced bespoke solutions with growth flexibility to meet our defence customers' evolving needs," added Ravinder.

ST Aerospace has been providing MRO support for over 1,500 military aircraft globally since 1975.

STAYING STRATEGIC TO SINGAPORE'S DEFENCE

The SAF, like other armed forces today, is faced with great uncertainty in the security landscape. In a keynote address delivered in 2016, Mr Ng Chee Khern, MINDEF's former Permanent Secretary (Defence Development), cited the need to "look towards technology to help [the SAF] build capabilities and platforms that allow for maximum flexibility". He also envisioned closer collaboration between operators and technologists in the development cycle.

In a speech to the graduands of the Specialist Cadet Course in 2016, LG Perry Lim, Chief of Defence Force (CDF), underlined the imperatives for an operationally ready force. He said, "... To be able to respond decisively, the SAF has restructured itself, stood up task forces across the three Services, and is constantly enhancing its capabilities, leveraging upon new technologies, weaponry and platforms."

DBG will strengthen ST Engineering's role as a strategic partner to MINDEF and the SAF and endeavour with the Defence Science and Technology Agency (DSTA), DSO and other relevant research institutions to meet their evolving needs – a commitment that entails continuous innovation and improvements in technologies, capabilities, systems and processes.

In his foreword for *Engineering Singapore's Defence – The Early Years*, a commemorative book series by Singapore's Defence Technology Community to mark its 50th Anniversary in 2016, the Minister for Defence, Dr Ng Eng Hen acknowledged the valuable contributions of the various stakeholders from the defence industry who have helped to transform the SAF. "... We want to thank especially its pioneers who were committed to achieve the unthinkable and were not daunted by severe challenges along the way. Their efforts and beliefs have spawned world-class agencies such as DSTA and DSO, and the family of Singapore Technologies companies," he wrote.

RSS Independence, 1st of the eight Littoral Mission Vessels built by ST Marine.

ASPIRING
OUR
FUTURE

Engineering Tomorrow

Vincent Chong
President & CEO, ST Engineering

Fifty years on and still in the making, ST Engineering has successfully built up a wide range of competencies from the development of platforms like satellites, ships, robotics and weapon systems to providing services in information management, maintenance, repair and overhaul (MRO) and airframe conversion that allows it to compete with leading companies globally.

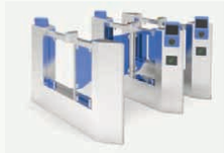
From a humble factory with a zinc roof in Jurong, ST Engineering has expanded to become a global leading engineering group with presence in 22 countries and 43 cities and a clientele in over 100 countries.

The past decade has been one of rapid expansion internationally. The Group has made its mark in many areas, including the following:

WORLD'S LARGEST COMMERCIAL AIRFRAME MRO SERVICES

WORLD'S LARGEST PRODUCER OF 40MM AMMUNITION

GLOBAL LEADER IN SATELLITE COMMUNICATIONS SOLUTIONS



WORLD-LEADING RAIL ELECTRONICS SOLUTIONS

RANKED AMONG THE WORLD'S MOST INNOVATIVE COMPANIES BY FORBES

"Today, we can truly claim to be a multinational. We have a formidable team of engineers who have developed a wide array of innovations and capabilities," said Mr Vincent Chong, President & CEO of ST Engineering. "But the world has changed. The pace of technology and business has accelerated exponentially in recent years. To drive the next lap of growth, we would have to leverage on our strengths to create more world-leading solutions. We have to do more and do some of the things differently to stay ahead."

Building a World-class Workforce

Vincent is a firm believer that an organisation is only as strong as its people. He explained, "To compete with the leading global companies, we are doubling our efforts in talent development and training to bring out our people's potential. We are building the structure and processes to support career development and provide more opportunities for job rotation, global mobility, and encourage cross-sector deployment."

Equally important is the need to inspire and sustain people's passion for innovation, customer value creation and excellence. "In the new digital age, we have to create a corresponding environment where employees are given the opportunity to pursue new ideas close to their hearts. We have to carve more space where there is greater tolerance for failure from trials and experimentation, and recognise that these failures are not accidental but a necessary learning process that will eventually lead to successful innovation," said Vincent. He cited the example of the AIR+ Smart Mask, which underwent more than 200 prototype testing before perfecting the mask and ventilator to go to market.

Another good example is the Infrared Fever Screening System (IFSS) that ST Electronics had developed with DSTA during the 2003 SARS crisis. The IFSS proved to be an effective mass-screening solution not only during the SARS crisis, it has been deployed for subsequent global epidemics like the avian flu, and is in use today at many immigration checkpoints.

"The motivation behind the invention of the IFSS was never commercial. There was a deep sense of national responsibility and a desire by the IFSS team to engineer a solution that can screen travellers efficiently to prevent the spread of a global epidemic. It has ultimately helped to save lives," said Vincent, pointing out the kind of passion the Group needs to drive its growth further.

"We have many of these heroes among us like Andy Hefner for High Throughput Satellites, Steve Wong for naval systems, and Teo Chew Kwee, who has a DTP Individual (Engineering) Award for his years of contribution to the development of Singapore howitzers. These are engineers who have dedicated their whole careers, and for some, even their entire lives, to their fields of expertise. You can't do this without passion," Vincent explained.

Vincent Chong and Human Resource staff with ST Engineering scholarship holders after a tea session in 2016.

ASPIRING
OUR
FUTURE

Coming together for a Strategic Planning Workshop in 2017 to map out the Group's aspirations.

Engineering Tomorrow

The Whole is Greater than the Sum of its Parts

Besides people, another key enabler is to leverage ST Engineering's diverse strengths and markets as an integrated group. This has helped the Group to punch above its weight – securing major contracts around the world and establishing partnerships and collaboration with global giants like Airbus, All Nippon Airways, Boeing, China Eastern Airlines, Japan Airlines and Motorola amongst others.

Vincent said, "It is absolutely critical to draw on the synergies and scale of the Group. Working as One ST Engineering would put us in a much stronger position to go head-to-head with first-tier multinationals and to continue developing innovative solutions that make a real difference in the world."

One of the efforts to enhance collaboration between business sectors is in the area of building greater capacity for growth. Common corporate services are shared to improve resource allocation, productivity and service delivery. These initiatives are expected to strengthen organisational efficiency and make ST Engineering a more competitive global player in the long run.

SHARING AS ONE

ST Engineering embarked on a shared service initiative, code-named Project Delta, for its Singapore business units in 2016. More than 70 work-streams, such as payroll and talent acquisition for HR, treasury and accounts payable for Finance, category management and strategic supplier management for Procurement, service management and knowledge management for IT, would be streamlined. The aim is to leverage the scale and synergies of the Group to achieve greater productivity and deeper functional expertise, and in so doing, create greater capacity for growth. The project will be implemented progressively.

Aw Kah Wai addressing participants in one of many forums and workshops organised under Project Delta.

Mr Jeffrey Lam, Chief Operating Officer of ST Aerospace, believes that Project Delta would build bridges between people and ideas, and reduce barriers amongst business units. He said, "There are many potential benefits that ST Engineering could gain from Project Delta, such as developing common IT systems to link people and automate work processes, unifying procurement and vendor management system to leverage on collective purchasing power and creating better career opportunities to deepen the support functions' competences."

Leveraging Technology and Innovation

"The ability to build strategic capabilities and businesses out of technology and innovation is one of our hallmarks," Vincent said. "R&D will continue to be a mainstay to develop differentiated solutions that can create real economic value for our customers."

The Group is, however, not looking for one-hit wonders but breakthrough innovations that will either strengthen its current portfolio of businesses or generate new lines of business. This will require astute technology investments and partnerships, a pervasive culture of innovation and an environment where engineers can brainstorm freely outside of business and operational constraints to develop new ideas and solutions.

Innosparks is an idea incubator set up in 2014 as a subsidiary of ST Dynamics to provide this unrestrained space for ideation. It has proven successful with several proprietary solutions that include the Airbitat Smart Cooler, which delivers tangible benefits in hot and humid climates by cooling outdoor temperatures to as low as 24 degrees Celsius with energy savings of up to 80% when compared to the average air conditioner of an equivalent capacity.

Vincent said, "We have since repositioned Innosparks to become the Open innovation Lab of ST Engineering. It is now located at LaunchPad @ one-north, a vibrant community for start-ups and incubators in Singapore, where engineers from different disciplines, internally and externally, can come together to collaborate on groundbreaking or disruptive solutions. We will also establish overseas technology scouting and acquisition offices in strategic locations around the world to be in the global centres of technology and innovation."

A HOME GROUND FOR ACCELERATING INNOVATION

ST Engineering's first Open Innovation Laboratory (Open Lab) is a springboard to new and disruptive technologies. A dynamic innovation platform and engineering-based incubator, the Open Lab serves to accelerate technology innovation, encourage experimentation, foster entrepreneurialism and collaborating among Singapore start-ups, while attracting the best and brightest engineering talent.

Spearheaded by Innosparks, the Open Lab thrives on co-creation and exchange. Its objective is to accelerate research and development cycles, shorten the time taken to introduce new ideas to markets, and to ignite innovation that could spawn new markets.

With an eco-system that is designed for open access, the possibilities are endless. Participation is not limited to ST Engineering units – local and international start-ups, inventors, entrepreneurs, technology partners are also give the space to crystallise and grow their ideas.

As a start, the Open Lab has been sited at Singapore's version of the Silicon Valley at one-north. It offers multi-disciplinary applied engineering capabilities through facilities such as a Mechanical & Control Lab, Electronics & Electrical Lab, Material & Chemical Lab, Software Lab and Design Lab.

"The Open Innovation Lab is truly a home ground for accelerating breakthrough innovation. It welcomes bold ideas, allows for radical experiments within an innovation eco-system, embraces the fail-fast mentality, and fosters rapid innovation exchange between the Group's engineers as well as the wider community. This is where engineers can dream big and fuel their passion to bring transformative solutions to the communities we live in," said Gareth Tang, Head - Open Lab, GM Innosparks.

Engineering Tomorrow

Disciplined Investments for long-term Sustainable Growth

"Defence will remain our core business. We will continue to build strategic capabilities and step up our product development and aftersales support for the SAF and other defence customers," said Vincent. He added that efforts would include strategic investments in advanced systems to further strengthen the Group's defence capabilities in the areas of autonomous technology, cyber security and connectivity for operational effectiveness.

"On the commercial front, to drive the next lap of growth would be challenging. It will not only require ST Engineering to stay ahead of the curve, we will have to go in with a new mindset and be prepared to lead in industry transformation," he said. Such an approach will call for a more disciplined and targeted approach towards investments and acquisitions in order to build greater capacity for innovation and to create new growth opportunities.

Augmented Reality.

Automated Baggage Tractor.

Part of it would also involve the divestment of outdated solutions and business lines that are no longer aligned to the Group's overall strategy and directions, like the specialty vehicle businesses in China. "These are hard decisions but they have to be made in order to streamline capacities and reallocate capital to gain new growth markets," said Vincent.

ST Engineering possesses many of the criteria and conditions to take on and benefit from new and higher growth opportunities brought about by digitalisation, the proliferation of robotics and the rise of autonomous solutions. There are great opportunities in smart cities, and the Group has developed significant domain expertise in sustainability, connectivity, mobility, public safety and security to improve the urban environment.

DPM Teo Chee Hean (3rd from right) viewing ST Electronics' latest C4I solutions during a facility visit in 2016.

Minister for Defence Dr Ng Eng Hen (front left) at the ST Engineering Pavilion during IMDEX Asia 2017.

ST Kinetics leads the Singapore Autonomous Vehicles Consortium to develop standards for adoption of AV technologies in Singapore.

"Over the last 50 years, ST Engineering has grown to be a global defence and engineering Group, respected in Singapore and known as a reliable partner where we do busines. Going forward, we aspire to elevate the Group to become a global technology, defence and engineering powerhouse by being more innovative and resilient than ever before. We will put in the right strategic systems and capabilities to stand out in our focus business areas and be the best possible partner to MINDEF and the SAF. We also aim to be a responsible technology leader that creates sustainable value for our customers, and an employer of choice for our people," Vincent continued.

"Our future triumphs will depend on the innovativeness and collective will of our employees in overcoming ever-evolving and increasingly tougher challenges. Together, we are focused on engineering tomorrow," he proclaimed.

Minister for Defence Dr Ng Eng Hen trying out a virtual reality headset during a visit to ST Kinetics in 2017.


S

SOLUTIONS AND SERVICES

The growth and success of an engineering company depend on its ability to come up with better solutions and services year after year. At ST Engineering, this is accomplished with a customer-first focus.

Across our four business sectors, customer solutions are conceived with a view towards delivering value – outcomes that advance societies, improve organisations and enhance people's lives. Our coveted accolades, engineering breakthroughs and loyal customers are the best testament to the significance and effectiveness of our work.

ACHIEVING CUSTOMER CENTRICITY

Creating Value for our Customers Worldwide

Lim Serh Ghee
President, ST Aerospace

With a continuous pursuit to achieve a high level of satisfaction from its customers worldwide, ST Aerospace has steadily expanded its engineering competencies to provide products and services that add value to its customers' businesses and operations. Inculcating a Customer Excellence culture and mindset in everything it does has created enduring success for ST Aerospace and it is no coincidence that ST Aerospace contributes to a third of ST Engineering's revenue.

"The company is organised around our mission, which is to keep aircraft flying safely. All our employees are duly trained and empowered to fulfil this simple but critical objective," said Mr Lim Serh Ghee, President of ST Aerospace.

"Following this mission has enabled us to establish a firm global footprint, with facilities in key aviation hubs in the US, Europe and Asia Pacific, so that we can be near our customers and serve them better. We are recognised as the world's largest independent airframe maintenance, repair and overhaul (MRO) service provider. We have over 8,000 certified engineers and aviation specialists," Serh Ghee said. "Has that made us world-class? Perhaps in some areas. But I would like to think that there is still plenty of room for improvement to serve our customers better."

Serh Ghee listed three key success elements that had over the years propelled ST Aerospace ahead of the pack. The first element was customer-centricity, which is a critical part of its Customer Excellence culture – the ability to match, or even exceed customers' expectations and deliver value-added services and products.

"ST Engineering as a Group has been successful over the years largely because we learnt to listen carefully to our customers. For our next lap of growth, we must go beyond listening to deepening relationships with our customers. This will require us to know our customers in depth, and not just for work, but to truly know them as individuals who possess different sets of values, interests, needs and concerns," said Serh Ghee.

In ST Aerospace, this focus on customers was reflected in its tag-line 'Creating value for our customers – worldwide' and backed by over 12 million man-hours it clocked annually in the commercial airframe MRO business. Such a feat could only have been possible with satisfied, returning customers.

The second element, a fundamental core, was the deep capabilities that were developed to support and keep up with the demands of a

ST Aerospace is the world's largest independent airframe MRO service provider with an annual capacity of 12.5 million man-hours in 2016.

WORLD'S LARGEST COMMERCIAL AIRFRAME MRO SERVICE PROVIDER IN NUMBERS

12,500,000
man-hours annual airframe capacity

1,000,000
components redelivered

15,250
commercial aircraft maintained and modified

3,260
aircraft redelivered to FedEx

550
engines serviced under total support programme

2,400
military aircraft serviced under maintenance programme

600
aircraft contracted under component maintenance-by-the-hour programme

141
Boeing 757 PTF conversions

first-class Air Force in Singapore, Republic of Singapore Air Force (RSAF). These capabilities are not just in the technical aspect for MRO and aircraft upgrades but also in standards and systems that uphold the quality, reliability and aviation safety culture of its workforce. ST Aerospace has been working with RSAF for over four decades. Our defence business remains important to us. The RSAF has been and continues to be a strategic customer of ST Aerospace.

The final element was the strategic move to deepen ST Aerospace's intellectual property in Passenger-to-Freighter (PTF) conversions by developing its own Supplemental Type Certificate (STC), a certificate issued by national aviation authorities to perform major modification and repair to existing type-certified aircraft and engines. In 2008, ST Aerospace developed its first Boeing 757 STC that landed a contract to convert 119 Boeing 757 from FedEx as well as a contract to modify a Boeing 757 from a passenger into a multi-role aircraft for the Royal New Zealand Air Force.

"A large part of our success lies in the trust our customers have in our people and capabilities, the reliability of our work and services, and our 'can-do' spirit," said Serh Ghee. This combination of teamwork, talent and tenacity was visibly demonstrated when the design

ST Aerospace provides an annual capacity of more than 300 engines with a full spectrum of services in close partnership with engine Original Equipment Manufacturers (OEMs).

Creating Value for Our Customers Worldwide

> I would like to compliment ST Aerospace on the professional team working with us. The team has carefully listened to our needs as a customer and advocated for us within your organisation to better meet those needs. As a result, from my perspective, your customer service has been exceptional.
>
> **Constance von Muehlen**
> *Managing Director, Airframe, Engine, Component MRO*
> *Alaska Airlines*

engineers from Singapore had to work hand-in-glove with their American counterparts to prototype the PTF conversion in the US for the STC. The intense collaboration between the transatlantic teams eventually saw the STC development completed in 11 months and the certificate issued by the Federal Aviation Authority (FAA) in just three weeks from the completion of the flight test – a timeframe that was unheard of in the aviation industry. ST Aerospace is now among the world's largest independent freighter conversion companies. Following these successes, ST Aerospace has gone on to develop PTF STCs for Airbus A330 and A320 aircraft.

This 'can-do' mindset is also manifested daily in the MRO work. "Most of the maintenance work is routine but it still demands the team to maintain constant commitment and attention to details to ensure quality and safety. You can't do it any other way," Serh Ghee said. He recalled sharing the importance of workplace safety with David Hall, CEO of Jetstar Australia and New Zealand once using a Singlish adage, 'happy, happy, come to work, safe, safe, go back home'. The customer was suitably impressed by the simplicity and clarity of the safety message that he began sharing it with his colleagues.

When the world went into an economic downturn for the most part of 2000s, price and cost pressure became a constant challenge. Adding to this challenge was the development of new aircraft which are more technologically advanced and hence, require less maintenance. Original Equipment Manufacturers (OEMs), facing similar pressures, also entered the aftersales market to capture downstream MRO revenues.

To stay competitive, ST Aerospace invested in productivity improvement with people development and Kaizen, a continuous improvement strategy, as well as turned upstream for new business opportunities.

In March 2015, the company formed a joint venture with Tenyru Holdings, a Japanese seat manufacturer to develop the next generation of lightweight and ergonomic seats. ST Aerospace Aircraft Seats, the joint venture, leverages ST Aerospace's engineering capabilities and Tenyru's rich experience in the industry to develop innovative seating solutions which are both aesthetically and commercially viable. The synergy of the joint venture partners allows for faster time-to-market for ST Aerospace to sell its new offering, which is crucial in a competitive airline industry.

"What truly sets us apart from most independent MROs that focus mainly on maintenance and servicing is our strong team of some 450 engineers and their in-depth design and engineering capabilities," shared Serh Ghee. "Having the depth in engineering allows us to provide bespoke solutions that effectively meet market needs."

ST Aerospace, in its constant strive to create value for its customers, also started to explore innovative solutions that could meet the dual challenges of aircraft downtime and rising costs. It turned to 3D printing for the replacement of cabin interior parts. "It takes too long to do a mould when 3D printing can reproduce the same part with similar quality faster and cheaper," said Serh Ghee. The 3D printing concept got piloted with Air New Zealand (ANZ).

Aircraft leasing with a focus on mid-life platforms was another new venture ST Aerospace went into. By bringing its full range of engineering, MRO and cabin interior capabilities to bear, the company is able to extract much synergistic value besides financial returns from leasing.

Said Serh Ghee, "Towards the end of its service as a passenger jet, the aircraft could either be converted into a freighter, or its serviceable engines and components harvested for reuse or resale. By integrating our services across the value chain, we are able to support our customers throughout the lifecycle of their principal capital assets."

CUSTOMER-CENTRIC CULTURE

The first thing that greets each ST Engineering employee when the computer is turned on is a pop-up screen showing quotes on customer excellence from renowned business leaders. This is part of ongoing efforts by the ST Engineering Customer Excellence Committee, chaired by Serh Ghee, to instil a Customer Excellence culture within the organisation. He said, "Customer-centricity, apart from the other key thrusts of engagement and soliciting valuable feedback, helps to ingrain a 'customer-first' mentality in our employees. Through these thrusts, we can better understand the relevance and context of the operational requirements of our customers."

ON-WING TO THE RESCUE

Three Kenya Airways Boeing 787 aircraft were grounded at the Jomo Kenyatta International airport in Kenya on 18 March 2016 due to engine-related issues. The airline required these planes to be back in service as they were already scheduled for revenue flights. Mr Wong Fu Weng and team were working on Kenya Airways' GEnx engines at the airport at that time, and they immediately reprioritised their work schedule to attend to the aircraft-on-ground (AOG) situation first. As On-Wing Support crew, Fu Weng and his team specialised in rectifying engine-related issues without removing the engines from the aircraft. This allowed airlines to resume operations once the aircraft has recovered from the unexpected faults.

"Engine repairs are complex and delicate missions that require skilful hands. With only 12 hours to recover three aircraft, we would also need steely nerves to perform the meticulous operations under tremendous time pressure. Our greatest satisfaction was in knowing that we had managed to rectify the problem together with the airline's engine technicians and in time for the airline to keep their scheduled flights," said Fu Weng.

Left to right: ST Aerospace On-Wing support specialists Tia Jee Kit (2nd from left), followed by Wong Fu Weng, Lim Tai Woei and Huang Wuyi with a ground crew and 2 representatives from GE.

3D-PRINTING INNOVATION

ST Aerospace and ANZ extended their great partnership through a 3D-printing pilot programme.

ANZ has a strong reputation for both its commitment to safety and quality as well as being an industry leader in aviation innovation. So, when Mr Andrew Hewitt, ANZ's Head of Engineering, spoke about the potential of 3D-printed parts for aircraft cabin at an MRO conference, ST Aerospace quickly proposed to develop a joint 3D-printing pilot programme with ANZ.

Printing parts for an aircraft is an intricate matter that requires meeting stringent regulatory certifications and aviation safety standards. Both ANZ and ST Aerospace overcame these challenges and successfully developed several cabin part prototypes, like the cocktail tray and the seat belt limiter bracket that could eventually be used for replacement of defective parts during aircraft maintenance.

Andrew said, "Both ST Aerospace and ANZ envision a virtual warehouse where cabin parts could be printed on-demand, on-site and just-in-time. These parts would be designed and certified to prevailing safety standards with ST Aerospace. When spare parts are needed, ANZ would simply initiate an order to direct the appropriate digital files to the printer and pick up the fully-certified parts once they have been printed. There would be significant cost and time savings as compared with conventional inventory management. We are expecting to lower costs on inventory, warehousing, shipping and handling as well as eliminating procurement lead time for the printed parts."

OUR KEY OFFERINGS

AEROSPACE

A REPUTATION BUILT ON TRUST AND QUALITY

With facilities in prime aviation hubs across Asia Pacific, US and Europe, we provide a suite of aviation services and solutions such as aircraft maintenance and modification, component and engine total support, aviation and training services, and aerospace engineering and manufacturing to a global clientele that includes leading airlines, airfreight and military operators.

We have a strong track record in servicing both military and commercial aircraft, and we have the engineering depth and operational expertise to develop customised solutions that range from Passenger-to-Freighter conversion and cabin interior refurbishment to aircraft seats design. Combining engineering expertise with rich experience in reliable and quality total aviation support, we are the trusted partner that the industry can count on to keep their aircraft flying.

BOEING 757 PASSENGER-TO-FREIGHTER CONVERSION

Aircraft Mission Computer

Aircraft Smoke Control Panel

Aircraft Seats

Aircraft Lavatory

H120 Revenue Sharing Programme

A320/A321 Passenger-to-Freighter Conversion

A330 Passenger-to-Freighter Conversion

SkyBlade III Unmanned Air System

SkyBlade IV Unmanned Air System

USTAR-Y Unmanned Air System

767 Passenger-to-Freighter Conversion

777 Line Maintenance

787 Airframe Heavy Maintenance

MD-11 Airframe Heavy Maintenance

Commercial Pilot Training

F-15SG Fighter Operations & Support

F-16C/D/D+ Fighter Operations & Support, and Upgrade

C-130 Operations & Support, and Modernisation

M346 Operations & Support

CH-47 Chinook Operations & Support

CFM56 Engine Maintenance (Commercial)

Makila Engine Maintenance (Military)

Centre of Excellence for Narrow-Body and General Aviation Aircraft Landing Gears

Centre of Excellence for Nacelles

787 Components MRO

OUR KEY OFFERINGS

ELECTRONICS

EMPOWERING THROUGH INNOVATION

We are a leading info-communication technology solutions provider in Asia with rich experience in intelligent transportation, satellite communications, and information communications technologies. We transform cutting-edge technologies into innovative solutions for government and commercial enterprises across 100 countries worldwide. With a presence in more than 20 countries, we specialise in advanced electronics and communications systems for rail and traffic management, satellite and broadband, command & control, training & simulation, intelligent building, integrated security, and cyber security.

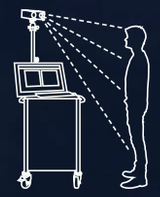
TELEOS-1, SINGAPORE'S FIRST COMMERCIAL EARTH OBESERVATION SATELLITE

Agilis High Altitude Pseudo Satellite Communication Solution

iDirect Universal Satellite Hub

AgilFence Perimeter Intrusion Detection System

AgilSense Microwave Sensors for Detection



Infrared Fever Screening System

SERIS - Maritime for Coastal Surveillance

SERIS - Smart Analytics through Social Media and Cyber

SERIS - Public Safety for Emergency Response Management

SERIS - Smart City

Integrated Battlefield Management System

Platform Screen Door System

Command, Control & Communication System for Rail

Automatic Fare Collection System for Rail

Integrated Security Management System

Unmanned Surface Vehicle

Train Cab Simulator

VR-Forces - Computer Generated Forces Platform

Car Parking Guidance System

Flight Simulation Training Services

Driving Simulator

DigiSAFE Data Diode for Secured & Fast One-way Data Transfer

DigiSAFE NetCrypt Mobile - Portable IP Encryptor

Intelligent Taxi Booking and Despatch System

Intelligent Aggregation Gateway Box - Smart City Platform Enabler

SuperneT Unified Communications Suite

OUR KEY OFFERINGS

LAND SYSTEMS

STRATEGIC PARTNER

TO INTERNATIONAL

DEFENCE FORCES

We design, produce and maintain a wide range of mobility, weapon and munitions solutions for defence and homeland security. We are a market leader in 40mm ammunition and delivery systems. Our family of armoured vehicles including Warthog, Terrex and Bronco, enables armed forces to stay ahead of evolving threats.

Our specialty vehicle business in US and India helps to raise the productivity of end users in the road construction and commercial sectors. We innovate and expand our engineering capabilities to robotics and autonomous vehicles solutions, and are proud to deploy the first fully operational autonomous vehicle in Asia.

TERREX 1 8X8 WHEELED
INFANTRY FIGHTING VEHICLE

40mm Family of Munitions for Grenade Launchers

40mm Automatic Grenade Launcher

Ultimax 100 Light Machine Gun

SAR21 Assault Rifle

120mm Super Rapid Advanced Mortar System

FH88 155mm 39-Calibre Towed Field Howitzer

FH2000 155mm 52-Calibre Self Propelled Field Howitzer

SSPH Primus 155mm 39-Calibre Self Propelled Howitzer

SLWH Pegasus 155mm 39-Calibre Light Weight Self Propelled Howitzer

Warthog Articulated Armoured Tracked Vehicle

Bionix Infantry Fighting Vehicle

Bronco All Terrain Tracked Carrier

Trailblazer Countermine Vehicle

Spider New Generation Light Strike Vehicle

New Generation Armoured Fighting Vehicle

LeeBoy Tracked Pavers

Hackney Emergency Vehicles

Cross Drive Solutions for Heavy Vehicles

Autonomous Vehicles

MAN City Bus

Maintenance, Repair and Overhaul

Training Solutions

Secured Logistics and Facilities Engineering

Engineering Test Services

Vehicle Inspection

OUR KEY OFFERINGS

MARINE

YOUR TRUSTED PARTNER

We are a premier shipyard providing solutions in turnkey building, repair and conversion services for a wide spectrum of naval and commercial vessels. We have proven capabilities in shipbuilding ranging from concept definition to detailed design, construction, system integration and through-life support. We also have established track records in shiprepair and conversion services to a worldwide clientele.

In addition, we also provide a suite of sustainable environmental engineering solutions and have successfully delivered projects in Singapore, Middle East, India, Thailand, China and Brunei.

RSS INDEPENDENCE
INDEPENDENCE CLASS
LITTORAL MISSION VESSEL

RSS Fearless
Fearless Class
Patrol Vessel

Al Seeb
Al-Ofouq Class
Patrol Vessel

RSS Endurance
Endurance Class
Landing Ship Tank

HTMS Angthong
Endurance Class
Landing Platform Dock

Al-Tahadd
Landing and Supply Craft

RSS Independence
Independence Class
Littoral Mission Vessel

RSS Formidable
Formidable Class
Frigate

S. Ezzat
Ambassador MK III
Fast Missile Craft

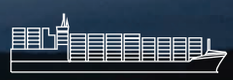
USNS Pathfinder
Pathfinder Class
Oceanographic Survey Ship

HMBS Bahamas
Offshore Patrol Vessel

Pacific Finder
Seismic Survey Vessel

Skandi Singapore
Dive Support Vessel

Marjorie C
Container and Roll-on/Roll-Off
Car Truck Carrier



El Coquí
LNG-powered Container
and Roll-on/Roll-off Carrier

Henry B. Bigelow
Fisheries Survey Vessel

William C High Tower
Platform Supply Vessel

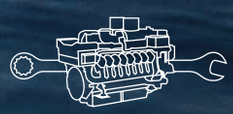
Pacific Diligence
D Class Anchor Tug Handling
Supply Vessel

City of Hamburg
Roll-on/Roll-off Vessel

Nova Star
Roll-on/Roll-off
Passenger Vessel

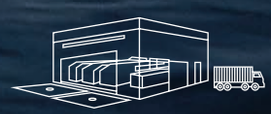
Swift Rescue
Submarine Support &
Rescue Vessel

Repair & Conversion



Engine Servicing

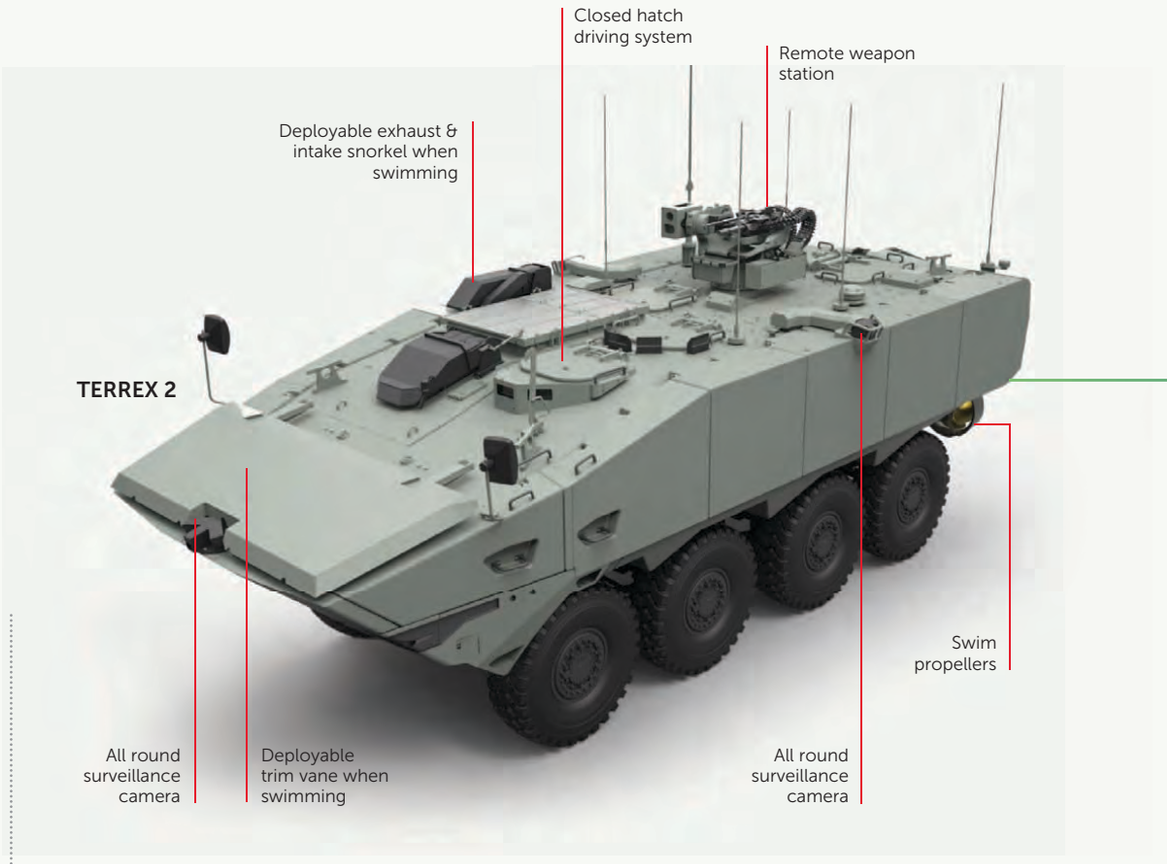
Integrated Logistics
Support



Brunei Darussalam
Integrated Waste
Management System

Kranji NEWater Plant
Water Treatment

Master of All Terrains



The introduction of the Terrex Infantry Carrier Vehicle (ICV) marked a significant milestone in the transformation journey to the 3rd Generation Singapore Armed Forces (SAF). Terrex's ability to enhance the army's fighting and networking capabilities was duly noted by Mr Teo Chee Hean, Deputy Prime Minister and then Minister for Defence, at the official launch of the Terrex in 2009, where he remarked, "The Terrex ICV, with its network capability, enables soldiers to carry the army's combat power in their backpack as they go into the battlefield."

Terrex started off as an in-house development programme after studies showed increasing mission demand for wheeled combat vehicles to support urban warfare. The pace of development picked up when the US Interim Armoured Vehicle (IAV) programme went to a wheeled platform in 2000, thus ending ST Kinetics' bid with its tracked Bionix.

The first prototype, called the AV81, was designed from scratch to incorporate the latest technology for fighting in built-up areas. Mr Pek Chong Guat, ST Kinetics' Chief Engineer of Wheeled Mobility, who headed the AV81 programme, recalled that when the vehicle was unveiled at a UK defence exhibition in 2001, it immediately caught the attention of leading defence companies. In May 2002, ST Kinetics signed an agreement with Otokar of Turkey to jointly adapt the AV81 to meet a potential Turkish requirement, resulting in the development of Yavuz 8x8 vehicle.

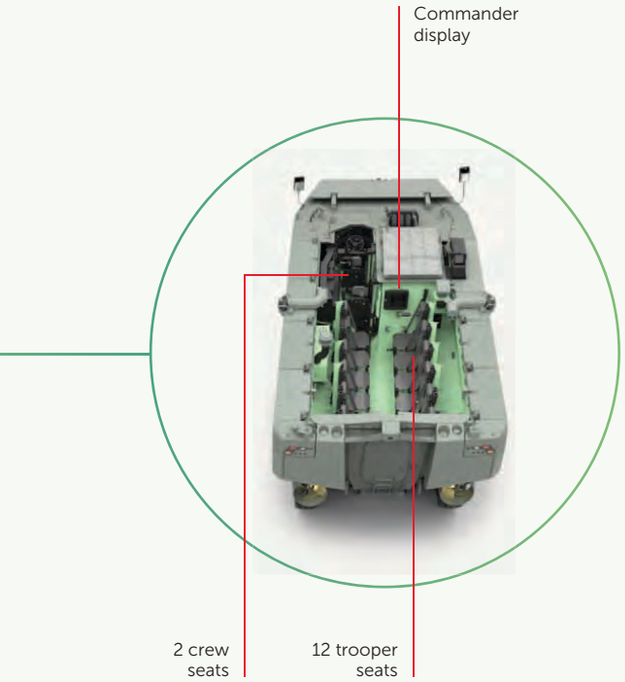
In 2007, ST Kinetics fielded an improved version of the AV81, which it named Terrex for a competitive tender to supply wheeled ICVs for the SAF. Mr Yeo Beng Hai, Vice President and Deputy General Manager of Kinetics Design and Manufacturing, and the Chief Engineer of Terrex, still remembered the elation when ST Kinetics finally won the bid from intense competition against in-service platforms, "That was only half the battle won. We spent the next 28 months working with the Defence Science and Technology Agency and SAF to enhance the baseline 8x8 into an ICV that would be capable of precision firepower, crew protection, situational awareness, swimming across inland waters and mobility with a top speed of 105 km/hr on land."

For the multiple innovations that went into the Terrex, ST Kinetics was awarded the prestigious Defence Technology Prize from the Ministry of Defence (MINDEF) in 2010. Beng Hai said, "The Terrex is the true embodiment of ST Engineering's engineering capability and versatility in the integration of the latest technologies and weapon systems to meet the stringent requirements of the SAF."

In anticipation of demands for wheeled armoured vehicles with better protection, higher payload, and capable of expeditious troop mobilisation in urban warfare, ST Kinetics continued to invest in the enhancement of its 8x8 design and added two variants to the family: Terrex 2 in 2015 and Terrex 3 in 2016.

Terrex 2 launching from USS Somerset (LPD-25) in a launch-and-recovery operation trial in 2017.

Photo courtesy of US Marine Corps



FIRST TO TAKE TO THE SEA

Development of Terrex 2 Infantry Fighting Vehicle started in 2013 as an amphibious version of its first generation counterpart. It would be capable of shore-to-shore and ship-to-shore operations at sea state and had better protection against mines and improvised explosive devices. In November 2015, Terrex 2 was one of two contenders shortlisted by the United States Marine Corps for its Amphibious Combat Vehicle programme. Science Applications International Corporation (SAIC) was ST Kinetics' US partner for this programme. Mr Tom Watson, SAIC's Senior Vice President and General Manager of the US Navy and Marine Corps Customer Group, commented, "SAIC is proud to partner ST Kinetics to deliver the high-tech and highly capable Terrex 2 to the Marine Corps. We are confident that this vehicle is equipped with the latest technology which will strengthen the amphibious capabilities of the Marine Corps today and into the future."

NINE MONTHS TO BIRTH THE BIGGEST

When ST Kinetics decided to participate in the Australia Land 400 down selection, it had less than a year to make two prototypes of a new armoured fighting vehicle for demonstration to the Australian Army in mid-2016. Mr Tan Soon Lee, Vice President and the Terrex 3 Project Lead for ST Kinetics, recalled how the odds were stacked up, "With our experience building 8x8s over the years, the best estimate was that it would take 18 months to deliver the two prototypes for trials. Time was not on our side. Adding to that, the team had to work across five different time zones. We overcame these limitations by building the system in stages and in the facilities of the component manufacturers. That accelerated production as engineering changes could be made on the fly and parts ordered ahead of time. We delivered the Terrex 3, the largest and most advanced variant in the 8x8 family in just nine months."

Mr Ravinder Singh, then President of ST Kinetics, revealed that his intention was to challenge the engineers to innovate through the various programmes. He said, "While Terrex 3 was not shortlisted for the Australian Land 400 programme, the team has surpassed everyone's expectation and built a combat vehicle that is up there with the world's best."

TERREX 3

DESIGNING WORLD-CLASS SYSTEMS

In the Wake of Endurance

Landing Ships Tank (LSTs) are the largest vessels in the Republic of Singapore Navy (RSN). They were designed and built by ST Marine, then known as Singapore Shipbuilding Engineering, to replace the RSN's ex-County class LSTs acquired from the US Navy in the 1970s.

Larger and faster, the new LSTs are capable of supporting various overseas training requirements, as well as participating in large-scale disaster relief and humanitarian assistance missions. To support these roles effectively, each LST is designed to carry the Fast Craft Utility and the Fast Craft Equipment and Personnel, which are readily deployable from the well dock and superstructure, and capable of operating in shallow waters. Their heli-decks are equipped with an ASIST system that aids in accurate positioning and landing of a helicopter and moving it along a track into the hangar.

For Mr Tan Ching Eng, Senior Vice President (Engineering Design Centre) at ST Marine, the challenge then was to develop a naval platform to meet the SAF's needs for tri-service integration. "It was ambitious and unprecedented on several fronts. On one hand, we had to establish the operational, information and technical architectures for combined air, land and sea operations and incorporate them into the ship's design and engineering concept. On the other hand, was the prerequisite to reduce its crew size."

By integrating the bridge and engineering systems to enhance the automation of ship navigation and control, ST Marine managed to reduce the manning level on board the LST to just 81 – an important breakthrough for ships of this scale, given the 130-strong crew required for the County class vessels.

In 1998, the first of four LSTs was named RSS Endurance after the first County class LST operated by the RSN. The Endurance class LSTs went on to serve as command platforms in maritime security operations in the Arabian Sea, in the waters off Somalia, and in the aftermath of the 2004 Asian Tsunami where it had supported the SAF Joint Task Force's humanitarian operations. With the extensive damage to roads and airports, the LSTs provided the only means for emergency supplies and heavy construction vehicles to reach affected areas.

The LST remains a strong testament to ST Marine's ability for turnkey solutions from design to construction and through-life support service. Our core competence remains the development of sophisticated naval vessels – a capability built up over successive cycles of shipbuilding and upgrading programmes for the RSN. The introduction of the LST generated much interest among international navies and led ST Marine to build one for the Royal Thai Navy (RTN) in 2012.

> "The Endurance class LSTs are equipped with more advanced capabilities to serve the RSN and SAF in our training and operational requirements and enabled us to participate more actively in exercises and deployments outside of Singapore. The successful completion of this ship building program is another example of the close partnership and collaboration between the Defence Science and Technology Agency, ST Marine and the RSN.
>
> **Rear-Admiral (R) Lui Tuck Yew**
> *Former Chief of Navy at commissioning ceremony of RSS Persistence and RSS Endeavour in 2001*

FROM CUSTOMER TO ADVOCATE

Siow Chee Khiang, Vice President of International Marketing at ST Marine was the first commanding officer of RSS Endurance. "I remember when I first set eyes on the ship, sitting atop the launch way at ST Marine in 1998. I was both apprehensive and amazed to be entrusted with the responsibility for this ship. I was even more impressed that such a sophisticated vessel had been designed and built in Singapore. It is 40% bigger and fitted with capabilities way beyond what was on the WWII-vintage County-class LSTs, which I sailed as a midshipman."

With his personal experience commanding and circumventing the globe on board a ship designed and built by ST Marine, he is both "convinced and convincing" when he interacts with potential customers looking at ST Marine's total naval solutions.

A PROVEN PLATFORM FOR THE THAI NAVY

The HTMS Angthong, a 141m long Landing Platform Dock (LPD) built by ST Marine, was delivered to the RTN in 2012. Designed based on the RSS Endurance, she is capable of missions ranging from sea transportation to naval support and civil search and rescue operations.

Admiral Surasak Rounroengrom, RTN's Commander-In-Chief, expressed his "sincere gratitude to ST Marine for their efficient supervision and construction of the ship as well as their kind support of RTN personnel."

Mr Ng Sing Chan, President of ST Marine shared, "We have always taken pride in our excellent design and shipbuilding capabilities as well as attentive customer service. The LPD team has done well once again and won ST Marine another happy customer in the RTN."

DESIGNING WORLD-CLASS SYSTEMS

Your Ticket to Smoother Train Journeys

Ever wondered what it takes to ensure seamless, smooth and smart journeys? For the millions of rail commuters in Singapore daily, factors like train availability, comfort, real-time travel advisory, connectivity, safety, security – as well as timely response to metro breakdowns – have become basic expectations. For city authorities and metro operators, effective planning and operations, good serviceability, sustainability and ability to handle growing commuter loads are the hallmarks of top service standards.

As the transport infrastructure grew with greater inter-connectedness across multi-modal networks, these demands had translated into increased complexities in managing rail networks with a higher emphasis placed on heavy-duty rail management systems that could meet the growing expectations.

It was with these requirements in mind that ST Electronics went into the design and development of rail electronics systems in 2002. The goal was to enable efficient network management of the metro while ensuring smoother train rides and a more pleasant commuting experience.

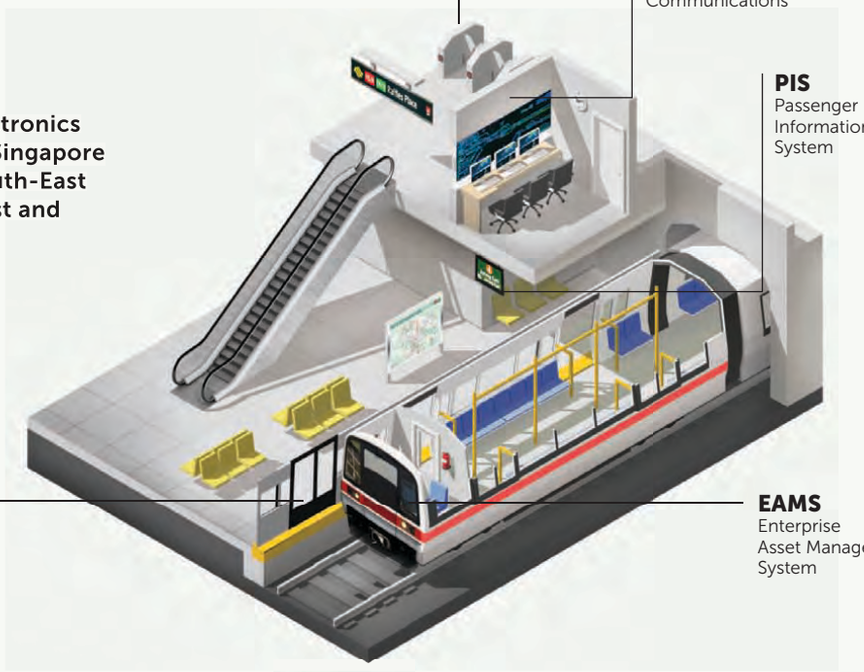
As Mr Yong Thiam Chong, Deputy President of ST Electronics vividly recalled, "Right from the onset, our design philosophy was geared towards efficiency and intuitiveness. Yet, ensuring an effortless and smooth experience for commuters involved a more complicated process for operators behind the scenes. The team worked tirelessly to improve the system designs and to simplify the workload of the operators as well as the maintenance crew by using the latest technologies. We know what an efficient Mass Rapid Transit or Light Rail Transit system means to Singaporeans. As citizens ourselves, we are in this together with our customers to improve the efficiency of public transport. The passion to innovate has not only given us an edge over the competition, it has also driven us to come up with greater value-add to our customers and their commuters."

Added Mr Bernard Chow, Senior Vice President of the Transportation Business Unit (TBU), "While we made sure our rail electronics systems were innovative and technologically advanced to meet the various exacting needs, we also considered factors like future-readiness. For example, we incorporated big data analytics and machine learning to predict system or commuter abnormalities and anticipate potential service disruptions. Such insights have been valuable to the authorities for future transport planning and policy implementation."

"For me, the greatest satisfaction from the project is the delivery of a suite of railway electronics solutions that enable safe, reliable and comfortable journeys on the rapid transit. Continuous innovation with solutions that overcome current and future challenges is what engineering is all about," said Mr Yong Kim Shen, Principal Engineer at TBU.

CREATING VALUE FOR TRAIN OPERATORS ACROSS ASIA

ST Electronics' suite of rail electronics systems has been deployed in Singapore and cities in Greater China, South-East Asia, South Asia, the Middle East and the Americas. Here is a quick overview of ST Electronics' rail electronics capabilities.








SMCC | EAMS | C3 | PSD | AFC | PIS

Smart Metro Control Centre (SMCC) allows authorities, operators and commuters to communicate in real-time on a centralised management platform. It uses big data and machine learning to ensure effective coordination, predict system and commuter abnormalities, and prevent service disruptions.

Enterprise Asset Management System (EAMS) optimises the lifecycle management of physical assets at the integrated system level. It predicts asset health, and is coupled with the SMCC to enable efficient operations and maintenance, improved service quality and reduced operating costs.

Command Control & Communication System (C3) enables the supervision and control of train operations at the line level. It features a built-in multi-layered cyber security system that is able to detect external and internal cyber threats and identify security breaches.

Platform Screen Door System (PSD) ensures commuter safety. It enables operators to provide emergency alerts and other commuter updates through a dynamic multimedia display.

Automatic Fare Collection System (AFC) is more than a seamless and secure platform for revenue collection. It also serves as a ticket vending machine, top-up terminal and customer service platform for commuters who require assistance.

Passenger Information System (PIS) provides real-time commuter information at the stations and on trains. It allows commuters to communicate with the train driver and operations command centre during emergencies.

Making Cities Smarter

Imagine this. The moment you step out of your house, you can access real-time traffic and public transport information, made possible by a network of sensors that monitors everything from transportation and crowd conditions to air quality and street lightings. "Many of these solutions are already in use to benefit citizens living in a smart city, and more will be deployed in the near future for cities around the world," said Mr Yao Shih Jih, Deputy President, ST Electronics (Info-Comm Systems).

As cities grow, technologies can be used to make them operate more efficiently and effectively. Mobility solutions can minimise congestions and enhance the travelling experience of commuters. "Multi-modal transport systems, smart corridor, autonomous vehicle monitoring and intelligent rail solutions are just some of the many solutions that pave the way for future land transportation," said Mr Lai Wee Leong, a project manager for mobility solutions at ST Electronics.

With Internet-of-Things (IoT), there is an extensive amount of data generated by sensors and mobile devices across different domains such as transportation, utilities, environment, security and healthcare. The data requires rigorous analysis to generate insights into the city's growing needs, and develop new applications and operation models to better serve the citizens.

Mr Ho See Rock, a senior system consultant in smart analytics for healthcare at ST Electronics explained, "Telemedicine, for instance, allows medical professionals to connect with patients at their homes and intervene when health monitoring devices show signs of abnormality. That reduces the need for patients to travel for medical care and improves their quality of life."

A city will inevitably leave huge environmental footprints in terms of energy consumption, waste and pollution. "Through the use of sensors, meters and network management systems to measure usage patterns, monitor and control networks for faults and leaks, our Smart Utilities Suite enhances the operational efficiencies of energy distributors, reduce carbon emissions and empower consumers to manage their utility usage more effectively," said Mr Joe Lim, a software engineer for smart utilities applications at ST Electronics.

A city that is smart must also be safe and secure for its residents. With cities facing threats in public safety and cyber security today, a smart city must be capable of leveraging technologies to protect its people, properties and economy. "Cyber security needs to be a key consideration in the system design and development of any smart city solution. ST Electronics has strong in-house capabilities and expertise to constantly innovate and develop new solutions that can stand up against evolving cyber threats," said Mr Koh Sze Liat, Manager for Cyber Security Solutions at ST Electronics.

Mr Lee Guan Chuan, a solutions architect at ST Electronics, added, "We use advanced sensing and visualisation technologies to unify independent systems and provide coherent information through a common user interface for effective communications. This strengthens cross-agency collaboration, enhances the agencies' speed of response and brings out the smartness of a city."

> "Today, cities around the world are confronted with the effects of rapid urbanisation and are compelled to look for solutions to support sustainable growth. As a pioneer of Smart Solutions with a record of engineering innovative solutions in intelligent transportation, smart utilities, secure infocomms technologies, as well as efficient communication systems, we have an opportunity to play a role in helping to shape and transform cities. We are excited to be at the forefront of this digital revolution, enabling resilient, connected and sustainable smart cities that support better living, build stronger communities and create opportunities for the future.
>
> **Ravinder Singh**
> *President, ST Electronics*

SMART MOBILITY

- Intelligent Transport Management
- Intelligent Rail Transport Management
- Intelligent Fleet (Bus/Taxi) Management
- Autonomous Vehicle Monitoring & Evaluation
- Smart Carpark Platform

SMART ENVIRONMENT

- Smart Utilities: Advanced Metering
- Intelligent Water Management System
- Smart Street Light Management
- Satellite Imagery Services

SMART PUBLIC SAFETY

- Integrated Security Management
  - Public Safety
  - Maritime
- Area Surveillance & Intrusion Detection

SMART INFRASTRUCTURE

- Smart Estate Management
- Smart Building Management

SMART HEALTH

- Integrated Healthcare Infrastructure
- Hospital Operations Centre
- Telemedicine & Vital Signs Monitoring

COMMUNICATIONS & SENSOR NETWORK MANAGEMENT

SMART DATA ANALYTICS

CYBER SECURITY

DESIGNING WORLD-CLASS SYSTEMS

MAKING EVERY SECOND COUNT

The Third Generation Mobilising System (TGMS) is an advanced C3 system that ST Electronics had designed and developed in 2005 for the Hong Kong Fire Services Department (HK FSD). It comprises a sophisticated set of sub-systems that prioritises and manages the stringent emergency response requirements of HK FSD. By employing advanced algorithms that considered the complex road networks and layout of the city, TGMS is able to consistently direct fire and medical rescue teams on the most expedient routes to incident sites.

Since its implementation, the TGMS has doubled the number of calls handled by the HK FSD and reduced processing time of each call by 60%. With more than 2,000 emergency calls received daily, the faster processing time directly translates to saving more lives and properties during emergencies.

The successful implementation of TGMS had won the HK FSD multiple awards in 2007. In a 2006 interview with the Singapore media, Mr Albert Li, then Senior Divisional Officer of HK FSD had acknowledged that the most remarkable feature of the TGMS was its ability to locate a fire engine or ambulance accurately, even while on the move.

In 2016, ST Electronics was awarded a long-term contract to maintain and upgrade the TGMS. Mr Tay Choon Hong, Project Director of TGMS, said, "As a real-time emergency response system, TGMS has successfully reduced the loss of lives and properties as a result of fire, and helped to make Hong Kong a safer and more secure city. We will continue to enhance the system to fulfil its vital role efficiently."

CAN YOU SPEAK MACHINE?

ST Electronics provides the Galaxy Machine-to-Machine (M2M) Communications Solutions that offer a single platform for multiple smart city and IoT applications including smart street lighting management, water resource management, advanced metering and utilities management. More than 15 million wireless devices, sensors and nodes for these applications are deployed in cities all over the world to help them monitor and manage their energy and utilities usage, reduce operational and maintenance costs, and respond faster to outages. Provided through ST Electronics' wholly-owned subsidiary, Telematics Wireless, it has more than two decades of experience developing M2M technologies, from radio frequency modules to a wide spectrum of smart city applications aimed at increasing efficiency, reliability and cost effectiveness for customers.

"Our team of engineers has constantly pushed the envelope in product research and development, driven by a strong passion and culture to innovate and overcome the challenges of urbanisation and globalisation. This has been the key driving force that has catapulted the company to its global prominence in the M2M industry," said Mr Eddy Kafry, CEO of Telematics Wireless.

SMART FENCE, SECURE FACILITIES

Along the perimeter of Singapore's Changi Airport is a long stretch of fence that keeps its runways and the world's best airport safe and secure. This is no ordinary fence. Built-in fibre-sensing technology has enabled it to sense minute movements at any point along its length. Known as the AgilFence Perimeter Intrusion Detection System (AgilFence), it was developed by ST Electronics for the Changi Airport Group in 2011, the first time such technology was used in perimeter security enhancement in the world.

Said Mr Bernard Lee, Vice President, Sensors Business, "AgilFence can easily detect a person climbing over or cutting the fence. A set of intelligent signal processing algorithms separates false alarms from actual intrusions. It has undergone trials in many countries and emerged top compared with other perimeter protection solutions. In 2013, it won the ASEAN Outstanding Engineering Achievement Award as well as the IES Prestigious Engineering Achievement Award; and was certified by the UK Centre for the Protection of National Infrastructure in 2016 for use in the protection of critical national installations."

BRINGING SMARTNESS TO BUILDINGS

The growing demand for a reliable solution that could continuously track and provide feedback on building performance was what inspired ST Electronics to develop a unique data-centric Smart Building Energy Management System (SBEMS).

"Over the three-year R&D period, we spoke to users, architects and building developers to understand their requirements for real-time measurement and verification tool," said Mr Tan Koh Hock, Chief Engineer of ST Electronics' Large Scale Systems Group (LSG).

Mr Eric Chan, Vice President of LSG, added, "The SBEMS captures a wider range of data sources, and is able to provide more accurate insights to users compared to conventional building management and metering systems. As an innovation that encapsulates ST Electronics' experience and expertise in infocomm technologies, building controls, and systems integration that date back to our first building automation system deployed for Changi Airport in 1978, it has given us an edge over global MNCs and hardware-focused players in the smart building energy management market."

Since its launch in late 2015, the SBEMS has been installed in facilities including educational institutions, industrial properties and commercial buildings.

ADDING VALUE FOR OUR CUSTOMERS

Developing a Family of Mission Computers

The idea of developing an in-country aircraft mission computer was first conceptualised in 1988. A small engineering team from ST Aerospace, then known as Singapore Aerospace, had just completed the A-4 avionics upgrade programme. Mr Lim Tau Fuie, Chief Technology Officer of ST Aerospace, was a young engineer with the team at that time and the team was convinced that if they could design the airborne computer hardware of an avionics suite, it would make system integration easier in future upgrades.

"It is not easy to find a suitable mission computer that could meet the system interface and graphics display requirements of the aircraft's operational flight programme (OFP), or a real-time operating system that can perfectly support the prescribed missions. There are also considerations like long development schedule, poor turnaround time and re-training to adjust to the new operating environment often encountered in the integration of OFP with third-party mission computers," said Tau Fuie.

However, the idea was placed on the back-burner due to other more pressing upgrade programmes and it was not until the late 1990s that another team of young engineers would re-propose to develop the mission computer in-house. Mr Tay Kok Khiang, then the Chief Operating Officer, recognised the importance for ST Aerospace to own the airborne computer hardware to complement the OFP development capability which the team had gradually built up, as it would lead to more cost-effective and efficient solution for the customers. He decided on the development of the mission computer in-house and sought the support of Mr Boon Swan Foo, then President & CEO of ST Engineering.

Tau Fuie recalled that to convince the RSAF to use ST Aerospace's mission computers, the company gave the commitment to provide full lifecycle support to the customer and with faster response in times of need. "The management became deeply involved in the technical discussions to understand the risks and impact. Its full attention and funding support enabled the avionics team to design and qualify the mission computer in a record time of 24 months," he said.

ST Aerospace went on to successfully design a family of mission computers, one of which was deployed as part of the upgrade of the Super Puma helicopters in 2013. For its effort, ST Aerospace was awarded the MINDEF Defence Technology Prize Engineering Award in 2008 together with Defence Science & Technology Agency (DSTA) and RSAF. ST Aerospace also leveraged its experience to design and develop flight control computers for Unmanned Aerial Vehicles (UAV).

ST Aerospace upgrades and modernises avionics systems including the development of mission computers to meet increasingly complex operational needs.

MOVING INTO COMMERCIAL AIRCRAFT SYSTEMS

Mr Gerald Lee, Director of Avionics Product Development Department at ST Aerospace's Engineering & Development Centre, believes that the achievement of the avionics team could not be overstated. He said, "To design, develop and manufacture an airborne computer is very challenging and requires a strong foundation in product design, development and testing. It is this strong foundation that gives us the confidence to pursue complex electronics development in commercial aircraft like our first in-house commercial Radio Technical Commission for Aeronautics and the DO-254 Hardware Design Assurance Level-B Smoke Control Panel for the Airbus A330 Passenger-to-Freighter programme in 2016."

DO-254 is a requirement-driven, process-orientated safety standard recognised by the US FAA and the European Aviation Safety Agency (EASA) for certifying complex electronics on commercial aircraft. "ST Aerospace's ability to move from delivering mission-critical mission computers for military aircraft to developing safety-critical systems for commercial aircraft had showcased its engineering maturity and versatility in making significant innovations and breakthroughs in entirely new fields," Gerald added.

ADDING VALUE FOR OUR CUSTOMERS

Comrades-in-arms

Since 1975, ST Aerospace has been supporting the RSAF in the maintenance of its aircraft from transport and trainer aircraft to fighter aircraft, helicopters and UAVs. Today, it handles every area of aircraft maintenance from traditional depot maintenance of aircraft, engines and components to direct operational support at the flight lines in airbases for the RSAF. Some programmes are managed under public-private partnership agreements where ST Aerospace owns and maintains the assets so that RSAF can focus on the flying missions. On top of maintenance services, ST Aerospace has built up substantial engineering capabilities in avionics upgrades and mission system enhancements. Through the consistent and responsive delivery of the integrated services, ST Aerospace has shown itself to be both a valued service provider and a strategic partner to the RSAF.

> “As a strategic partner to the RSAF, ST Aerospace has done well in the design and development, upgrade and integration of our defence capabilities. It has also reinforced the RSAF’s operational capability through the undertaking of outsourced engineering and maintenance services, as well as the provision of cost effective technological solutions to meet the strategic imperatives of the RSAF.
>
> **ME8 Francis Cheong**
> *Head Air Engineering and Logistics, RSAF*

RSAF 112 Squadron won the ‘Best Air Combat Support Squadron’ award in work year 2014/2015 supported by ST Aerospace’s KC135 Programme Team.

SINCE DAY 1

By the mid-1980s, ST Aerospace had developed sufficient capabilities to take on Contractor Logistics Support (CLS) programmes with the RSAF. It started with the SF-260 light trainer and progressed to the A-4 and F-5 fighters where it undertook the whole works from heavy engineering to maintenance and logistics of the aircraft fleets.

Former President ST Aerospace, Mr Tay Kok Khiang, remembered working with Singapore Aircraft Industries (SAI), the precursor of ST Aerospace, on the CLS programme when he was Head Air Logistics in the RSAF. He said "The RSAF gave a lot of support to build up SAI's engineering capability. It helped that many of the SAI team involved in CLS were previously from the RSAF. Mutual trust was important, especially when it comes to sensitive aspects of a customer's operations but that trust had, above all, to be earned."

Kok Khiang recalled that when he joined ST Aerospace in 1993, he had to manage the surge of aircraft at the tail-end of the A-4 Super Skyhawk, and the F-5E/F and RF-5 upgrade programmes. It would be the first of many programmes where ST Aerospace would prove its mettle by going against all odds to fulfil RSAF's operational needs. After the A-4 and F-5 upgrade programmes, ST Aerospace was subsequently contracted by the RSAF to upgrade other platforms, including the E-2C, F-16C/D and C-130. Its MRO capabilities were progressively expanded to support these and newly acquired RSAF assets.

ST Aerospace's crew performing final checks on an F-5 fighter aircraft during Exercise Cope Tiger in Korat Air Base, Thailand.

Said Mr Sarbjit Singh, ST Aerospace's Executive Vice President of Defence Business, "ST Aerospace's military aircraft engineering capabilities was developed in tandem with the advancement of the RSAF and cross-fertilised with experience from its commercial engineering programmes. We have worked alongside the RSAF since our inception, providing cost-effective maintenance and engineering solutions that contribute to the build-up of an outstanding air force."

> "ST Aerospace plays a critical role in the ever-changing defence needs of the RSAF. From the design and development of unique solutions, major avionics upgrades and systems integration, to the provision of outsourced services, ST Aerospace is like an extended engineering arm of the RSAF.
>
> **MG Mervyn Tan**
> *Chief of Air Force, RSAF*

RAISING HERCULES

Since 1977, ST Aerospace has maintained the RSAF C-130 Hercules and built up comprehensive MRO capabilities for the transport aircraft. In 1997, the company took on the first-line support for the C-130 squadron, which includes launching and recovering flights for all local and overseas missions as well as participating in humanitarian and disaster relief operations, like the logistics support in New Zealand in support of the RSAF's operations during the 2011 Christchurch earthquake, and the supply of aids and evacuation of Singaporeans from Kathmandu during the 2015 Nepal earthquake. Other than the aircrew, the rest of the ground technical support crew were from ST Aerospace.

In 2007, ST Aerospace was contracted to provide a turnkey solution to upgrade RSAF's fleet of legacy C-130s. The aircraft's system capabilities were enhanced and an advanced air traffic management system installed to enable the C-130 to operate in regulated civil airspace. Mr Loh Piang Khuen, Programme Manager for the C-130 upgrade, credited the success of the large-scale and highly complex modernisation programme to the high level of trust between RSAF and ST Aerospace, which had facilitated close collaboration and open dialogue among the project team.

ADDING VALUE FOR OUR CUSTOMERS

Over 400 Conversions and Counting

Passenger-to-freighter (PTF) conversions are highly demanding tasks. Depending on whether a narrow or wide-body aircraft is involved, a passenger plane would have undergone between 800 to 1,250 critical tasks or work cards before it emerges from the hangar as a freighter aircraft.

For instance, the paint is stripped off, and the interiors and furnishings are removed. Floor structures are reinforced to carry heavier loads, and large doors are installed to allow the loading of cargo pallets. Barriers are also retrofitted to prevent cargo movement during flight, along with cargo handling systems.

Freighter conversions were added to ST Aerospace's service offerings in the early 1990s when the first Boeing 727 aircraft was successfully converted in Mobile Aerospace Engineering (now VT MAE) for FedEx.

"ST Aerospace did not start by pursuing PTF as a business. We were looking for jobs that had more engineering content so we could leverage on our engineering experience from military aircraft work. We also did not want to compete directly with the airlines on MRO services as they had the base-load and significantly more experience than us," said Mr Tay Kok Khiang, President of ST Aerospace from 2001 to 2010, looking back at the success of the PTF business.

In view of that, ST Aerospace decided to start with the commercial aviation engineering modification market. At that time, the Section 41 modification for the Boeing 747-200 and 747-300 to rectify a major structural problem, surfaced as the most relevant work. The then Singapore Aviation Services Company, known now as ST Aerospace Services Company (SASCO) took this on and built up its commercial MRO capabilities from the associated work done as part of the work package. In the US, capabilities grew slowly through similar programmes like the Boeing 727 PTF for FedEx.

"It was our experience with doing PTF conversions that led to the build up of relatively strong engineering capabilities within a short time as

we tried very hard to enhance our value-add to our PTF customers' work through our engineering know-how. Progressively we worked to undertake engineering development work in commercial aircraft, which in time included undertaking development of PTF design, working in collaboration with aircraft manufacturers like Boeing, and later Airbus. This enabled ST Aerospace to become a prime contractor capable of taking on large engineering programmes directly with airlines and freight operators, like the upgrade of an entire aircraft fleet," Kok Khiang added.

Of the many complex PTF conversions ST Aerospace has performed on Boeing aircraft, the 757 PTF programme was indisputably its biggest and proudest. Aside from the impressive 119 redeliveries achieved under this programme between 2008 and 2016, the FAA-approved STC accorded to the ST Aerospace's design with data licensed from Boeing was achieved in a record-breaking 11 months.

Mr Lim Serh Ghee, President of ST Aerospace, recounted an amusing anecdote from the certification process, "We received our STC for the 757 PTF conversion from the FAA on 2 April 2008, even though it was expected on 1 April. The FAA thoughtfully decided to delay the announcement by a day just in case we might think it was an April Fools' joke!"

ST Aerospace has grown to become one of the world's largest PTF conversion houses with industry giants such as FedEx, UPS, DHL, Japan Airlines, All Nippon Airways and SF Airlines among its major clients. It has converted more than 400 aircraft ranging from DC-10s and MD-11s to 727s, 757s and 767s to date – and with the acquisition of Airbus' subsidiary, Elbe Flugzeugwerke GmbH (EFW), that portfolio has expanded to include the A320s and A330s.

"We have initiated our PTF programmes for Airbus aircraft, and are excited to be working alongside EFW on this effort. The first A330 PTF prototype redelivery for our launch customer DHL is due in 2017, while the A320/A321 PTF prototype will be rolled out by 2019," said Dr Yip Yuen Cheong, Executive Vice President of Aerospace Engineering & Manufacturing, ST Aerospace.

"The A320/A321 PTF programme with ST Aerospace through EFW will be the only A320-family freighter conversion programme to benefit from our design knowledge of the Airbus aircraft, our engineering know-how, as well as the extensive operational experience from the thousands of single-aisle Airbus aircraft in service today," affirmed Mr Tom Williams, Chief Operating Officer of Airbus.

ST Aerospace secured DHL Express as launch customer for four A330-300 PTF conversions in 2016. DHL Express ordered additional four firm and 10 optional A330-300 PTF conversions in 2017.

ADDING VALUE FOR OUR CUSTOMERS

James R. Parker

Executive Vice President of Air Operations, FedEx

"ST Aerospace has been a valuable partner to FedEx since the early 1990s, when we inducted an aircraft for maintenance at your Mobile, Alabama facility. Today, ST Aerospace remains FedEx's largest aircraft maintenance vendor, providing airframe maintenance on our fleet of A300, MD-10, MD-11, 757, 767 and 777 aircraft at various locations around the world. We look forward to continuing this outstanding partnership.

M Razali Ahmad

Programme Manager for 757 PTF conversions, ST Aerospace Engineering

"Working on the FedEx PTF programme has been an eye-opening experience. I led my team through technical challenges that we never had to perform before. Even the Quality Assurance requirements were more stringent than what we encountered in the past. There's a tremendous sense of pride and confidence within the team for having accomplished such a monumental feat. We are especially proud to have left our marks in the making of the world's largest PTF conversion house.

Chuwa Lee Soon

Deputy Chief Engineer, Engineering & Development Centre, ST Aerospace

"When we took on our first FedEx 757 PTF at MAE, the certification of the Main Deck Cargo Door was a concern. Although our design concept had been proven by service history, the criteria for STC application had become more stringent at the time. Constrained by the schedule and deadline, the engineering team poured through the available options and consulted with subject matter experts. A series of discussions with the Authorities to determine the mitigation actions ensued, followed by a team effort to ensure that the latest certification requirements were met. This was only possible with the resourcefulness and perseverance of the many stakeholders working hand-in-hand, including engineers, mechanics and crew, and senior management. We managed to redeliver the very first converted 757 aircraft to FedEx on time, paving the way for many more to come.

EARNING OUR INDUSTRY REPUTATION

By the early 2000s, ST Aerospace had acquired a reputation as a reliable MRO provider. Boeing had been in Singapore looking for a partner to outsource their DC-10 PTF work which was believed to have a good business potential. "We met the Boeing team and convinced them that we had the capabilities to get the job done well," said Kok Khiang, remembering how Boeing was eventually persuaded to let SASCO handle their DC-10 conversions.

"We made it a point to turnaround and redeliver the first aircraft in record time to a suitably impressed Boeing team. Although the market demand for DC-10 freighters did not materialise as Boeing had anticipated, our experience with the DC-10s would pave the way for SASCO to win a UPS MD-11 PTF contract a few years later. We gradually became known as a significant player in heavy aircraft engineering and design as we had the best facilities and capabilities in the world. Our relationship with UPS was therefore built up on two independent tracks - as an MRO in San Antonio and as a PTF conversion house in Singapore.

With the PTF conversions came the MRO work. Kok Khiang said, "When the aircraft was going to sit in the hangar for more than a month, the airlines would pack in as much maintenance requirements as possible. We undertook the whole works, did them well and built up our reputation as a competent MRO shop."

Michael J Fleming

Vice President Fleet Services, CAS, Boeing Commercial Airplanes

“Boeing’s relationship with ST Aerospace began in 1999 with the conversions of the DC-10, MD-11 and 757-200 passenger airplanes to freighters. In 2004, SASCO was made ‘Boeing Supplier of the Year’ for its performance on the MD-11 PTF modifications. Our established relationship with ST Aerospace has continued to expand. SASCO has been performing our 767-300 PTF conversions since early 2007. ST Aerospace also performs our 757-200 PTF conversions under the 757-200SF STC, which it designed under a data license agreement with Boeing. We value ST Aerospace’s dependability in meeting our expectations of high quality work and performance.

DELIVERING WORLD-BEST MRO SERVICES

Staying Number 1 in Airframe MRO

VT San Antonio Aerospace facility in San Antonio International Airport, USA.

ST Aerospace's commercial airframe MRO business started in 1991 with SASCO in Singapore. Today, it has seven airframe facilities spread out in North America, Europe, China and Singapore, offering worldwide customers great flexibility in selecting maintenance slots that suit their flight schedules and convenience.

"ST Aerospace is effectively an integral part of our customers' operational network," said Mr Ang Chye Kiat, Executive Vice President of Airframe Maintenance & Modification. "For instance, FedEx can send its planes to any of our facilities in the US or Singapore depending on its operational needs, and JAL can have its planes worked on in Singapore or Guangzhou. Wherever the aircraft are being maintained, our customers are assured of the same high quality of service and customer focus."

Mr Tay Kok Khiang, former President of ST Aerospace, revealed that this focus on quality and performance was a deliberate decision from the start. "ST Aerospace has decided not to compete on the basis of being a low-cost provider but to build strong MRO capabilities so that it can deliver safety, quality and value-for-money services for its customers.

This direction has led the company to invest in and retain a skilled technical workforce that can serve its airline customers better. This is ST Aerospace's value proposition to its customers," he said.

Perhaps even more important to the airlines than fast turnaround would be the consistency of work delivered. ST Aerospace uses a consistent set of quality system and procedures which allows it to repeat its success in different parts of the world. Mr Ambrose William, Executive Vice President of Corporate Marketing, said, "ST Aerospace's ability to control and deliver consistently good quality services has given it a huge competitive edge. It has allowed the company to stay profitable and become a global leader in the commercial MRO industry."

He added, "Customers are always seeking greater value-add in service innovation. Beyond the traditional services, like airframe maintenance and component repair, we proactively engage the customers to identify their specific MRO needs and formulate a complete support package."

Another success factor in airframe MRO is ST Aerospace's wide span of customer relationship with some of the biggest commercial airlines in the industry. Interestingly, some of ST Aerospace's best customers were also its trainers.

"In the aviation industry, no airline will entrust an aircraft to an MRO service provider that does not already have a proven track record for that aircraft type. Because of our good relationship with the airlines, they have helped us by training our MRO teams on the new aircraft types and provide the first aircraft for us to work on. This established the track record we needed to secure new jobs," said Chye Kiat.

He added that while pursuing the big customers, ST Aerospace has never neglected the smaller carriers. Many of its successes today could be traced back to its support of budding airlines that later became significant players, like AirAsia and Jetstar Airways.

Yuji Akasaka

Senior Vice President Engineering & Maintenance, and President, JAL Engineering

JAL's partnership with ST Aerospace started in 1991 with SASCO, our joint venture in aircraft heavy maintenance and major modifications. In 2016, JAL celebrated its 200th aircraft input to SASCO and started sending our 737s to ST Aerospace Guangzhou for heavy maintenance. ST Aerospace is a valuable and indispensable partner of JAL and we look forward to continuing this partnership for many years to come.

Ed Geers

VP Aircraft Maintenance and Engineering, United Parcel Service (UPS)

UPS Airlines has worked with ST Aerospace since 2001, starting with MD-11 conversions. We appreciate the quality and responsiveness of the team, and look forward to continuing this long-standing relationship.

Chris Snook

Executive Manager, Engineering & Maintenance, Jetstar

ST Aerospace has supported Jetstar since we began operation in 2004. ST Aerospace has always been committed to providing safe, reliable and cost-effective engineering solutions to meet Jetstar's requirements. Ours is a successful and long-standing partnership.

George Psycharis

Managing Director, Maintenance and Strategy, Air Canada

ST Aerospace has supported the maintenance programme of Air Canada's entire 777 and A330 fleet since 2012. Our collaboration with ST Aerospace went beyond airframe MRO when in early 2013, ST Aerospace performed a turnkey project for Air Canada's Rouge 767 cabin modification. We are appreciative of ST Aerospace's strong commitment in providing excellent support for our fleet.

Tatsuhiko Mitsukura

EVP, Operation Division, Engineering & Maintenance Centre, Training Centre, All Nippon Airways (ANA)

ST Aerospace has been a close partner of ANA since 1997, supporting us on heavy maintenance, cabin interior modifications and PTF conversions for our 737NG, 767 and 777. In 2016, ST Aerospace took on our first turnkey maintenance outsourcing programme for the 787. ST Aerospace is a strong partner and an essential member of the ANA team. Its consistently high level of maintenance services has contributed to ANA's success.

DELIVERING WORLD-BEST MRO SERVICES

Total Support for Aircraft Components

One of ST Aerospace's core capability is in providing Component Total Support (CTS) to commercial, military and general aviation aircraft. CTS comprises two complementary businesses – Maintenance-By-the-Hour (MBH) and Components Repair and Overhaul (CRO) – that together with airframe MRO, engine maintenance and engineering development expertise, offer significant value to customers and make ST Aerospace an MRO partner of choice.

Mr Goh Poh Loh, Executive Vice President of CTS, said, "The main differentiating factor in CTS is our people. We have a strong team of dedicated engineers and technicians with sound engineering fundamentals and in-depth understanding of the customers' needs and expectations. Through this team, we have been able to uphold the highest quality standards in MBH and CRO services and secure strong partnerships with 25 OEMs around the world."

As a testament to ST Aerospace's strong and growing component support capability into new aircraft platform, it was voted by global industry experts and aircraft operators as the Best Component MRO Service Provider at the 2015 Air Transport Engineering and Maintenance Awards in London. UTC Aerospace Systems, one of the world's largest suppliers of aerospace and defence products, also appointed ST Aerospace in 2013 as one of a handful of approved licensees for the maintenance of its electrical and environmental products as well as aerostructures products fitted on the Boeing 787 liners, which covered up to 70% of the total components fitted on the aircraft.

"ST Aerospace is a certified repair station with 16 Airworthiness Authorities, including Singapore's CAAS, the US' FAA, the EU's EASA, China's CAAC and Japan's JCAB," said Poh Loh. "We have a comprehensive component MRO capability to support more than 25,000 part numbers – spanning from digital avionics, fuel and power generation to landing gears and transmissions – for a wide range of aircraft and helicopters. We are constantly developing innovative and cost-effective engineering solutions, like setting up the Landing Gear Centre of Excellence in Singapore, to serve our customers better."

He added that under the CTS business, ST Aerospace had serviced more than a million aircraft components for loyal customers which include top aerospace OEMs like Boeing and Airbus, full service airlines like JAL, ANA, China Airlines, Delta Airlines and American Airlines, and low cost carriers like Jetstar Australia, Flybe, Jeju Air and AirAsia.

> "FedEx had an urgent and critical requirement for the fuel booster pump assemblies on its fleet of MD-11 to comply with a new maintenance service bulletin by the component manufacturer. This modification was new to us and we had to work very closely with the customer and vendors to design and fabricate special fixtures and to adapt an existing test stand – all within a week in order to meet the short deadline. FedEx was very pleased when we completed all the pump assemblies on time! However, I would say the greater satisfaction belong to our team, knowing that we had overcome a tough technical challenge and kept our customers' aircraft flying safely.
>
> **Kadir Dawood**
> *Assistant Principal Engineer, ST Aerospace*

OVERCOMING HEADWINDS IN EUROPE

With the MRO and engineering businesses in US and Singapore taking off by the mid-2000s, ST Aerospace started to look at Europe as a potential market for further expansion. In 2006, it acquired SAS Components from Scandinavian Airlines and renamed it ST Aerospace Solutions (STAS). The Denmark-based STAS was to serve as ST Aerospace's CTS arm in Europe and to grow its MBH and CRO businesses.

Two years later in 2008, ST Aerospace furthered its European expansion with the setup of Madrid Aerospace Services (MAeS) in Spain, a joint venture with Iberia Airlines, to consolidate and strengthen ST Aerospace's MRO capabilities in Europe, with a focus on Airbus landing gears.

Soon after that, the European economy went into a deep recession amidst the global financial crisis triggered by the US sub-prime crisis in end 2008. Unable to sustain the ensuing stagnated market demand, STAS was eventually downsized and MAeS had to cease operation in 2014.

Poh Loh revealed that the main drawback of MAeS was in the parts rework arrangement. "The parts rework, which constituted about 40% of the overall landing gear overhaul work, was subcontracted to the JV partner who had the existing facility to do the jobs. Due to the difference in priority and cost structure, as well as undue administrative efforts, we found it difficult to control the turnaround time and the cost to stay competitive and secure new customers," said Poh Loh.

Comprehensive components MRO capabilites.

As for STAS, the operations were facing headwinds from the start. SAS Components' repair capability and rotable assets were tailored to support legacy platforms, like the MD80/90 and Boeing 767, which were phasing out. Typical of an airline MRO shop, several of STAS' capabilities, like cabin equipment, inflight entertainment system, wheels and brakes, were typically done by the airlines themselves and there were no market opportunities for STAS in those areas as well. "We had to invest a lot of effort to improve cost efficiency and to integrate shop floor processes. These engagements were in itself valuable lessons in cross-cultural management," said Poh Loh.

A decision was eventually made to restructure STAS by discontinuing unprofitable product lines, divesting the legacy inventory and rationalising products and services that would allow STAS to regain market competitiveness. The restructured STAS managed to retain high-value work by leveraging its deep experience in aerostructures and mechanical components and repositioning itself as ST Aerospace's Centre of Excellence for Aerostructure.

Managing Customers' Operations and Assets

The provision of managed services by ST Engineering grew out of its core activities in design, development, upgrade and MRO. One of the Group's earliest managed services was to support the commercialisation of RSAF SF-260 training aircraft in the late 1980s. This was followed by the provision of packaged design, operations and support for simulators, integrated logistics management, and comprehensive training services. As demand for managed services grew, so did the value-add for customers, culminating in innovative service models like Total Aviation Support and IT Infrastructure-as-a-Business.

From comprehensive managed services in areas such as acquisition, operation, management, leasing, support and retirement of assets, equipment and infrastructure, the Group has extended into specialised public-private partnerships, such as the operational support of sea vessels for the RSN and aircraft for the RSAF. It is also one of Singapore's largest business process outsourcing (BPO) and shared services solution providers.

Secure and Green Data Centres

With enterprises facing a growing business need for secure data management, ST Electronics started to offer a comprehensive service in 2006 known as the Total IT Solution which included data centres, IT infrastructure and managed services. The round-the-clock data management and support by ST Electronics provided customers the assurance that their data were protected and secure, enabling them to focus on growing their core business.

"With three data centre facilities totalling 400,000 sqft and close to 80 customers, ST Electronics is one of the top data centre providers in Singapore," said Mr Clement Teo, Vice President & General Manager, Data Centre Solutions of ST Electronics. "Our customers include government agencies, public healthcare, financial institutions and multinationals. We provide design and build, preventive maintenance, and facilities management of data centres, as well as customised private suite hosting to support our customers' operational needs."

Each turnkey data centre project is further designed to reside in a reliable and sustainable platform. These green data centres are more energy efficient, generate minimal environmental impact and offer long-term cost savings for the customers. More importantly, critical IT assets are always available and readily accessible for business operations. "Security and business continuity are top priorities in the operation of ST Electronics' data centres," emphasised Clement.

Expanding into Business Process Outsourcing

ST Electronics, through e-Services (eServ), is one of Singapore's largest BPO and shared services solutions provider in Singapore. By providing multi-functional support in areas like finance, accounting, human resources and training, it frees up customers' capacity to focus on core operations.

According to General Manager and the SAF's first female Colonel, Ms Karen Tan, the foray into BPO business came about in 2007 when ST Electronics won a contract to provide shared services to the MINDEF and the SAF. "Our initial goal was to ensure a smooth transition of the service delivery to eServ." As confidence grew, the team started to pitch for commercial projects as well as acquire COMAT, an IT-training and certification company, in 2010 to expand its business offerings.

"The COMAT business and having to bid and compete for projects were new to us and we learned to sharpen our instincts on service quality. With COMAT on board, we were able to combine technology-enabled learning with instructor-led delivery in our learning curriculum and content design," Karen said.

"Our value creation for customers is a constant work-in-progress. Already, we are looking into building new capabilities in advanced analytics, robotic process automation, knowledge management, social and collaborative learning, and technology-enhanced serious games to meet customers' future needs," she added.

> "We are impressed by the dedication of the eServ team, which was mobilised at short notice to support our recovery operations. eServ was instrumental in the entire operation, working long hours including the weekend to minimise the impact to the stakeholders. Special credit goes to Angela Ong, Cristiana Tan, Jason Ho, Jacky Peh and team for their knowledge and expertise, which have contributed significantly to our success. The commitment and drive exemplified by eServ underscore why this partnership is so special. We thank the management and team of eServ for their professionalism!
>
> **Tan Wee Beng**
> *Deputy Chief Executive (Operations), SkillsFuture Singapore*

LEARNING THROUGH PLAY

"Decisive Combat", a serious game co-developed by ST Electronics, DSTA and the SAF, beat the US Army and FBI to bag the top prize in the International Serious Games Showcase and Challenge in 2013, under the Best Government category. "Decisive Combat" develops critical thinking skills in junior military leaders.

Total Aviation Support

Being an independent MRO shop has been a key competitive advantage for ST Aerospace. It provides the flexibility for ST Aerospace to develop a complete suite of services from airframe and engineering maintenance to engine, components and line maintenance that differentiates it from other players. Said Mr Ambrose William, ST Aerospace's Executive Vice President of Corporate Marketing, "We are widely recognised in the industry today as a provider of Total Aviation Support. We have been able to bring the high level of quality service from years of engineering and MRO experience supporting military aircraft operations to our commercial customers. Airlines and freight operators can be assured of cost efficiency and that we will help to keep their aircraft flying safely."

AIRCRAFT AND ENGINE LEASING

To augment its Total Aviation Support offering, ST Aerospace expanded its asset management services to include aircraft and engine leasing. In fact, ST Aerospace's engine leasing business can be traced back to 1998 when it bought the first JT8D-200 engine to fulfil a service level guarantee in the Power-By-The-Hour Agreement with South African SAFAIR. The engine inventory was later expanded to include CFM56-3 and CFM56-7 engines to support other customers.

In 2011, ST Aerospace set up Total Engine Asset Management (TEAM), a joint venture company with Japan's Marubeni Corporation, to lease aircraft engines. The company started with the CFM56 engines and expanded to include the V2500 engines. According to Mr Tan Shih Shiuan, Vice President of TEAM, new engine models, like GEnx, LEAP and PW1100, would be progressively added to the leasing programme.

"Aircraft leasing was a new business to ST Aerospace," said Mr Chang Cheow Teck, former President of ST Aerospace. "My management team and I took more than two years to deliberate the matter before we finally decided to launch into the business. It was a deliberate strategy to diversify our business into the more capital-intensive venture with a focus on mid-life narrow body aircraft segment to create new value stream for both our customers and shareholders."

ST Aerospace set up Keystone Holdings as an investment company for aircraft assets in 2015 before leveraging it as an aircraft leasing joint venture platform with Japan's Sojitz Corporation in 2016. Sojitz Corporation is well connected in both aircraft leasing and the financial networks in Japan to support the competitive funding required for aircraft leasing programmes.

Mr Goh Yong Kiat, Executive Vice President of Aviation Training & Services, believes that the company's in-depth understanding of aircraft, maintenance cost, reliability and aftermarket conditions gave its aircraft and engine leasing businesses an edge over competition. He said, "Take engine leasing, for instance. When an engine is sent in for servicing, we would offer the customer the option to lease a replacement engine to reduce the aircraft downtime. As an MRO service provider, we also understand the criticality of spares support in aircraft operations better than any other aircraft and engine leasing pure plays."

NO MORE COMPONENT WOES

Modern aircraft are highly sophisticated, comprising thousands of expensive components. Any failure of these components could result in operational delay, and even grounding of aircraft. To mitigate such risks, airlines have traditionally held a large inventory of rotables for replacement of faulty components. To help airlines overcome the operational costs and risks, ST Aerospace set up Airline Rotables (ARL) in Stansted, UK to provide component power-by-the-hour service to its customers in 1991. This was marketed as the MBH programme in 2004.

"Rotables are high-value aircraft components that can be repaired and restored to serviceable use. Under MBH, we provide the rotables and round-the-clock customer support to meet the airlines' needs. Airlines will pay for aircraft availability based on actual flight hours and no longer have to hold expensive inventories. This is especially valuable to operators with a small fleet of an aircraft type or who want to be asset-light," said Mr Goh Poh Loh, ST Aerospace's Executive Vice President of Component Total Support.

Mr Francis Ho, Vice President and General Manager of STA Supplies, who developed the MBH business in Asia recalled the challenges he faced in the initial years trying to secure interest in customers. "The concept was very new in Asia back then and we had to customise every proposal to prove to the airlines that MBH would be able to deliver better value for their operations. In 1999, we finally signed up Indonesia's Merpati Nusantara Airlines as our first Asian MBH customer."

Every MBH solution continues to be tailored to the specific operational needs of full-service airlines and low-cost carriers. More than 600 aircraft operated by 17 airlines are supported by STA Supplies in the Asia Pacific, and by ARL in Europe, the Middle East and Africa.

PERFECTING MANAGED SERVICES

Keeping the SAF Operationally Ready 24/7

As the SAF's operations and military hardware grew, so has its needs for logistics support and managed services. MINDEF and the SAF recognised the merits and cost effectiveness of outsourcing its non-core functions to the local defence industry.

ST Engineering has supported MINDEF/SAF with depot-level maintenance and repairs as well as platform upgrades and calibrations since the early 1970s. Having honed our technical proficiencies from operating hand in glove with the SAF for close to 50 years, it is not uncommon to now find ST Engineering's staff working alongside their SAF counterparts in the camps and bases in Singapore, and providing logistics services in overseas missions. Some have even been deployed along with the RSAF to United Nation's missions in the Middle East.

FROM CUSTOMER TO ADVOCATE

A team of 34 STA Engineering technicians were stationed on board a LST to provide round-the-clock maintenance support for the RSAF's Super Puma helicopters. The three-month mission in 2011 was to counter piracy in the Gulf of Aden. The team faced new challenges in the humid and salt-laden environment, which resulted in heavier demands on maintenance activities. These efforts paid off, for example, when meeting a distress call in high sea. The helicopter was successfully deployed and the door guns were fired to deter the pirates. The success of this mission is one example of the readiness of the helicopters, and the professionalism and dedication of the STA Engineering support team.

FROM VENDOR TO TRUSTED PARTNER

Beyond being a MRO provider, in 1989 ST Aerospace Engineering (STA Engineering), a business unit of ST Aerospace, won its first contract to provide CLS for the RSAF SF-260 aircraft used in pilot training. STA Engineering has since progressed to provide CLS for other RSAF aircraft that include transport planes, helicopters, UAVs and fighter aircraft. Besides the traditional heavy maintenance work, the services have expanded to include line maintenance and unscheduled maintenance within the airbases as well as on the ramp. Over the 28 years, STA Engineering has supported more than 350,000 flying hours under CLS for the RSAF. This includes 16 military aircraft types and flying operations support in five continents, namely Asia, Australasia, Africa, North America and Europe.

"We took on the RSAF commercialisation programmes to further strengthen the close bonds with RSAF. This included maintenance engineering, launching and recovering aircraft according to RSAF's schedules and MRO – we did everything except flying the aircraft. From there, we learned to support operational flying, which was more situational and ad hoc, and quite different from the scheduled work of heavy aircraft maintenance. These experiences also proved to be invaluable when we had to convince the airlines to take up our maintenance engineering and by-the-hour support services," shared Mr Tay Kok Khiang, former President of ST Aerospace.

"Many of us in STA Engineering have served in the RSAF and we understand intimately the requirements and expectations of the customer," said Mr Mario Yeo, General Manager of STA Engineering. "We have supported the RSAF squadrons on choppy waters and in scorching deserts. The sense of responsibility and diligence is second nature to us. We are always ready to serve the RSAF anytime and anywhere."

SIMULATING THEATRES OF WAR

ST Electronics had supported the SAF in simulation training, maintenance and upgrades since the 1990s. This partnership started with the maintenance of the RSAF Air Combat Simulator, and progressed to A-4 and F-5 Operational Flight Trainers and the C-130 Full Flight Simulator. These projects offered ST Electronics the opportunity to develop deep technical capabilities in simulators, which would be used to co-develop the S-211 and Super Puma Operational Flight Trainers with key industry partners. By 2000, ST Electronics had gained sufficient experience to develop its own Air Mission Trainer for the RSAF. The trainer was recognised as one of the world's most advanced combat simulators at that time.

Following its success with the Air Mission Trainer, ST Electronics began developing simulators for the Army and the Navy. The Armour Gunnery and Tactical Simulator, and the Driving Training Simulation System were developed in 2002 for the Singapore Army. Both simulators helped to overcome resource constraints and allowed the software to be updated to current warfighting scenarios. The shore-based Damage Control Trainer was developed for the Navy in 2011. This was a unique trainer that used a full-scale ship replica complete with smoke effects and real water flooding to create a controlled yet realistic training environment.

In 2010, ST Electronics was awarded a contract by the RSAF in 2010 to maintain and manage the Flight Simulation Centre, as well as to conduct training operations at the facility. It won another similar contract for the Helicopter Simulation Centre in 2012.

Mr Aaron Koh, Division Manager of Training and Services in ST Electronics credited these successes to the team's commitment to training excellence. He said, "By offering end-to-end training services and support, we are able to offer simulation training that enables our military customers to turn constraints into strengths, and to enhance mission readiness against emerging security threats."

Armour Gunnery and Tactical Simulator

PERFECTING MANAGED SERVICES

MADE FOR SWIFT RESCUE

MV Swift Rescue was built by ST Marine under a 20-year public-private partnership arrangement with the RSN. First Response Marine, a 50:50 joint venture company with submarine rescue expert, James Fisher Defence was formed in 2007 to operate and maintain the ship and submarine rescue assets and to ensure their operational readiness.

MV Swift Rescue is the first privately-owned ship in the region equipped with a comprehensive suite of Submarine Escape and Rescue capabilities that allows the RSN to conduct rapid evacuation of personnel from submarines in distress. Since entering into service in 2009, it has participated in a number of regional and international defence exercises and humanitarian operations, including the search and rescue missions for Malaysia Airlines Flight MH370 and AirAsia Flight QZ8501 in 2014.

During the mission to locate Flight QZ 8501, the ship had to frequently endure the harsh conditions at sea, with waves sometimes reaching up to 5 metres, poor visibility and inclement weather. Amidst this challenging environment, MV Swift Rescue achieved its objective and located the aircraft's fuselage on 14 Jan 2015.

PROVIDING WIN-WIN SOLUTIONS

ST Marine and RSN IWF Team.

While ST Marine has been supporting the RSN's non-core functions since its formative years, a turning point came in 2000 when it took on the commercialised management of the RSN's naval workshops under the SAF's Integrated Work Force (IWF) framework. The IWF was a radical departure from the traditional concept of outsourcing. Under the IWF framework, ST Marine is accountable to the Commanding Officer of the RSN Maintenance Base for the performance of the workshops and the resource utilisation. ST Marine is vested with the autonomy to supervise and deploy a mixed workforce comprising both RSN and ST Marine personnel for the routine repairs and corrective maintenance of system components such as filters, valves and electrical motors for the RSN's corvettes and patrol vessels.

By counting on ST Marine to manage its workshop facilities and day-to-day maintenance support activities, the RSN can devote their attention to functions that would have more direct operational impact such as defect trend analysis, safety and engineering audits, problem solving and defect prevention, observed Mr Spencer Lim, Manager (Operations, Naval Bases). "The IWF has brought about substantial improvements in cost and manpower utilisation with no compromise on operational support. The savings can now be channelled to enhancing the operations support capability of ships and systems."

THE ONE-STOP SHOP FOR INTEGRATED LOGISTICS SERVICES

The logistics capabilities of ST Synthesis, a business unit of ST Kinetics, expanded in 2007 with a strategic move to address emerging opportunities in the defence and security market segment. It started with the consolidation of the land systems' warehousing teams and matured into a logistics services arm for the other ST Engineering units in Singapore.

With the internal track record and established base-load, the team collaborated with the business sectors to secure a number of SAF's tri-service requirements for centralised and decentralised warehouse management, information resource centre management, facilities maintenance, as well as critical equipment asset control.

When the opportunity to offer end-to-end logistics services for the SAF's training needs in Rockhampton, Australia came about, Mr Puah Lian Seng, General Manager, decided the team was ready to up the ante for customer support. "Together with our partners, we proposed a total logistics package that involved inland transportation, customised sea shipment, in-theatre support, as well as platform maintenance – and we secured a term contract for the requirements. An operation of this scale requires meticulous planning and massive coordination. As a one-stop service provider, we were able to organise the activities effectively and free our customer to focus fully on their training objectives."

Various supplementary and new freight competencies were subsequently developed in the areas of heavy airlift as well as secured freight management. The integrated logistics competencies led further to ST Synthesis' emergence as a key partner to the SAF for its training and mobilisation equipping needs.

Lian Seng shared another momentous operation when ST Synthesis was awarded consecutive contracts to assist the SAF's Transport Headquarters and the Elections Department in the execution of ground logistics during the General Elections. "General Elections 2015 represented an engineering transformation of our logistics operations as the national event was the first whereby we established a virtual command centre to enable two-way communications between the headquarters and over 300 logistics specialists deployed at numerous decentralised sites.

"Just as the needs of our customers have evolved, our logistics solutions have also progressed to ensure effective support. We will continue to leverage the Group's strength to innovate in the logistics space to serve our customers well!"

STANDARDS AND SYSTEMS

At ST Engineering, the execution of business processes and management of corporate governance are guided by exemplary standards of excellence.

We spare no effort across the Group in ensuring that all products and solutions that are rolled out of our facilities comply, if not, exceed internationally recognised standards of safety and quality. At the same time, our governance framework reflects an unwavering commitment to build a trusted and respected organisation supported by a sound system of practices and processes to engineer excellence in everything we do.

PURSUING
BUSINESS
EXCELLENCE

Family of Bronco All Terrain Tracked Carriers.

Engineering Excellence by Design

ST Kinetics is the embodiment of a legacy handed down by the Chartered Industries of Singapore (CIS) and Singapore Automotive Engineering (SAE). Taking the arsenal of ordnance products and automotive services that were developed for the fledgling Singapore Army since 1967, it has punched above its weight to distinguish itself in the global market.

Today, the ST Kinetics portfolio includes uniquely Singaporean products such as the Bionix Infantry Fighting Vehicle, Bronco All-Terrain Tracked Carrier (ATTC), SAR21 assault rifle, and Terrex 8x8 family of Infantry Fighting Vehicles. On the world stage, the company has established itself as a leading supplier of 40mm munitions. Its Warthog, a highly survivable variant of the Bronco ATTC, proved itself in actual combat operations with the British Army in Afghanistan.

The company has also entered the commercial vehicles market, offering a wide range of mass transport solutions, road construction equipment and specialty vehicles through partnerships with leading global players as well as subsidiaries in Brazil, India and the US.

Dr Lee Shiang Long
President, ST Kinetics

FROM ELECTRIC DRIVES TO ELECTRIC UNMANNED BUSES

ST Kinetics' involvement in clean transportation technology started in 1998, before green products had become a popular trend, with investments in start-ups that focused on drive systems for pure electric and hybrid electric vehicles. The technology was enhanced over the years and applied in projects such as the hybrid bus for the inaugural Youth Olympic Games in Singapore in 2010, pure electric bus for Qingdao, China in 2011, and hybrid inner-city buses for Tianjin Eco-city in 2015. ST Kinetics continues to innovate on green transportation, including incorporating unmanned technology to develop public transport solutions for smart cities of tomorrow. This has led to a partnership with Singapore's Land Transport Authority (LTA) in 2017 to develop two autonomous 40-seater electric buses for a public trial.

ST Kinetics' hybrid electric bus deployed to ferry participants of the 2010 Youth Olympic Games in Singapore.

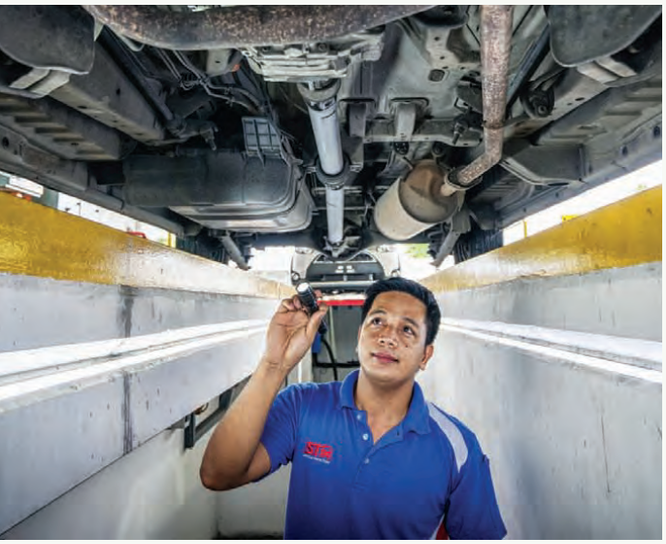
E-560 Electric Drive from ST Kinetics' Canadian subsidiary Kinetics Drive Solutions.

Target evaluation and action plan review at an EHS Committee meeting.

CHAMPIONING ENVIRONMENT, HEALTH & SAFETY

ST Engineering's Environment, Health and Safety (EHS) Committee is chaired by Dr Lee. It champions environmental sustainability and the well-being, health and safety of the Group's employees, customers and communities where it operates. Supported by the Environment, Energy, Occupational Health, Workplace Safety and System Safety sub-committees, the EHS Committee actively promotes the Group's motto of 'Safety Before Profits' and the push towards meeting globally recognised certification standards.

PURSUING BUSINESS EXCELLENCE



ST Kinetics is a LTA-licensed provider for vehicle inspection related services in Singapore since 1982.

"The sheer volume of engineering and systems design that has gone into our extensive range of solutions is astounding!" said Mr Ravinder Singh, ST Kinetics' President from 2015 to 2017.

Citing the US Marine Corps Amphibious Combat Vehicle Phase 1 Increment 1 programme, where a larger and more capable variant of the Terrex was selected for trial over comparable platforms from other reputable international players, he added, "We want to benchmark ourselves and compete with the best in the business. We have every intention to excel both locally and overseas in niche areas where we have considerable engineering expertise and proven track record."

The commitment to maintaining high standards in design and development across the diverse product range, whether it is ammunition, vehicles or weapon systems, demands meticulous attention to detail and systems safety."

Quality is everything in our business," Ravinder added. "Our commercial customers count on our products to maximise their investments. In the defence market, our products equip armed forces and security organisations with mobility, protection and firepower."

Dr Lee Shiang Long, who took over the leadership reins from Ravinder in 2017, agreed, attributing the company's present success to the engineers, welders, technicians and many other unsung heroes within the organisation. "Uncompromising dedication to the highest standards and a deep passion for engineering excellence has always been in our DNA."

"In particular, the tripartite alliance with Ministry of Defence (MINDEF) and the Defence Science and Technology Agency (DSTA) has greatly benefitted ST Kinetics. Our engineering expertise came about because of the close rapport with the Army. Technical specifications were conceived to deliver the operational capabilities they required to fight well," Shiang Long noted. "Without a strong relationship with our strategic partners, none of ST Kinetics' expertise or achievements in international markets would have been possible."

One of the key areas ST Kinetics is pursuing is robotics, which has wide-ranging applications in healthcare, transport, security and urban development that underlie Singapore's Smart Nation vision. Shiang Long pointed out that the company's forte in engineering has positioned it well for this up-and-coming field, which requires a mastery of both electronic and mechanical engineering disciplines.

With the growing interest in sustainable urban transport, other growth areas for ST Kinetics are electric vehicles and autonomous vehicles for last-mile delivery. The company intends to build on its experience as an importer and distributor for MAN Truck and Bus in Singapore, and develop advanced commercial transportation solutions. "There are significant benefits for commercial and military operations. And driverless platforms incorporated with digitised and smart features will be in demand," Shiang Long explained.

Meanwhile, the decision to divest the specialty vehicles and construction equipment business in China has enabled ST Kinetics to consolidate its commercial equipment business position in other markets like the US. "Given that we had not been in the specialised truck bodies and road construction equipment business before, we have achieved remarkable success with VT Hackney and VT LeeBoy in the US," Shiang Long said. "Having emerged stronger and more resilient through each economic cycle, we will continue to harness synergies in terms of processes and know-how."

Looking ahead, the company is ready to accelerate innovation and deepen its diverse engineering capabilities, making greater strides towards higher operating standards. "We owe what we have in the present to the pioneering spirit of our forefathers, but the future is in our hands," Shiang Long said.

SAFE TO BUILD, OPERATE & MAINTAIN

System safety is deeply rooted in ST Kinetics. Ms Siow Seet Ting and her colleagues in the systems safety team would spend countless meetings reviewing and analysing potential hazards and their safety impacts together with the project teams, partners, suppliers and customers, before recommending the best mitigation measures.

Said Seet Ting, "As a system safety manager, I am driven by the goal that no one gets injured in the delivery, operation and maintenance of ST Kinetics' products. For the Terrex programme, I was involved in the assessment of the armament sub-system. As a team, we have spent much effort to analyse and review the design meticulously to develop and verify mitigation measures. This is to ensure that the trials were conducted safely and that the system would be safe to use and maintain under all possible scenarios. Our motto is to always design our products as if our loved ones are the users. That has reinforced our determination to make sure safety is accorded the highest priority above cost, deadline and other considerations."

Seet Ting (right) with Terrex System Safety Lead, Peter Cheak.

Bionix engine undergoing maintenance at ST Kinetics' component workshop.

ACHIEVING OPERATIONAL EXCELLENCE

In Pursuit of Excellence

In conversation with our leaders at Business Excellence Seminar 2017.

The quest for exacting standards is second nature to all involved in production or process control at ST Engineering. The culture traces back to the company's roots in defence, where standards of quality assurance and product safety could mean the difference between life and death.

Mr Dennis Heng, who headed business excellence at ST Kinetics for over 21 years, said, "The first CIS product was the 5.56mm NATO round. Quality for these rounds was so well controlled that even production-run bullets were of competition grade. CIS went on to produce many weapons under licence and at each turn, it learnt from the best that each Original Equipment Manufacturer (OEM) could impart to develop its own robust quality and safety system. CIS was the first in the Group to be certified to ISO 9001 Quality Management System in 1988."

ST Aerospace, too, focused on quality and safety from day one. "We inherited the Singapore operations of Lockheed Aircraft Services Singapore and with that, the US military standards for aviation. Working with a highly disciplined and safety conscious Republic of Singapore Air Force further honed our quality and safety culture over the years. By the time we diversified into commercial operations and started going overseas, our quality and safety standards stood us in good stead to obtain certifications from national aviation bodies and to compete globally," recollected Mr Quek Gim Chuah, Vice President of Quality and Head of Business Excellence for ST Aerospace.

ST Marine was another regional pioneer in quality processes. "From the very onset, we worked with the best in the world and built industry-specific standards into all our operations. We became the first shipyard outside Japan and Western Europe to be certified to ISO 9001 standards in 1991 by Lloyds Register Quality Assurance," said

ST Engineering has been and remains committed to upholding high standards in quality management and achieving business excellence through continuous improvements.

ST Engineering was conferred the SQA in 2002 and the SQA with Special Commendation in 2007.

Mr Tan Kim Hock, Vice President of Benoi Yard and Head of Business Excellence in ST Marine.

Along the way, the Group achieved other international certifications such as ISO 14001 for environmental management system, OHSAS 18001 for occupational health and safety management system, and ISO 50001 for energy management systems. It also advocated continuous workplace improvement. SAE was the first in the Group to introduce Quality Control Circles in 1985 and this evolved into the Total Quality Commitment movement in 1990. Singapore's Business Excellence Framework, with its focus on people, service and innovation, was adopted by the Group from 1995, and many of the Group's business units achieved their People Developer and Service Class certifications during this period.

Mr Harnek Singh, ST Engineering's Head of Business Excellence from 1999 to 2016, said, "We took a bold step back in 2001 to apply for the Singapore Quality Award (SQA) at the Group level. The President & CEO together with the business sectors' Presidents were personally involved in the steering committee to streamline systems and processes across the four sectors. That's how ST Engineering became the first Singapore-listed SQA-certified organisation in 2002, and recipient of the inaugural 'SQA with Special Commendation' award in 2007."

In that same year, the Business Excellence Council (BEC) was set up to sustain ST Engineering's business excellence initiatives. Six component committees, each headed by a senior management member, ensured greater coordination and consistency in the group-wide effort. "Ultimately, there should be alignment across the sectors when the initiatives are deployed. The BEC presents a good forum for sharing and learning of best practices across the Group," added Harnek, who helped put the BEC together.

ST Engineering has also garnered international accolades for its focus on business excellence. In 2011, it was the World Class Winner of the Global Performance Excellence Awards by Asia Pacific Quality Organisation. "Business excellence comes in various forms and guises, but more importantly, it's how business units build on their strengths for sustainable growth," Harnek concluded, assuredly.

ACHIEVING OPERATIONAL EXCELLENCE

Setting a New Platinum Standard for Aviation MRO

A Boeing 757 undergoing maintenance at a VT MAE hangar in Mobile, Alabama, US.

Following the deregulation of the US airline industry, competition escalated and carriers started to outsource low-value work to stay lean and profitable.

"Back in the 1990s, Maintenance, Repair and Overhaul (MRO) service providers did not enjoy the best reputation in the industry. Most started out as shoe-string businesses – poorly run, and without the resources and tooling to do the jobs properly. It's typical for customers to dispatch their staff on-site to oversee the MRO work. The airlines simply did not trust the MRO companies to deliver the high standard of services required to meet stringent requirements by the Federal Aviation Administration," recalled Mr Bill Hafner, President of VT Mobile Aerospace Engineering (VT MAE).

Bill and his team were determined to change the poor customer experience and set out to transform the MRO service standard in the US. ST Aerospace's SASCO business unit was recognised worldwide as the gold standard for MRO, with many of its processes evolved from ST Aerospace's broader experience in the maintenance of military aircraft. VT MAE had adopted SASCO's systems and processes from the onset and adapted it for the US commercial carriers. "We began to establish high levels of safety and quality standards in our operations, and gradually build up our reputation as a reliable MRO service partner," Bill said.

He cited UPS' decision for VT MAE to maintain a larger number of its fleet of Boeing 757 as an illustration of VT MAE's leading service standards. UPS has four Boeing 757 aircraft in maintenance at any time to support continuous operation. It has always been UPS' practice to run separate lines with two aircraft assigned to two MRO operators. This approach mitigates operational risks and conforms to the tight flight schedules. In 2013, VT MAE was awarded a five-year MRO contract by UPS to be one of the two MRO service providers.

"In 2016, every one of the aircraft serviced by VT MAE went straight to freight operations. One aircraft took a 45-minute delay but made a revenue flight that day," Bill said. UPS was delighted with the highly reliable service and performance and increased the number of aircraft to be serviced by VT MAE at the start of 2017.

Terrex production line.

The 8KQB Quality Culture

The quality culture in ST Kinetics was refreshed in 2014 with a set of quality behaviours – Knowledge, Integrity, Nimbleness, Excellence, Teamwork, Inventiveness, Customer Centricity and Safety Focus, known collectively as the '8KQB'.

Mr Kok Yeow Chuen, then Vice President of Quality Assurance at ST Kinetics, explained, "'8KQB' stands for the Eight Kinetics Quality Behaviours. We wanted to have a simple way to share the key principles of quality and their impact on daily work behaviours. Together with some of my colleagues, we localised the quality lingoes and published them in an '8KQB' book. This was used to communicate and reinforce the core quality values and right work disciplines across local operations so as to enhance product and service quality."

Besides the 8KQB, Yeow Chuen also introduced a self-auditing tool called 'Quality Focus' which he adapted from ST Aerospace. He said, "The four-step (Define-Execute-Evaluate-Promote) 'Quality Focus' emphasises greater ownership and accountability in establishing quality within processes. This underscores best practice sharing across the Group."

Mr David Mak was the armoured vehicles production manager at ST Kinetics when the '8KQB' and 'Quality Focus' were launched. He observed how the quality framework had positively reshaped the thinking of the line units and project teams towards quality processes and practices. "My team is able to better appreciate the importance of good workmanship at every stage of production, and identify and address quality gaps in processes. For instance, in one of the projects, we were able to reduce vehicle defects per unit at final acceptance stage from 2.36 in 2014 to 0.43 in 2016 – a significant 80% improvement. We will continue to leverage the quality framework to enhance work performance and customer satisfaction," said David.

ACHIEVING OPERATIONAL EXCELLENCE

It all Started with 'Hell Week'

In 1997, ST Aerospace was the first business sector within the Group to adopt Kaizen, the Japanese approach towards continuous improvement. Mr Goh Poh Loh, Executive Vice President of Component Total Support, then an Assistant General Manager of Operations at STA Systems, was sent to Japan to train in Kaizen practices. "Kaizen is a simple yet effective

ALL HANDS ON AIRCRAFT

When it comes to airframe MRO, every minute of downtime matters. Mr Johari Bin Tamy Chik, Airframe and Propulsion (A&P) Inspector, explained, "Engineers and mechanics should be focusing on actual maintenance activities instead of spending their time searching for data or engineering manuals." That was how the Aerobook came about in the 1990s. "It is an e-tool that enables us to look up technical data and demand for spare parts without leaving the work site," said Mr William Lin, A&P Inspector.

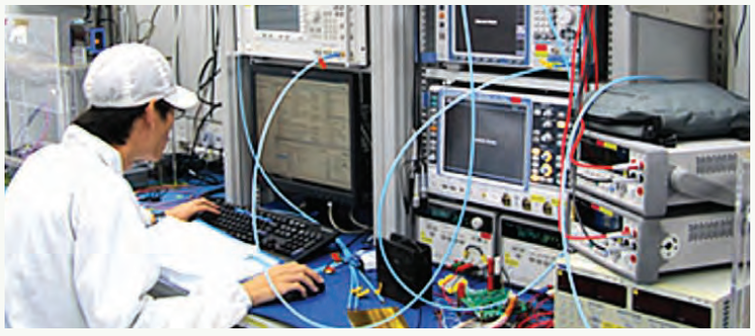
Today, the third-generation of Aerobook is in use, and according to operations manager Mr Chan Koon Ping, it has been a huge step towards a digitised and connected workplace in the hangar. "As data is automatically captured, analysed and available at our fingertips, productivity has greatly improved. Everyone from the shop floor to management can focus on delivering the aircraft on time, within budget and to the highest quality standard." Mr Leonardo Cabrera Agno, A&P Inspector, added, "Aerobook 3.0 has minimised the need to walk to-and-fro the dock and the aircraft, and I can pay closer attention to my job as an inspector and supervisor."

THE NEED FOR SPEED

At ST Electronics, an existing methodology for testing radio frequency (RF) equipment proved to be inefficient when the production team had to deliver three types of RF modules in various quantities for a turnkey manufacturing project. "Our process was not fully automated at that time, and it would have taken too long to set up the tester for the large volumes required," explained Mr Fong Kok Kee, Principal Engineer for the project.

The team wasted no time in re-designing the test set-up, acquiring additional equipment and modifying the test programme to accommodate further automation. These initiatives resulted in higher test throughputs, and a 20% reduction in manpower, thereby creating capacity for larger production contracts. The project won the ST Electronics Outstanding Economic Value Added Initiative Awards in 2016, during which Kok Kee proudly admitted, "Nothing is impossible if we work together with a shared vision, committed heart and focused mind!"

Enhancing MRO productivity through the use of Aerobook.



Improving productivity through innovative enhancement of automated testers for microwave modules.

continuous improvement tool that everyone at all levels of the organisation can use to improve the daily task in a structured manner to ensure impactful and lasting results. It not only improves productivity, but also quality and safety," said Poh Loh who led the Kaizen movement at ST Aerospace from 1998 to 2006.

Mr Wee Siew Kim, President of ST Aerospace from 1997 to 2001, recalled, "The first Kaizen session was definitely a cultural shock for all of the participants. The Japanese consultant's attitude was that if improvement had been identified, our job would be to 'Do It Now' – there was no question or explanation needed. Kaizen week was even termed as 'hell week' by some participants as all needed to work late into the night. At the end of the week, we saw the results and fully internalised the need of taking immediate actions, which is the essence of Gemba (on the spot) Kaizen."

Infectiously, the Kaizen movement caught on at ST Engineering. ST Marine was the next to adopt it in 1998, followed by ST Kinetics and ST Electronics in 1999. It has remained a key tenet for productivity improvement in the Group.

ST Aerospace employees in discussion with the Japanese Kaizen consultant (left).

POWERED BY PRODUCTIVITY

Over the years, productivity initiatives like Six Sigma, Kaizen and Staff Suggestion Schemes have significantly enhanced ST Kinetics' competitiveness as a manufacturer. At Advanced Material Engineering alone, over S$12 million in productivity savings have been achieved through 180 Kaizen projects since 2011, said Productivity Manager, Mr Wong Thye Hiam.

A Kaizen project to review the sub-assembly of fuses and projectiles for 40mm munitions is a good example. The cycle time for fuse assembly was reduced by 40% through a new fixture and pneumatic press, while the assembly time for projectiles was slashed by 43% thanks to an automated glue dispenser and other innovative tools designed and fabricated by the team. The project was awarded Most Outstanding Kaizen Project at ST Kinetics' Kaizen Week 2013. "We started this project to improve our delivery schedules, but I'm proud to add that we've managed to cut costs, improve quality and enhance customer satisfaction in the process!" Thye Hiam beamed.

Kaizen Project Team Respirator with ST Kinetics Management.

BRILLIANCE IN SIMPLICITY

The welding of butt joints is a time-consuming and labour-intensive process in shipbuilding. Typically, a reinforcement bar is tack-welded along the weld joints to align the plates before welding. Thereafter, the bar will have to be removed, and the scars from tack welding grinded away.

After a training session on productivity and innovation, a project team from ST Marine came up with the idea of a jig that would eliminate the need for reinforcement bars when welding butt joints. The new process shortened welding time by 36%. Manpower deployment was significantly reduced, and safety and quality were greatly enhanced. The project won ST Marine its first Gold Award at the Workforce Development Agency – Singapore Manufacturing Federation Productivity & Innovation Awards in 2013. Said Mr Lim Nian Hua, Deputy President (Engineering & Operations) at ST Marine, "We embrace the concept of Kaizen to continually improve our processes and work methods to strive for higher productivity. The Kaizen movement also encouraged our staff to always explore better ways to do their work, thereby achieving a higher sense of ownership and job satisfaction."

ST Marine hull department Kaizen team.

ACHIEVING OPERATIONAL EXCELLENCE

Be Responsible

We promote a safe & conducive workplace
We conserve, reduce & recycle
We deliver reliable & safe solutions
We are an exemplary global citizen

Be Future Ready

We have a clear vision
We empower and develop our people
We invest for the long term

Be Sustainable

We optimise use of capital
We stay innovative and adaptable
We embrace operational excellence

Building a Sustainable Business

ST Engineering is committed to being a responsible engineering and technology group. It takes a long-term view of the impact its operations has on the environment and local communities, and invests in the development of sustainability solutions internally as well as for customers and communities.

Said Ms Alice Chua, ST Engineering's Head of Risk & Sustainability, "Our commitment to governance and sustainability goes beyond measures of revenues and profits. We believe that a robust risk management system, supported by a strong culture for doing the right thing, can drive business performance and growth for the long term. To us, risk management and sustainability are two sides of the same coin – to be sustainable is to manage risks well."

The Enterprise Risk Management (ERM) framework underpins the risk management and internal control systems. It helps the Group to identify and assess significant business risks, prioritise management's attention and resources in areas critical to long-term performance, and align its risk and sustainability agenda across the business sectors and with key stakeholders.

As the Group expands its operations internationally, managing risks and performance takes on a new level of complexity. Systems and processes have to adapt to local conditions like cultural expectations, business practices and regulations. Alice is, however, undeterred. "It is essential to get everyone onboard our commitment. We promulgate this through the global code of conduct and business ethics so that everyone stays rooted in the Group's core values. Ultimately, the success and sustainability of the Group will depend on its people," she said.

BUSINESS UNINTERRUPTED

Businesses are exposed to a great variety of operational risks – from natural disasters and man-made crises to cyber threats, terrorism and power failures, that could compromise operations, and even lead to significant financial and reputational losses. As a global enterprise, ST Engineering supports many customers in critical operations such as public transport, data centres, communications and national security. It is crucial for the Group to be prepared and to recover quickly from any form of disruption.

ST Engineering has a comprehensive Business Continuity Management (BCM) framework to provide assurance to the customers on the continuity of its services while safeguarding the safety and health of its staff. The operations of all business sectors in Singapore are certified to the latest BCM standards, while many of overseas operations are BCM-ready. To help staff internalise their roles and to build greater resilience during times of crisis, regular communications are conducted through road shows, forums, exercises, trainings, handbooks and videos on crisis response.

Ms Yvonne Boudevillie, who has been managing ST Kinetics' BCM efforts since 2008, said, "The success of BCM stems from a strong resilience in our people during times of emergency. To prepare the staff, we send them for capability-building trainings and put them through exercises to reinforce their confidence and readiness. This included a 'Managing Critical Situations' programme to train selected staff in basic psychological first aid and crisis counselling."

The preparedness of ST Engineering was put to the test during the H1N1 'Bird Flu' pandemic and several episodes of severe haze pollution in Singapore. With the well-honed BCM systems and procedures, ST Engineering was able to carry on its operations uninterrupted and protect the interests of its stakeholders.

SCDF demonstrating chemical spillage control at ST Electronics' Emergency Response exercise.

ST Kinetics performing temperature screening during the H1N1 influenza outbreak in 2009.

PAVING THE WAY TO SAFER GROUNDS

LeeBoy India (LBI) is a subsidiary of ST Kinetics that manufactures and sells road construction equipment like motor graders, excavators and backhoe loaders to more than 20 countries. Mr Amarnath Ramachandran, President of LBI, credited ST Engineering's ERM framework for helping LBI systematically identify, analyse and manage operational risks.

He said, "LBI started out as a greenfield operation. LeeBoy as a brand, while well established in the US was relatively unknown in the Asian and African regions, and the products were sold off-the-shelf. To manage the risk of product acceptance in a new environment, we invested time to understand local market requirements and redesigned the equipment to cater to these needs. We also began to actively promote the LeeBoy brand."

The efforts paid off and LBI was able to gain a foothold in the market, and increase market share with time. Understanding the risks has allowed LBI to quickly adapt to volatile market conditions. "When demand in Indian domestic markets fell, LBI was able to switch to export sales to cushion the impact. We also expanded the supply chain and harmonised components across product models to keep costs stable for our customers," said Amarnath.

Raising the Bar

As the Chief Financial Officer (CFO) of ST Engineering from 2008 to 2017, Ms Eleana Tan played a pivotal role in managing the Group's expansive financial functions worldwide, covering corporate finance, treasury, tax, financial reporting, investor relations and insurance. She led a team of financial professionals to ensure that the financial systems comply with prevailing corporate governance requirements, international accounting standards and local regulations where the Group operates in.

Their efforts had contributed to ST Engineering's robust financial standing and earned the Group consistently highest ratings from credit rating agencies. "We have a rigorous accounting and governance framework maintained by a team of highly competent and suitably empowered financial controllers and accountants. These are good people we trust to respond judiciously and swiftly to manage the Group's financial exposures," said Eleana.

Even then, Eleana would make sure she had her fingers on the pulse of the financial positions of the business sectors and the developments in the volatile business environment. It was her way of maintaining oversight of activities and be in an informed position to intervene should the need arise. Her hands-on approach towards financial management had proven effective in reducing financing costs for the Group.

"For instance, through consolidating our hedging activities, we have been able to achieve better economy of scale, reduce the floating fund and keep the cost of financing to a minimum. We also adopted an active treasury management approach, hedging long-term contracts in multiple tranches while keeping close tab on balance sheet and profit and loss exposure. This enabled us to adjust to emerging economic conditions, and gave greater flexibility and options to manage market and foreign exchange risks. We achieved substantial savings over time, and were able to do more with less resources," she said.

In fact, Eleana's brand of pragmatic financial management could be seen throughout her long career with ST Engineering, interspersed by a stint at the holding company Singapore Technologies Pte Ltd (STPL), and later Temasek Holdings (Temasek). She joined the corporate finance consolidation team of Singapore Aerospace in 1987. Before long, her desire to learn about operational finance prompted her to volunteer for line accounting with the business units. "I spoke to my boss, and he agreed immediately. I was put in charge of the finance of not one but two subsidiaries. It was very demanding work but the experience was priceless. I was able to know more about these businesses," she said.

After spending seven years in ST Aerospace, Eleana decided it was time to move on. In 1994, she joined Singapore Shipbuilding & Engineering, now ST Marine, as its Group Financial Controller, a role that put her in charge of the financials of a listed company and allowed her to learn a new business. She held on to that position until 2000 while concurrently taking on the role of Group Financial Controller at ST Engineering, a year after the Group was formed in 1997.

> "One of the things I am truly proud of is to find the financial framework I put in place in the late 1990s still in operation when I returned to the Group. There were, of course, subsequent changes that had to be made, like addressing emerging threats in terrorism and cybersecurity in insurance coverage, and risk areas from on-boarding new business units. But, by and large, the financial framework has proven robust to meet most business requirements and regulatory compliance, and I'm confident it will continue to serve the Group well into the future.
>
> **Eleana Tan**
> *Chief Corporate Officer,*
> *former CFO (2008 to 2017)*
> *ST Engineering*

Finance team at a workshop and team building event in 2017.

"Those were exciting years. Besides being the first government-linked company to obtain a credit rating, we were among the first listed companies to file quarterly financial reports. We won many awards, including the Most Transparent Company Award. We also put in place a system to consolidate idling cash for better placement and started a central treasury system. It was a lot of work by my team and they did a wonderful job!" Eleana recalled.

After seeing the Group through 13 years of accelerated growth, Eleana left ST Engineering in 2001 to attend to family commitments. She reconnected with ST Engineering in 2003 when she joined STPL as its Director Finance. When STPL was restructured and had its assets transferred to Temasek in 2004, Eleana crossed over to Temasek as its Managing Director of Finance. In 2008, she returned to ST Engineering as the CFO, and brought with her valuable experiences from STPL and Temasek in treasury, syndication of loans and managing a portfolio of sizeable assets.

"I came back to an ST Engineering that had greatly expanded. The US businesses had grown significantly and there were new pockets of operations around the globe," said Eleana. "Later that year, the US sub-prime crisis shocked the world, and in particular, the US capital markets. Everyone was hit. Fear ruled in those days, and some of our US bank facilities were discontinued. However, with our strong financial standing, we were able to raise our war chest to support the Group's expansion in 2009."

Since her return, Eleana had strengthened the Group's treasury management and aligned the Group's insurance policies. "The past nine years had been a period of rapid expansion into new markets and new businesses. While the businesses brought in the top lines, my team and I sought to protect the margins and minimise financial risks for the Group," she reflected.

The Journey towards Workplace Safety

ST Engineering is committed to 'Safety Before Profit' and the health and safety of its employees and contractors. Workplace safety and health (WSH) management is underpinned by local regulations and industry standards, like the OHSAS 18001, which is adopted by all the business sectors. The Group promotes a pro-safety workplace culture and closely monitors the implementation of safety programmes, such as Behaviour Based Safety and Culture Safe. Local subcontractors are encouraged to participate in the Group's risk management programme as well as Singapore's BizSafe programme. Senior management reinforces the safety culture by conducting regular WSH walks. WSH practices are benchmarked against leading industry players, and workplace safety lessons shared with practitioners at WSH forums. These efforts have kept ST Engineering's workplace safety record above industry norms.

NO ROOM FOR ERROR

There is always a heightened sense of workplace safety at Advanced Material Engineering (AME), the ammunition and explosives specialist at ST Kinetics. The very nature of the vocation demands the highest level of safety awareness, discipline and teamwork – and everyone is responsible for their own safety and the safety of all others working around them.

Mr Joshua Cheah, Senior Manager in charge of safety explained, "The key to safety in AME is a robust organisational safety culture, embedded in routines, norms, priorities and values. For instance, safety briefings are conducted at the munitions plants twice a day, before work starts in the morning and in the afternoon after lunch. No one is allowed to bring in a match or lighter, all production equipment are grounded, and all staff wear cotton uniforms to avoid generating static electricity."

It is an operation where no work is carried out unless there are written and authorised procedures. If there is any safety concern or doubt, the worker is empowered to cease work and escalate the issue to the next management level for action. All new work procedures must also be cleared at formal safety board sittings involving top management to ensure all safety angles have been looked at.

"It is said that safety regulations in ammunition testing and manufacturing are written in blood. This is why we have preached safety as a culture from the very day we started this business and embedded them into all our work instructions," stressed Mr Lek Huat Lee, Manager, who has been developing safe work procedures at AME for the past 25 years.

Mr Lim Beng Lee, AME's General Manager emphasised, "Our motto, 'Safety Before Profits', is ingrained in the hearts and minds of all of us in AME. From the operators to the engineers and me, we will never compromise safety nor tolerate any safety breach, no matter how big or small."

ST Kinetics' volunteer firefighters and first aiders.

CROWDSOURCING

SAFETY

Embracing the latest smartphone technology, ST Marine has developed a hazard reporting app called the Electronic Safety Observation Card (eSOC). eSOC is a first-of-its-kind crowdsourcing app in Singapore that enables ST Marine staff to work towards reducing workplace hazards and injuries collectively. During the three-month trial period in 2016, eSOC recorded more than 3,000 observations from over 700 staff.

Said Mr Mohamad Zahid, Vice President of EHS at ST Marine, "The outcome of the eSOC trial exceeded expectation. We saw greater employee and contractor participation to improve workplace safety. 90% of the cases reported through eSOC were resolved on the same day and we did away with paper reporting completely. Through backend analytics, the EHS team can perform detailed analysis of workplace safety to strengthen our overall safety programme and move towards our commitment for Vision Zero – the zero-incident target for ST Marine employees and contractors."

eSOC was fully implemented in ST Marine in 2017 and will be progressively implemented across the ST Engineering Group.

SAFETY THROUGH THE ARTS

A national competition jointly organised by ST Engineering and Singapore's WSH Council, the Safety@Work Creative Awards advocated the importance of workplace safety through the creative talents of students. Winning entries of the two contest categories - Poster Design and Digital Animation - were reproduced and distributed by the Ministry of Manpower as posters to be displayed at factories and work premises, and used for safety training purposes respectively.

The competition ran from 2005 to 2015, and attracted some 1,500 teams from tertiary institutions in Singapore.

Safety helmets, specially designed by local artists, were given out as trophies to the winners, and also presented to the panel of independent judges as a token of appreciation for their time and commitment. The judges comprised professionals in the fields of art, design and animation.

ENSURING SAFETY

We Keep Aircraft Flying Safely

Safety before profit. That is the unambiguous stance ST Aerospace takes towards aviation safety and workplace safety. "There is no compromise when it comes to safety. We put safety before everything else," said Mr Quek Gim Chuah, ST Aerospace's Vice President, Quality.

Everything in and about ST Aerospace gravitates towards safety assurance. The company is constantly looking for ways to communicate safety and make it easier for staff to work safely.

"Take our mission statement for instance. It used to be very long. We were expected to memorise it by rote and even then, many of us found it hard to remember every single word," recollected Gim Chuah. The mission statement was simplified in 1998 to the clear and succinct "We keep aircraft flying safely", which remains relevant and in use today, a good two decades later.

The safety doctrines are encapsulated in the policy and standard operating procedure manuals as well as the various quality standards that ST Aerospace abides by, including AS9100, AS9110, AS9120, ISO 9001, ISO 14001 and OHSAS 18001 and the relevant civil aviation authorities regulations. Safety messages are regularly communicated to the staff through hand-outs like posters, pocket flyers, handbooks, bookmarks and stickers, and during staff meetings, new staff orientations, staff briefings, daily toolbox briefings and corporate events.

To further strengthen its safety culture, ST Aerospace initiated the new Aviation Behaviour Based Safety (ABBS) programme in 2012 to emphasise the importance of ensuring safe behaviours at work. Under a new tagline "We actively care", staff are reminded that they are individually accountable for their own safety and to watch out for any behaviour by others that could pose a threat to workplace safety.

CHAMPIONS OF HANGAR SAFETY

A successful initiative is the Hangar Safety Champions Programme in the US by VT San Antonio Aerospace (VT SAA). Since its start in 2012, the programme has lowered the Lost Work Days Incidence Rate to almost zero, well below the industry average of 1.3 lost days per 200,000 man-hours.

The secret to this, according to Mr Noel Casiño, VT SAA's Vice President for Quality and Organisational Excellence, is to make safety practices a habit, much like a "muscle memory". The programme encourages the maintenance crew to look out for one another during work and to enforce safety measures. Some 300 mechanics have been trained as safety champions. Their roles are to spread the safety message and inculcate the safety mindset at the working level where it is needed most. They are also fully empowered to stop any job that could result in potential aircraft damage or safety issues.

A Hangar Safety Champion ensuring safety protocols and procedures are observed at all times in the hangar.

A DAY IN THE LIFE OF AN AIRCRAFT TECHNICIAN

0800hr

The technician signs in for work and joins the line in the apron to participate in the Foreign Objects Debris (FOD) walk. This is a regular morning ritual to pick up any objects, however small, which could become a safety hazard if they were sucked into the engine of the aircraft.

0810hr

The supervisor conducts the morning toolbox briefing and reminds the team about safety precautions related to each of the jobs on hand as well as to look out for one another's safety as part of ABBS.

0820hr

Work commences and the technician collects the required materials, tools, equipment and maintenance manuals based on the work cards requirements while observing the safety guidelines and practices. He dons his safety harness as he works on the wing of the aircraft.

1230hr

The team pauses for lunch break. All the work-in-progress items and parts are stowed in designated places to keep the hangar free of FOD.

1315hr

The team returns to work. A new part is required to replace a worn component in the aircraft. The technician inspects the new part, checks the part against the maintenance manual and work card to ensure the correct part is used before replacing the part. Upon completion of the installation, he signs off the work in the work card. An independent inspection is performed by another technician on the installation as per instructions in the work card. The independent inspection is then duly signed off. The technician continues with other jobs in the work cards.

1500hr

The team completes the assigned jobs on the aircraft. The supervisor checks the work done, checks the completed work cards and signs on the work cards to indicate release to service of these systems.

1510hr

As the technician picks up new work cards for subsequent jobs from the dock room, he notices a team mate walking down an eight-step work stand with one hand holding the tool box and another hand holding a maintenance manual. He goes forward and reminds his team mate to ensure a proper three-point contact when going up and down the work stand. The team mate acknowledges and appreciates the feedback.

1730hr

The team performs another FOD walk and housekeeping before returning home after a day of good and safe work.

System Safety: Different Generations, Same Passion

From left: Yeap Khek Teong, Tan See Heng, Onn Eng Ling and Ivan Goh

"What is amiss?"

That was the first thought in Mr Tan See Heng's mind in the aftermath of the tragic 1997 gun howitzer incident. A 155mm artillery round had exploded in the chamber of a FH2000 howitzer during an SAF training exercise in New Zealand, resulting in the deaths of two full-time national servicemen. The premature explosion was traced to a defective fuse in the 155mm shell that was loaded into the howitzer.

It was a brutal wake-up call nonetheless, and See Heng vividly remembers the agonised soul searching that followed. "It didn't matter that our quality and manufacturing systems were modelled after the top European ordnance manufacturers. As manufacturers, we're ultimately responsible for our own product safety," he reflected.

"At that time, quality management systems could only ensure that products were made to design drawings. So we called into question every aspect of our quality systems, engineering processes, operating techniques and even management principles. We needed a robust standard of system safety that was backed by all of these elements," said See Heng.

He recalled presenting the concept for system safety adoption at a highly charged MINDEF-ST Engineering Conference following the incident. "Someone asked 'Who should be held responsible if such an accident happened again?' My answer was 'You can look for me!'"

So that was how system safety came into being, with See Heng becoming the first System Safety Director in ST Kinetics. "We had a lot to learn, and staff mindsets had to undergo radical change," he remembered. Together with Ms Onn Eng Ling, a System Safety Engineer at the time, he initiated process changes, design improvements and other detailed procedures to strengthen product safety.

"After my first System Safety Conference at Forth Worth in the US in 2000, I became fully convinced that system safety practice is the way to go for us. The belief drove me in the journey to propagate and implement System Safety across ST Kinetics," shared Eng Ling, who oversees system safety for ST Kinetics' defence business.

With the help of then President of International System Safety Society, Eng Ling organised the first local System Safety course in 2001 and instituted system safety practices based on the MIL-STD-882 standard adopted by all US military and defence agencies. She was also instrumental in starting the Singapore Chapter of the US System Safety Society in 2002 and organising the 2008 International System Safety Regional Conference in Singapore.

Not surprisingly, customers are increasingly favouring manufacturers who are able to provide System Safety assurance. Yet, with changing times and technologies, See Heng observed that newer generations of System Safety Engineers are faced with completely different sets of challenges.

Mr Yeap Khek Teong, who chairs the ST Kinetics Safety Review Board, agrees. "With increasing use of automation and controls, and as system-of-system requirements become more complex, the software written to support various tasks will have to be more robust.

"The policies and standards for system safety of today have become more encompassing. They have to cover not just the product design and operational aspects, but also the processes involved in maintenance and entire lifecycle management," elaborated Khek Teong, who took over as ST Kinetics' System Safety Director after See Heng's retirement in 2007.

Mr Ivan Goh, a System Safety Engineer who joined the team in 2012, believes that future generations of System Safety practitioners will have to be even more holistic in their approach to systems analysis: "They'll have to identify and address the hazards of individual systems, as well as assess and mitigate any potential hazards that may emerge when systems interact with each other. There'll also be more commercial off-the-shelf elements, whose safety requirements have to be considered and integrated."

Today, system safety goes beyond the safety assessment of products – it is an integral part of the ST Kinetics design and development culture. While it has been two decades since the practice was formalised, the passion and dedication to system safety have not diminished and the same golden principle continues to hold true: Never make assumptions when it comes to safety. The devil is in the details, and there are no shortcuts to ensuring safety.

Onn Eng Ling delivering an opening address at ISSRC 2008, attended by senior members of the defence eco-system, government bodies and institutes of higher learning.

IDEAS AND INNOVATIONS

Technology and innovation are vital to maintaining the Group's position as a leading global provider of engineering solutions. By challenging conventions, embracing fresh paradigms and redefining perspectives, ST Engineering aspires to do better each time – engendering concepts and ideas that transcend the ordinary.

We forge a supportive culture of innovation that enables engineers to dream and push the frontiers of technology and engineering. From the depths of the ocean to the vastness of space, we have left our mark in the form of game-changing solutions that shape a better future.

Traversing through Terra-incognito

Without doubt, ST Engineering has managed to brave and thrive in the rough terrain of internationalisation, riding on the strength and diversity of its people. It has negotiated uncertainties and stayed above the competition by actively seeking overseas opportunities, developing trendsetting products and providing dependable services.

Mr Fong Saik Hay, Chief Technology Officer (CTO) of the Group, believes that part of ST Engineering's success is due to its immense capacity to adapt and develop practical and innovative solutions to solve real-world problems. "It has been close to four decades of internationalisation since we first ventured out into the world through Unicorn International. From the start, we have tried to make ourselves known as a group that is innovative and uncompromising in the quality and reliability of our products and services," said Saik Hay. "And we did!"

These innovative solutions have come from across the Group. ST Engineering is the original equipment manufacturer for advanced armoured platforms like the Warthog All Terrain Vehicle, Terrex Infantry Fighting Vehicle, and Next Generation Armoured Fighting Vehicle; advanced sea vessels like the Littoral Mission Vessel and Landing Platform Dock; and the world-leading 40mm munitions. Its Aerospace business is the world's first Airbus-approved A320 and A330 Passenger-to-Freighter converter, and its Electronics business has gained tremendous traction as a global player in intelligent rail electronics systems and satellite solutions. In particular, VT iDirect leads the market in IP-based satellite communications, and space has become a new opportunity for ST Electronics with the launch of TeLEOS-1, Singapore's first commercial Earth observation satellite.

ST Engineering is also leveraging its engineering capabilities to tackle everyday problems. Examples include the development of the AIR^{+} Smart Mask, specially designed to suit the smaller faces of children, and the Airbitat Smart Cooler for cost-effective ambient temperature control. Another example is the AgilFence, which provides good

perimeter security with its ability to detect small movements along the entire stretch of its length.

On preparing the organisation for the next wave of technology disruption, Saik Hay said that the challenge has always been to navigate a clear path through the relentless market disruptions and rapid technological advances. "We are constantly scanning the horizon for potential technologies and capabilities that could either augment present strengths and competencies or create fresh opportunities," he said.

Another critical element is to find like-minded partners who can co-create new ideas and solutions. Through forging winning partnerships based on trust and respect, ST Engineering will earn the reputation as an equal-opportunity collaborator. "We aspire to be a mother ship from which successful partnerships could be forged, especially with talented individuals and small but highly innovative enterprises," Saik Hay said.

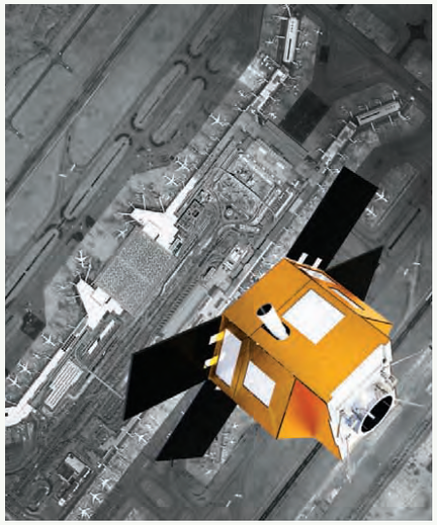
"A big part of generating new and constructive ideas would still have to come from within the organisation," he continued, noting the need for a significant shift in employees' mindsets and a safe space away from business operations where ideas could be allowed to germinate and grow. ST Dynamics is that safe space for fostering new ideas which has seeded many solutions like unmanned aerial vehicles (UAVs), robotics and additive manufacturing for the Group. The Group had also carved out Innosparks as an Open Innovation Lab and incubator of ideas.

"Fifty years ago, ST Engineering's raison d'être was to be the defence industry for the Singapore Armed Forces (SAF). While that remains our anchor, we have built a strong base of competencies to become a key technological and engineering force with world-leading solutions. Our next lap of growth will require a brave new mindset – to design for the world and be the best at it. This should be the new normal required of a world-class technology, defence and engineering Group," said Saik Hay.

> "The security of Singapore depends on the success of many things, including equipping our soldiers with state-of-the-art equipment and technologies. This does not, however, mean that we buy the best weapons and systems from the market because if we can, so can others. It is important for Singapore to have the capability to develop solutions indigenously and to give the SAF a clear technological edge. To do that, we need to build a strong local defence industry that can grow alongside the SAF as well as collaborate effectively with research and development partners worldwide to maximise the use of Singapore's limited resources. ST Engineering has been a reliable and trusted partner of the SAF from the start.
>
> **Quek Gim Pew**
> *ST Engineering Director since 2016, and Chief Defence Scientist of MINDEF*

Fong Saik Hay
Chief Technology Officer, ST Engineering

TURNING THE WHEELS OF INNOVATION



The ability to leverage technologies, create intellectual property and encourage innovation differentiates ST Engineering as a game changer. The Technology, Intellectual Property and Innovation (TII) Committee is a key component in ST Engineering's Business Excellence Council. It is chaired by the CTO with representatives from the four business sectors. TII's role is to ensure the Group stays at the forefront of technology and maintains its strong competitive edge in its strategic capabilities. It does this by fostering an innovative culture, applying emerging technologies to solutions that are valuable to the customers, and establishing robust frameworks to drive the development of products, processes, services and capabilities, as well as eco-friendly technologies.

MOVING IDEAS TO INNOVATIONS

UPPING THE COOL FACTOR

The Airbitat Smart Cooler is an eco-friendly invention designed to reduce ambient temperatures within five to 10 metres of reach. It produces no heat and is 80% more energy efficient than conventional air conditioners. At designated "cool zones" in the Singapore Zoo where the outdoor system was trialled, visitors have been enjoying outdoor temperatures as low as 24°C, all thanks to this Innosparks development.

> "As engineers, we are always looking for better ways to solve problems. Urban heat is pervasive in Singapore, so instead of fighting against nature, we took inspiration from nature's way of cooling and found a way to supercharge it. The fact that our first prototype looks completely different from the final product is proof of an extremely iterative engineering journey. Despite the many challenges, it is immensely rewarding to see children, families and tourists enjoying the cool air produced by the fruit of our labour.
>
> **Dr Li Fuyun**
> *Head of Engineering, Innosparks*

RE-DEFINING PROTECTIVE MASK TECHNOLOGY

The AIR+ Smart Mask is N95 certified, and designed to fit a wide range of face profiles, including children. It also features the world's first attachable micro ventilator to effectively extract heat, moisture and carbon dioxide from the mask for improved breathing comfort. The idea for a smart mask for children was conceived after the harsh 2013 Southeast Asian haze, during which school activities had to be halted. To come up with a snug-fitting mask that was suitable for prolonged use, engineers at Innosparks worked relentlessly to perfect the design.

"We had absolutely no background on protective respiratory products. All we had was the drive to create an effective product that can protect our society and loved ones from the haze. The face sizes of over 800 children were measured, while the design of the micro ventilator would go back to the drawing board over 200 times before the mask was ready to hit the market. With each failure, we learned to be more agile in rebuilding our concepts and approaches to solve the problem. To have been a part of such a meaningful project was truly a privilege," said Mr Jerome Lee, Head of Engineering, Innosparks.

> "At Innosparks, we are wired for innovation – we're big dreamers and we embrace failure. In fact, failing is a big driver in pushing us past conventional boundaries, and to develop truly differentiated products that can touch lives. Our AIR+ Smart Mask and the Airbitat Smart Cooler came about in response to real needs in Singapore. Having almost no experience in these industries was not a weakness but our biggest advantage as we can bring fresh thinking and radical perspectives to these engineering challenges.
>
> **Gareth Tang**
> *Head- Open Lab, GM Innosparks*

LaunchPad @ one-north, Singapore where the ST Engineering Open Lab is located.

RAINMAKERS OF CHANGE

ST Engineering's success as a global technology, defence and engineering group depends very much on the quality of its innovations as well as its speed to market. The CTO Team, coupled with ST Dynamics, the Group's Advanced Engineering Centre, and the engineering development centres of the four business sectors, are the Group's innovation engines. Together, they are responsible for driving the next lap of R&D growth in areas such as unmanned technologies and artificial intelligence.

Besides developing concepts and enablers for existing businesses, incubating potentially disruptive technologies and exploring high-payoff dual-use technologies for new markets, the CTO Office works in close consultation with the business sectors to shepherd the process of ideation to commercialisation. The R&D for material science, for example, is championed by ST Kinetics. The outcomes, however, can be applied across sectors.

To extend its outreach for new technologies and capabilities and to productise the outcomes, the Group has set up an Open Innovation Laboratory at one-north. The concept of open innovation is supplemented with technology scouting and acquisition offices in Singapore and overseas. Separately, the ST Engineering-NTU Corporate Lab is looking into new platforms such as robotics and autonomous systems.

The Group's Corporate Technology Venture Fund will create additional capacity for enhancing the innovation pipeline. This is a US$150 million evergreen fund providing the means for seizing new opportunities and engaging in business and technology collaboration. In addition, an annual licensing and innovation budget is set aside for financing proofs of concept for new technologies to create win-win outcomes for ST Engineering and start-ups.

Other R&D ventures include the Centre for Smart Systems with the Singapore University of Technology and Design (SUTD) to facilitate collaborations in smart systems technology and design; the ST Electronics-SUTD Cyber Security Laboratory that aims to advance cyber security technologies; and the Singapore Autonomous Vehicles (AV) Consortium, which fosters partnerships between industry and institutes of higher learning on the development of AV technologies and standards in Singapore.

An R&D Dashboard enables the CTO office to align and prioritise each R&D effort, so that ST Engineering can keep track of development initiatives being undertaken across the Group.

PLANT 7: REVISITED

"I remember attending an exhibition organised by the British Far East Forces Vehicle Maintenance at Plant 7 at Portsdown Road as a teenager. It was a big showcase of British industrial products and the display was proudly called the MICOT – Most Ingenious Creation of Technology. It made quite an impression on me. I left Plant 7 that day with a burning desire to be an engineer to create new products for Singapore that we could call our own.

I joined CIS in the early 1980s, and a few years later, started the Vehicle Technology Group to develop indigenous armoured vehicles. By then, Plant 7 had come under Singapore Automotive Engineering. When ST Engineering sold the Warthog to the British Armed Forces in 2009, I had become the Group CTO and it was with a certain satisfaction that I attended the unveiling of the Warthog at Plant 7.

Fong Saik Hay
Chief Technology Officer, ST Engineering

General Ian Simpson of Britain's Ministry of Defence reviewing Warthog production at 5 Portsdown Road which was until 1971, the British Far East Land Forces Army Workshop.

(Plant 7 was torn down in 2011 when ST Kinetics consolidated its operations at 249 Jalan Boon Lay.)

ENABLING AUTONOMY

Flying Unmanned

The opportunity for ST Aerospace to develop UAVs came about in the mid-2000s when SAF indicated a requirement for a man-portable system to equip soldiers for independent reconnaissance missions. The Skyblade III mini-UAV was a result of the drive to develop an indigenous capability for unmanned aircraft.

Preceded by two prototypes, the Skyblade I and II, the Skyblade III was jointly developed with the DSO National Laboratories (DSO). The innovation garnered a Defence Technology Prize in 2009, before the first production Skyblade III system was delivered in 2010.

Besides the aeromechanical aspects of the UAV, it was the knowledge and experience of ST Aerospace's engineers who had worked on mission computers for past Republic of Singapore Air Force's (RSAF's) aircraft upgrades that contributed significantly towards the development of the flight control computer for the Skyblade III.

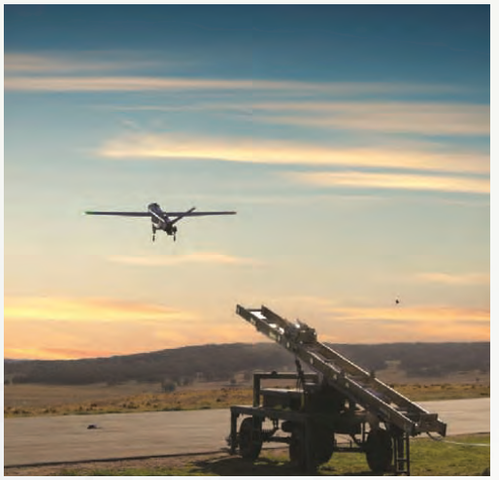
With the experience built up, ST Aerospace went on to develop the Skyblade IV together with DSO. Their innovative and creative spirit also led them to develop their very own Unmanned Hybrid Vehicle (UHV) that is able to fly and swim.

"The market for UAVs will grow, not only in volume but also in the types of applications. This new business area has enabled our engineers to learn and experience the exciting process of creating UAV systems. The innovations have led to new features such as video exploitation that have greatly enhanced our solutions and made our system unique," explained Ms Milly Tay, Senior Vice President of ST Aerospace's Engineering & Development Centre (EDC).

"The most fulfilling part about my job is the ability to see through the design process from conceptualisation to building, testing and delivery. The short design cycle brings about unique challenges, as I often have to solve problems quickly and spontaneously. But nothing beats the gratification I've gained from witnessing the success of hard work and persistence," added Ms Ang Hui Shan, System Engineer, Advanced Systems Department, EDC.

The capabilities built up have also enabled ST Aerospace to develop unmanned aircraft systems for the commercial market. The Urban-Surveillance & Tracking Autonomous Rotorcraft (USTAR), for example, started in 2011 as a self-initiated, self-funded project by three ST Aerospace engineers, Mr Lim Weng Rong, Mr Randy Leong and Mr Lin Zhi Kang, fuelled entirely by their belief, passion and spare time.

According to Weng Rong, Principal Engineer, Advance System Department, EDC, "The initial phase was challenging but memorable, with numerous weekends spent in each other's homes to build and programme our first multi-rotor from scratch. Our first flight test revealed numerous issues, but we persevered and finally had a functional prototype. When it was time to present the prototype to management, the team was quietly confident that there would be a buy-in. As it turned out, management was fully supportive and released the funding for us to further develop the USTAR."



Maiden flight of Skyblade IV in 2009

"The high point came when we debuted the system during the Singapore Airshow 2014. Since then, USTAR has continued to grow and develop in terms of capability. It was also used as the test bed platform for numerous technologies and projects," added Weng Rong proudly.

Leading Singapore's Budding Robotics Industry

The ST Engineering-NTU Corporate Lab is a joint research lab set up to develop advanced robotics and autonomous systems that will improve airport operations and disaster rescue efforts. The lab aims to find new innovations in airport precision and airside technology, such as baggage transfer systems, aerobridges and aircraft tow trucks, and in enhancing intelligence support for crisis management.

ST Engineering started working with Nanyang Technological University (NTU) on unmanned technology in 1999 when Dr Richard Kwok, then Head of Technology at ST Automotive, set up the joint Advanced Intelligent Mechatronics (AIM) Laboratory with NTU. Its first project was to convert the M113 into an unmanned platform. The Group's collaboration with NTU continued through Intellisys in 2004, and the ST Engineering-NTU Corporate Lab (Robotics Corp Lab) in 2015.

Mr Tan Pheng Hock, former President and CEO of ST Engineering, had said during the launch of the Robotics Corp Lab that its vision is to develop the next generation of robotics and autonomous systems that could be applied to areas such as healthcare, urban development, transportation, environmental conservation as well as defence and homeland security solutions.

"By leveraging the multi-disciplinary faculties of NTU and the engineering capabilities of ST Engineering, the Robotics Corp Lab aims to develop collaborative and autonomous unmanned systems capable of operating seamlessly and safely in complex environments," said Mr Paul Tan, Co-Director of the Robotics Corp Lab and Vice President of Technology Development at ST Dynamics.

The Airport Precision Air-side Robotics Technology (APART) and Crisis Response Intelligence Support Programme (CRISP) are two initiatives birthed at the Robotics Corp Lab. APART focuses on enhanced productivity, safety and passenger transit experience at Singapore Changi Airport, while CRISP explores the potential of unmanned systems for data gathering, improved situational awareness and search for survivors in the aftermath of an emergency.

Such initiatives add value to the collaborative robotics algorithms being developed at ST Dynamics to coordinate real-time search and rescue operations by unmanned aerial and ground vehicles. They also augment ST Electronics' efforts in developing algorithms for the quick detection and location of casualties or floating objects in the sea by unmanned surface vehicles.

Paul added, "What we are doing at the Robotics Corp Lab is very exciting and will contribute towards solving the labour crunch in stretched economies, saving lives in a disaster and automating the mundane and risky tasks – all for a better tomorrow!"

ENABLING AUTONOMY

Look Ma, No Driver!

ST Kinetics partnered Easymile to launch Auto Rider in 2015 at Gardens by the Bay, becoming Asia's first fully operational autonomous vehicle.

It used to be the materials of science fiction and horror stories for a car to move on its own. Today, AVs are not only a reality; they are changing the future of transport.

AVs have great potential for a wide range of real-world applications. Put the sensors and command and control systems into larger vehicles to automate a fleet of buses for public transport. Incorporate the same into terminal port movers, forklifts or container trucks, and the productivity of logistics and supply chains can be enhanced. Unmanned technologies can also be used in patrol vehicles to support border security, inner city security operations and emergency response.

"Not many know that in 2000, well before AVs were popularised by Google and Uber, ST Kinetics had already invested in tele-operation, autonomous navigation and fleet management – the basic ingredients for unmanned solutions," said Mr Tan Nai Kwan, ST Kinetics' Chief Robotics Engineer. "Besides experimenting on unmanned military platforms, we had worked on robots with different payloads such as chemical, biological, radiological and explosives detection and disposal."

The Auto Rider can accommodate 10 people and is wheelchair-accessible.

The turning point came in 2004 when Cornell University approached VT Systems to obtain a vehicle for the DARPA Grand Challenge. ST Kinetics sponsored a Spider Light Strike Vehicle that was converted into an unmanned vehicle. The collaboration provided the golden opportunity needed for ST Kinetics to develop its AV capabilities. It paved the way for the Cornell-ST Engineering team to participate in the DARPA Urban Challenge in 2007, coming in among the top six.

"We're always seeking opportunities to test our ideas and solutions. In 2009, we invested further, on top of a government funding, to enhance our robotics expertise by establishing a centre of excellence for autonomous capability," recalled Nai Kwan. "The Security Patroller for protection of key installations and the Port Automated Guided Vehicle for port automation, as well as several highly manoeuvrable and ruggedised robots for specialised missions, were among the solutions we developed."

By 2015, ST Kinetics has accumulated sufficient knowledge and capability to participate in an AV test-bed in Singapore's one-north. A sports utility vehicle was converted into an AV called the TERRAV and put on road trial. Later that year, two Auto Riders, ST Kinetics' autonomous solution for urban city mobility, went on a two-week trial at Gardens by the Bay. In 2016, the Auto Riders were officially deployed at Gardens by the Bay, making them the first AV to enter into operations in Singapore.

ST Kinetics has since announced several initiatives to support Singapore's Smart Mobility 2030 vision. It launched the Singapore Autonomous Vehicles Consortium together with A*STAR's Institute for Infocomm Research and several institutes of higher learning to establish AV standards for real-world applications and develop niche technologies such as automotive cyber security and platform-agnostic AV kits.

It also partnered with Singapore's Land Transport Authority (LTA) to develop and trial autonomous 40-seater electric buses at various sites, with the goal to ply selected routes by 2020.

ST Kinetics aims to develop safe and reliable autonomous solutions and robotics management systems for land-based vehicles. This could prove to be the game-changer that would provide ST Kinetics with a new engine of growth.

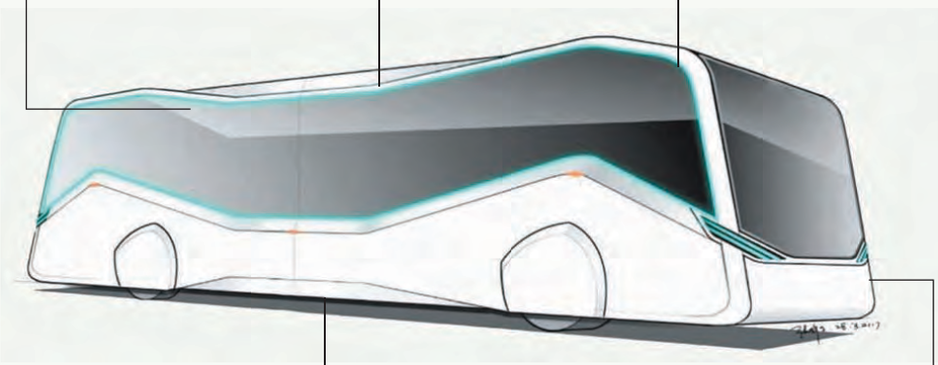
RIDE INTO THE FUTURE

An artist's impression of the autonomous electric buses co-developed by ST Kinetics and LTA: these vehicles can travel at speeds of 60 km/h for up to 50 km.

Connectivity
Communicates with Command & Control Centre, other AVs and road infrastructures through vehicle-to-everything devices.

Precise Positioning
Uses satellite-based differential GPS system and in-vehicle sensors for global localisation in any environment.

Perception Sensors
Perceives the environment for obstacle detection and avoidance through 2D & 3D perception maps.



Lightweight Chassis Powered by Electricity
Consumes less energy though full aluminium body and chassis with low maintenance and long lifespan.

Pedestrian and Vehicle Detection
Scans the area within a distance of 10m in front of the vehicle before moving off through radars and sonars placed around the vehicle. Long-range radars detect vehicles up to 200m ahead.

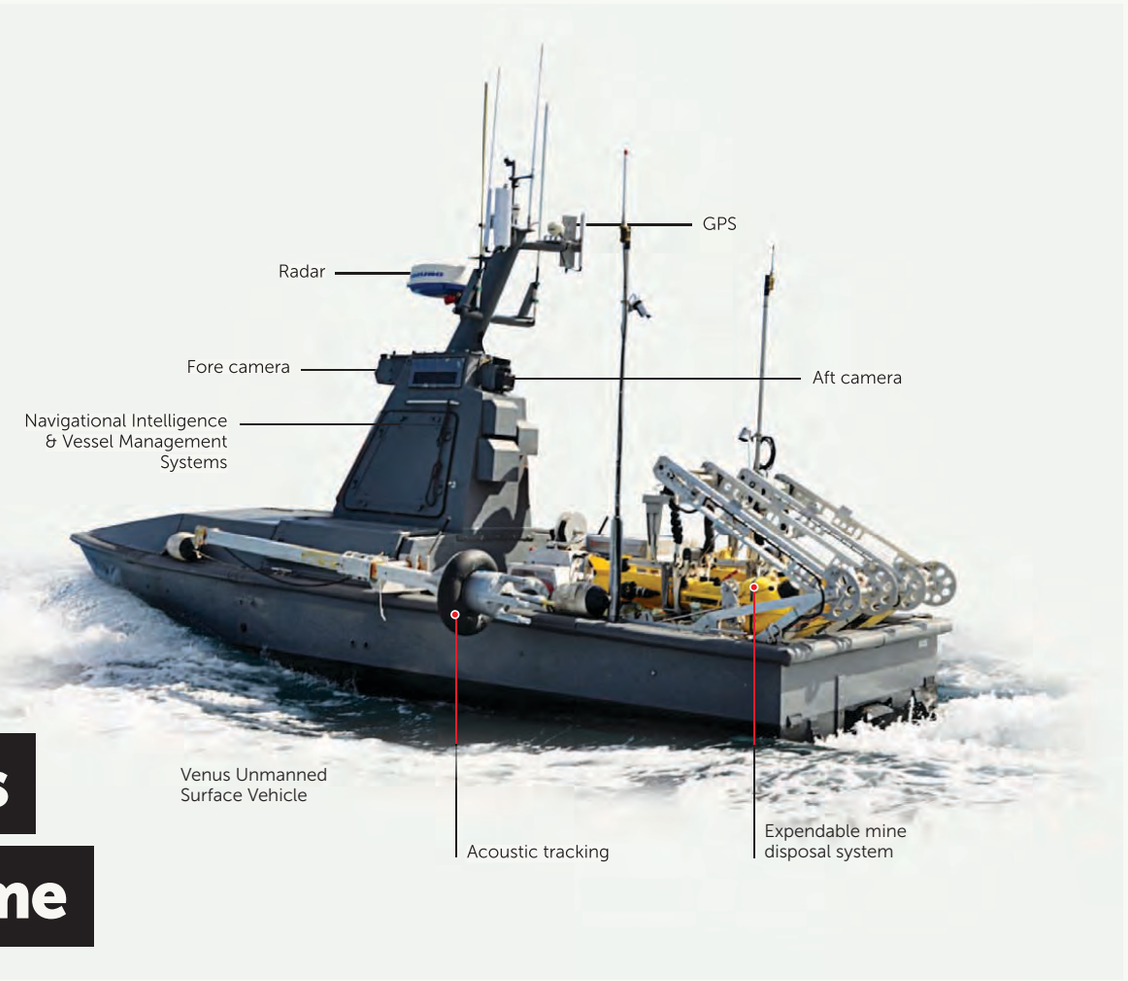
Detects obstacles and supplements perception maps with environmental analysis and classification (such as road signs, traffic lights) using a suite of cameras.

MOBILITY ON DEMAND

Four driverless pods will be plying Sentosa as part of a trial jointly conducted by the Singapore Ministry of Transport, Sentosa Development Corporation and ST Kinetics. Sentosa visitors can expect to hail these vehicles through their smartphones or information kiosks located across the island as early as 2019. It features a platform-agnostic fleet management system, developed by ST Kinetics, which optimises route management based on passenger demand. With the incorporation of deep learning algorithms, the pods are designed to emulate the behaviour of an expert human driver.

An artist's impression of the driverless vehicle at Sentosa.

> "The autonomous mobility-on-demand trial in Sentosa and the autonomous bus trial with ST Kinetics are further major steps in our plan to leverage the technology to improve urban mobility in Singapore. We will progressively launch more trials, including in other parts of Singapore, with the aim of eventually deploying such mobility concepts as part and parcel of our transport system. I am also pleased to see the formation of the Singapore Autonomous Vehicles Consortium. It will be another significant piece of the eco-system which we are building to grow the AV industry in Singapore.
>
> **Pang Kin Keong**
> *Permanent Secretary for Transport and Chairman of the Committee on Autonomous Road Transport*



Venus is Her Name

The Venus Unmanned Surface Vehicle (USV) is an autonomous seafaring craft that was designed and developed by ST Electronics. It was launched at the Singapore Airshow 2010 to international acclaim. The modular design facilitates different mission payloads for operations ranging from mine countermeasure and anti-submarine warfare to force protection, coastal patrol and maritime security. Built-in navigation Artificial Intelligence (AI) and radar enable the USV to detect obstacles and avoid collision, while its night vision capability allows it to operate continuously round-the-clock.

According to Mr Andrew Yue, Director of USV Intelligence and Autonomous Operations, the navigation AI has been rigorously tested in congested waters and over-the-horizon. Besides navigation AI, the USV team has also developed mission AI for the automatic launch and recovery of a drone at sea. "We're continually enhancing the navigation AI and communication infrastructure to deepen the perception and autonomous capabilities of Venus. The ultimate goal is to allow Venus to tunnel safely through the anchorages in Singapore's crowded waters," said Andrew.

"The Singapore Ministry of Defence (MINDEF) has been investing in USV development since 2007 as it is important for the Republic of Singapore Navy (RSN) to have unmanned capability for various missions," said Mr George Loh, former Director of Maritime System at Future Systems and Technology Directorate, MINDEF. "ST Electronics' strong commitment to invest in USV capabilities has been a critical success factor for this programme."

LTC Thomas Ong, Head of Unmanned and Robotics System Branch, RSN's Naval Warfare Centre, noted in particular the professionalism and passion of ST Electronics' USV team, and said, "It is truly inspiring to work with a team that shares the same vision to develop deep mission capabilities for the RSN."

The Sun, The Sand and The Sea

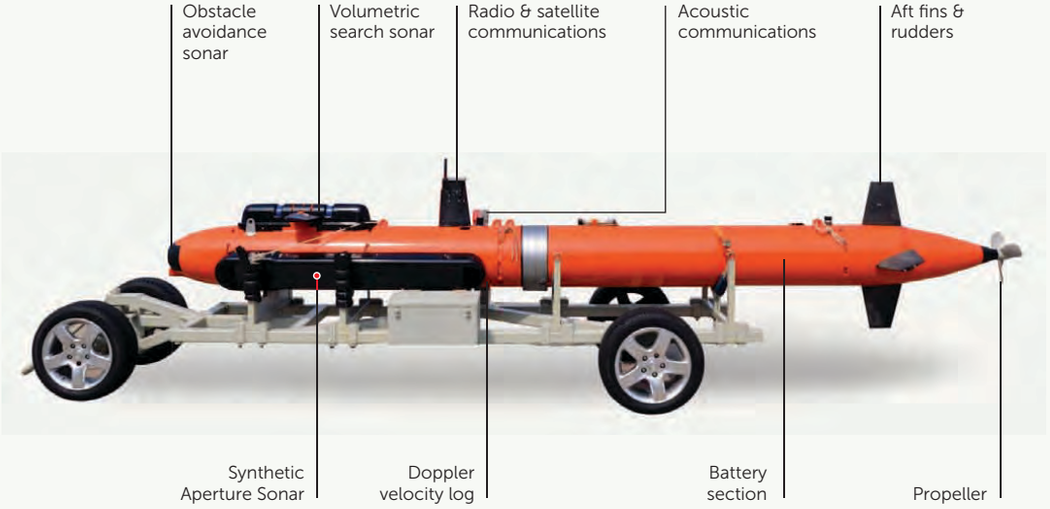
Engineers readying the Mercury AUV for sea trials in Singapore.

That was how Mr Tan Chee Yong, Division Manager who oversaw the Mercury Autonomous Underwater Vehicle (AUV) programme at ST Electronics, sold the job to potential engineering candidates in 2010, as the engineers would typically spend weeks out in the open sea, conducting field trials as part of the process to develop operational AUVs.

"The AUV is essentially a 'miniature submarine' capable of performing underwater operations autonomously. The underwater environment is extremely challenging for AUV operations," said Mr Lin Ming Liang, a guidance and control engineer. "Control of the AUV is a multi-disciplinary field which requires knowledge in the areas of dynamics, kinematics, hydrostatics and hydrodynamics. Fusing these information together and ensuring the AUV's stability underwater is a feat that requires vast amount of perseverance and dedication by the entire team."

The team has progressed from developing an AUV prototype to producing operational AUVs with capabilities such as mine countermeasures. Chee Yong felt that the team's success is a testament of their passion, hard work and teamwork. "We have to work as a team to resolve challenges and built up trust in one another," he said.

Mr Brien Lim, the team's deployment expert, agreed, "Deploying the AUV is demanding work. We are constantly at the mercy of the sea and weather. The team has come a long way from knowing next to nothing on AUVs to building our expertise and market presence in AUVs. Our goal is to develop AUVs that are 'a joy to operate and a joy to maintain'."



Mercury Autonomous Unmanned Vehicle

ADVANCING INNOVATIONS

Technologies on the Horizon

A SEA CHANGE IN SHIPBUILDING

"The marine industry, along with customer expectations in terms of vessel performance and product research and development, has changed significantly. With naval platforms, the requirement for operations and technology integration has produced faster and smarter ships.

A good example is the Integrated Bridge Platform Management System found on the Littoral Mission Vessel. While enabling leaner manning through automation, it provides data analytics for better situational awareness, accelerates decision-making and enhances logistics and engineering support.

There is also a growing demand for multi-mission platforms with modular payloads. Our aim is to equip naval and commercial customers with plug-and-play capability for mission modules depending on the circumstance and purpose. This could be a medical container or an unmanned fire fighting vessel.

As autonomy becomes an industry game changer, we want to deepen capabilities in long-endurance unmanned systems, robotics and related technologies. We are also looking into energy-saving innovations such as hybrid propulsion, direct current power system and liquefied natural gas propulsion system to reduce operating costs while moving towards greener fleets.

Collaboration will remain a key enabler for ST Marine. We have been and will continue to work with local and overseas institutes of higher learning, research centres, design consultants, ship owners, equipment suppliers and even shipyards on research and ideas for product development and enhancement.

Tan Ching Eng
Chief Technology Officer, ST Marine

Patrol Vessels (PV) play a critical role in protecting a nation's territorial waters. These vessels are highly versatile workhorses that can quickly switch roles between surveillance, support, enforcement, and search and rescue (SAR).

In 2012, ST Marine was awarded a turnkey contract to produce four 75-metre PVs for the Royal Navy of Oman (RNO). After some years of project planning, design and execution, these Al-Ofouq-class of PVs (also known as Fearless 75-OM) are plying the Gulf of Oman today to safeguard the Exclusive Economic Zone and carry out deterrent operations against unlawful activities like piracy, drug trafficking and illegal immigration in Omani waters. They would also assist distressed vessels, undertake SAR operations in rough weather conditions, and support fire-fighting and damage control operations.

"The Al-Ofouq-class PVs is a testament to ST Marine's capabilities and innovativeness in component design, system integration and through-life support," said Ching Eng. "A lot of technologies had gone into these vessels, which we had to integrate using innovative models so that they could operate seamlessly together."

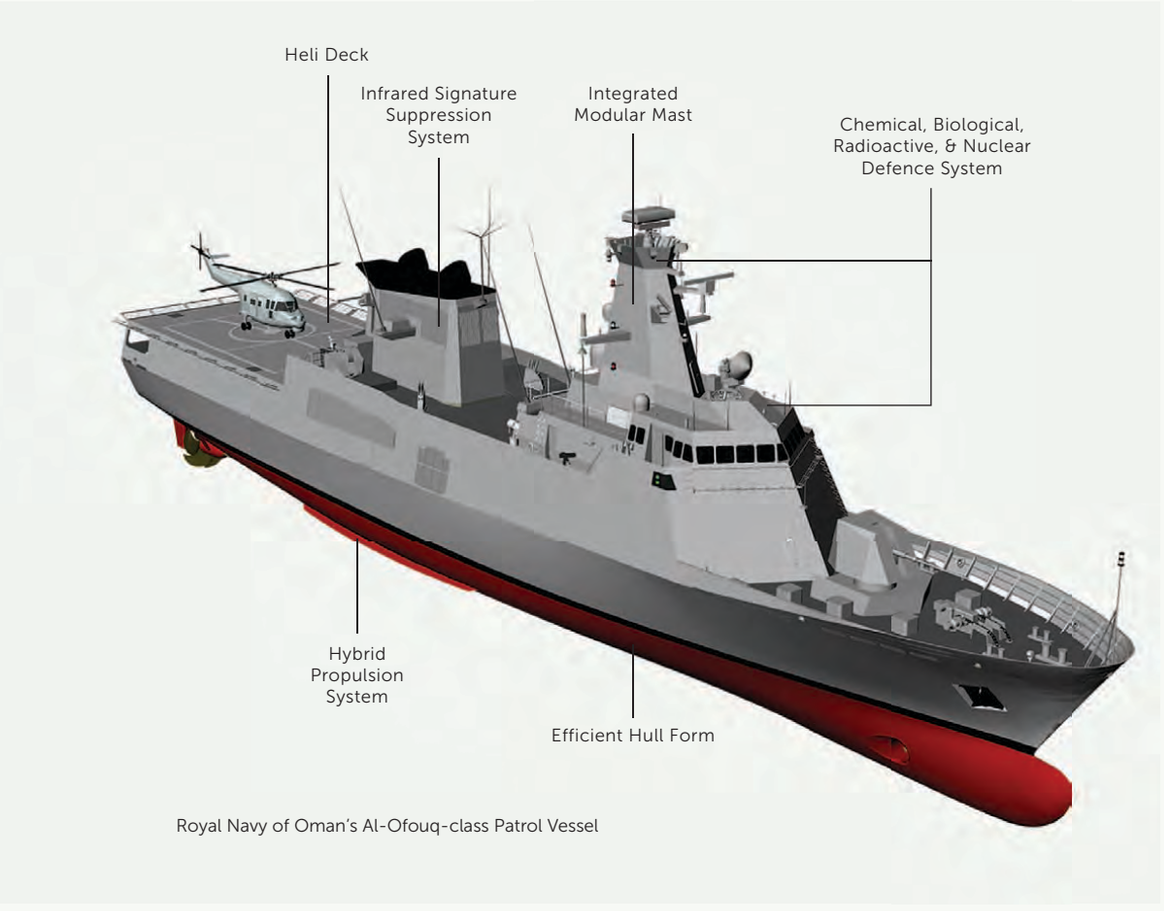
An important innovation is the hull design, which enabled the PVs to achieve optimal fuel efficiency at both top as well as cruising speed. Besides an efficient hull form and rudder design the hull had features such as the bulbous bow, build-in stern wedge and ducktail and partial tunnels for larger and more efficient propellers. These hydrodynamic improvements are verified by the use of Computational Fluid Dynamics (CFD) analysis, ship model tests and propeller cavitation tests before the start of the construction.

Another key innovation was the integrated modular mast that housed the communication antennas, navigation, surveillance sensors and electronic cabinets. The mast was shaped and streamlined to optimise air flow and minimise radar signature.

Mr Alex Ting, a Principal Engineer on the PV team, recalled the challenge of the iterative design process, "In order to design the mast to minimise electronic interference from the suite of electronic modules, and still keep to a small radar footprint, we conducted numerous detailed studies and simulations to optimise the sensors and antennas arrangement and mast design. It took us several months of hard work before we finally arrived at the ideal layout and design."

Besides design and construction, ST Marine made use of its knowledge in System Life-cycle Management to provide RNO the full spectrum of Integrated Logistics Support (ILS) for the vessel. This covered the maintenance plan, spares provisioning, maintenance training, and product lifecycle cost projection. A computerised maintenance management system was also incorporated onboard the PVs to support the implementation of the ILS maintenance plan.

"Our team had to be overseas frequently to conduct model tests and modify the design to achieve the best performance for the PVs. It was especially tough for many of us to be away from our families for long stretches of time," Ms Daisy Dong, Assistant Director of ST Marine's Hull Department, recounted. "We were elated when the model test results validated the simulation studies, and the actual ship performance came close to our calculations. It made all our efforts and sacrifices worthwhile!"



Royal Navy of Oman's Al-Ofouq-class Patrol Vessel

ADVANCING TOWARDS NEW FRONTIERS

With rapid technology changes, industries have become more borderless. Competition has intensified, with customers demanding for better, faster, cheaper and smarter solutions. As a next-generation land systems solutions provider, we would have to be more disruptive with our ideas, and to come up with products and services with unique value propositions.

To manage change, we need to adapt swiftly based on a culture that promotes and embraces innovation. To strengthen our networks, we have set up research laboratories in collaboration with institutes of higher learning. We need to build up our knowledge and capacity for engineering and research, and develop good business acumen. We must do more to protect our intellectual property and knowhow.

The world is undergoing massive changes towards a new economy amidst unprecedented security concerns. Growing populations and rising urbanisation will create stronger demand for smart city technologies, smart transportation and homeland security solutions. To stay ahead, our innovations must contribute to society. Our people must be more reflective and embrace a multi-disciplinary approach to problem solving instead of doing more of the same.

Dr Richard Kwok
Chief Technology Officer, ST Kinetics

From Dream to Reality

Fong Saik Hay (far right) showcasing the XV1 to (from left) LG Winston Choo, LTC Lee Hsien Yang and COL Teo Chee Hean in 1990.

The Bionix (BX) is a medium-weight tracked vehicle designed and built to operate hand-in-hand with the Singapore Armed Forces' (SAF) fleet of M113 Armoured Personnel Carriers and AMX-13 SM1 Tanks. As described by then Singapore Deputy Prime Minister and Minister for Defence, Dr Tony Tan, developing an armoured Infantry Fighting Vehicle (IFV) almost from scratch is no mean achievement. Twenty years into service with the Singapore Armoured Regiment, the BX has remained at the epitome of ST Engineering's triumphs.

The tripartite team behind its development – the SAF, Defence Material Organisation and ST Automotive – were honoured by MINDEF with a Defence Technology Prize in 1997 for their significant contributions to the defence capability of Singapore.

Mr Fong Saik Hay, CTO of ST Engineering and leader of the BX design team, remembers the birth of Singapore's and Southeast Asia's first indigenous armoured vehicle.

It all started in 1987, when CIS, the then parent company of Singapore Automotive Engineering (SAE), the precursor of ST Automotive, formed a Vehicle Technology Group to build up capabilities in vehicle upgrade and design. Our first proposal was that of a Tank Demonstrator Experimenter using the AMX-13 platform. SAE was looking to do likewise and a year later, we moved to its Portsdown facilities to combine our resources. At about the same time, the SAF started thinking about a fleet of new armoured vehicles for its growth and asked for a demonstration of what SAE could come up with.

We cobbled together a demonstrator in less than four months using AMX-13 and M113 parts. It had a simulated turret and body made from mild steel and we called it 'Armoured Vehicle 1' or AV1 for short. We invited the customer to review the AV1 at our Portsdown facility. Thankfully, this took place without a hitch.

To convince the SAF to go for an indigenous design as opposed to modifying a licensed basic unit from an established manufacturer, I wrote a white paper to explain the rationale and link the operational requirements with the technical specifications. I supported local production because to build true capabilities, we needed to learn how to develop our own platform. The risks were higher, but deep in my heart, I wanted it to be Singapore's own.

Meanwhile, the SAF did its own studies and concluded that no vehicle in the market was able to satisfy its requirements adequately, and that indigenous development would also serve to build up the capability of the local defence industries. With the success of AV1, the SAF contracted ST Automotive to develop two experimental vehicles named XV1 and XV2 between 1990 and 1992.


Experimental vehicle XV-1

From Dream to Reality

We tested XV1 in the middle of the night – it was all very secretive. Some of the outcomes were disastrous – wheels and rollers fell off during the first road test and the swimming trial did not go as planned. We were naturally disappointed with these initial failures but they taught us a lot about designing a better vehicle.

We persevered, improved the experimental vehicles and convinced the customer to develop three vehicle test beds that were rolled out successfully in 1993. This led to the development of three final prototypes and one pre-production model, which were comprehensively tested between 1995 and 1997. The BX was officially commissioned in 1997 and operationalised in 1999.

The BX marked ST Automotive's big leap from 'systems integrator' to 'indigenous designer'. Besides hard capabilities like hull and turret design and protection science, others like human factors engineering and simulation and modelling were built up. For the first time, we incorporated a system engineering process, and used a computer-aided system to design and control the manufacturing processes. We also installed the latest state-of-the-art plate-cutting machines and the largest twin-column computer numerical control machining and robotic-welding centres in the region, as a result of the BX programme.

Through this journey, we built up engineering talent like Dr Richard Kwok, who took charge of the BX's turret and advance systems and became the CTO of ST Kinetics; Mr Loh Heng Fong who led the running gear and chassis development and went on to be Chief Engineer for Tracked Vehicles; and Mr Mah Chi Jui, who oversaw the crew compartment and later, the development of the Bronco All Terrain Tracked Carrier.


The BX team involved from design to production.

EVERYTHING MUST TRY!

"We've never built an armoured vehicle before the BX, and thus, our philosophy to technology was to try everything. My team's first focus was to develop the powerpack comprising the engine and transmission, as well as the tracks and suspension system. They were the 'heart' and 'legs' of the vehicle. We studied the terrain on field trips to make sure our 'leg' design could do the job well.

The design considerations weren't just mechanical in nature; human factors engineering also came into play. Few would know, for instance, that the top deck of the BX has a 1.7-degree slope to accommodate taller soldiers in the vehicle. In doing so, it provided a better depression angle for the turret.

As Chief Engineer of the BX programme, I spared no effort in making sure that chances of vehicle overturns or on-board fires were mitigated or eliminated. Through the BX family, we built up a wealth of capabilities for subsequent vehicle development projects.

When the Next Generation Armoured Fighting Vehicle (NGAFV) came about, the focus has shifted from the 'heart' and 'legs' to the 'brain' – the vehicle electronics that monitor vehicle performance and the decision-making systems that fuse information from the vehicle's sensors and other external inputs to enable greater situational awareness.

In my 35 years with the Group, the most enjoyable days were spent developing the BX. We had fantastic support from leaders like Ms Ho Ching, Mr Lye Fei and Mr Fong Saik Hay. We had an 'mm-zai-see' (fearless) attitude to demonstrate that Singapore can build a world-class IFV."

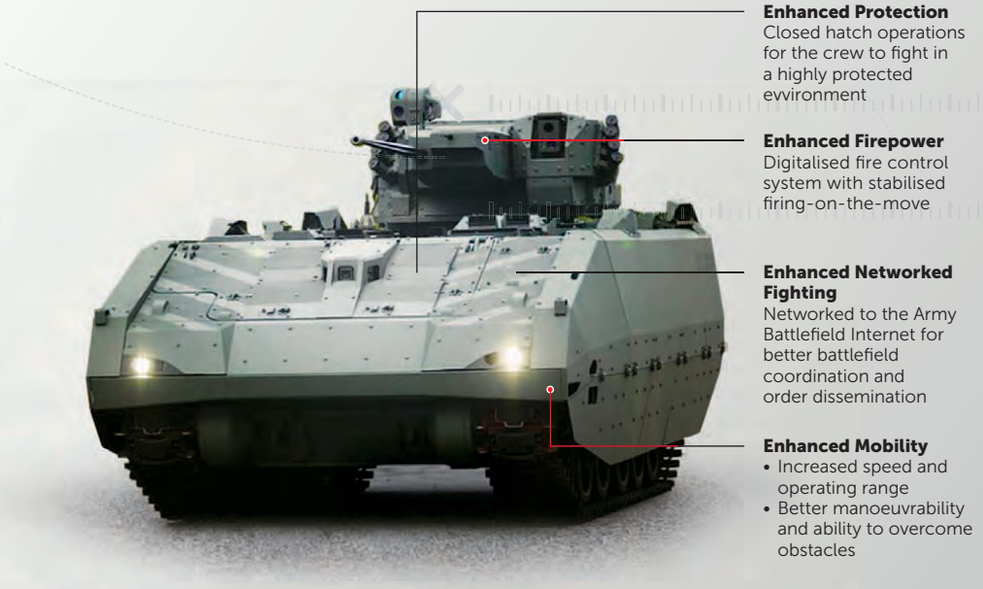
Loh Heng Fong
Chief Engineer, BX Programme
Former Vice President / Head, Tracked Mobility Centre, ST Kinetics

From BX to NGAFV

The SAF's Next-Generation Armoured Fighting Vehicle (NGAFV) will provide its armoured forces with enhanced firepower, protection, mobility and situational awareness.

"The NGAFV is a digitised platform that will provide superior situational awareness for the SAF to fight more effectively in a network-centric environment. It has enhanced firepower, protection and mobility to give our armoured forces the decisive edge in achieving mission success."

Major-General Melvyn Ong
Chief of Army, Singapore Army



ST Kinetics' NGAFV will replace the SAF's aging M113 Ultras from 2019. According to Mr Ong Kian Beng, Senior Principal Engineer, ST Kinetics, who was involved in both the BX and NGAFV programmes, the digitisation of the NGAFV makes it a far more capable vehicle compared to the BX. "The performance and reliability trials for the NGAFV were also more intense and complex," he added.

Mr Dave Eng, the Vetronics Lead for the NGAFV programme explained, "To enable the advanced capabilities, we innovated a strong digital backbone which we named the Land Vehicle Architecture. It marries all the digital systems on board with a highly intuitive interface catered to the next generation of digital native users."

Dr Lee Shiang Long, President of ST Kinetics, said, "The NGAFV supports the 'system of systems' concept of warfighting and therefore, it requires the platform and electronics teams to work seamlessly together to deliver a highly integrated solution. It is a remarkable testament to ST Engineering prowess as an integrated group – and for ST Kinetics, it is the culmination of years of hard work in developing armoured fighting platforms."

Equipping Soldiers of the Future

After more than a decade of experimentation by the SAF with ST Electronics, the first Advanced Combat Man System (ACMS) equipping programme was launched in 2009. The ACMS is a networked urban fighting system that leverages technology to enhance the combat effectiveness and safety of soldiers. It provides soldiers with greater command, control, communications and computers (C4) connectivity, situational awareness, survivability and combat capability on the battlefield, with the additional ability to integrate surveillance robots and around-the-corner sensors.

In 2013, ST Electronics introduced ACMS iLITE, a lighter version of the original ACMS with modified smartphones and broadband communications, making it intuitive to use. Designed by Mr Ang Chin Leng, System Architect, ST Electronics (Info-Comm Systems), the ACMS iLITE could also be integrated with training systems to enable realistic training.

Mr Goh Ming Sung, ST Engineering's Director of Soldier Systems Centre, explained that the next generation soldier systems would continue to evolve as a network-centric system capable of supporting new fighting scenarios. "The system would be integrated with increasingly secure and better connectivity, and ergonomically designed to suit the demands of future battlefields," said Ming Sung.

In anticipation of these opportunities, ST Kinetics has developed the next generation infantry fighting system called the Army Individual Eco-Lightweight Equipment (ARIELE). It is specifically designed to reduce performance impediments the modern soldier would commonly face on the battlefield, like physical and mental fatigue due to encumbrance, heat and stress.

"Soldiers today are already interacting with a multitude of networked devices on the battlefield. In the near future, they could be working alongside autonomous and robotic systems that would put more demand on their mental and physical capacities. We aim to develop ARIELE into a future-ready system capable of supporting new fighting scenarios to improve mission success," said Mr Benjamin Ho, ST Kinetics' Head of Soldier-Platform Integrated Systems.

Ming Sung added that both ACMS and ARIELE would complement each other. While ARIELE would lighten the weight burden for soldiers and improve their survivability and endurance during missions, ACMS would focus on C4 connectivity to provide troops with better situational awareness especially in future manned and unmanned battlefield. The ARIELE-enhanced ACMS would be a world leading soldier system for the next generation defence forces.

ARIELE SOLDIER SYSTEM

Operational Challenges

- Cognitive overload
- Heat stress
- Higher energy demand
- Weight burden

Solution

ARIELE features a full suite of advanced solutions aimed to address the challenges faced by modern day soldiers.

Enhanced Situational Awareness
- Critical information displayed through heads-up display system
- Heads up, eyes out and hands on trigger

Prolonged Mission Endurance
- Power management and energy scavenging
- Highest energy density and lightest weight
- Intuitive and safety certified for rugged use

Improved Protection and Sustainability
- Advanced material technologies for strength and weight reduction
- Superior comfort and ergonomic for local population and environment

Upgraded Performance
- Real-time vital signs monitoring
- Modality score for effective training regime
- Post-mission data analytics

Bullpup Multirole
Combat Rifle

PLATE
Body Armour

ARCTIC
Body Cooler

SHADES
Eyewear

PROTEC
Load Bearing Vest

SENSE
Soldier Performance
Monitoring System

Wireless Charging and
Energy Management System

POWER
Fuel Cell

Small yet Lethal

The history of small arms in ST Kinetics is a story of the enterprising spirit of a group of engineers who dared to be different. It started in 1968 when the newly established CIS was tasked by Dr Goh Keng Swee to supply small arms for the fledgling SAF. The following year, CIS successfully negotiated with the Colt Company to produce the AR15/M16 rifle under license for the SAF.

In 1977, concerned that the plant would run out of jobs after the M16 orders were fulfilled, Dr Goh asked CIS to develop other weapons for export sales. The task fell on Mr Henry Cheong, Director of Engineering, who formed a small arms team to take on the challenge. Coincidentally, Mr Leroy James Sullivan, who was involved in designing the M16, was seeking a partner to develop a new concept light machine gun. The CIS team decided to collaborate with him and in 1982, they produced the Ultimax 100 Light Machine Gun (U100), the world's lightest and lowest recoil light machine gun.

While the U100 was under development, the team also worked on the SAR80, Singapore's first indigenous rifle. They went on to develop the 0.5" Machine Gun in 1983, and the 40mm Automatic Grenade Launcher (40AGL) in 1985. These small arms were subsequently introduced into service by the SAF and exported to other countries.

In 1990, Henry began conceptualising a new rifle to replace the M16. The new rifle, subsequently named the Singapore Assault Rifle – 21st Century (SAR21), would be CIS' most ambitious small arms project. Mr Lai Hon Nam, Chief Design Engineer of SAR21 said, "We designed the rifle to be compact to cater to the tight spaces in urban warfare and eliminated field zeroing by adding a laser aiming device and optical scope. We were also the first to use engineered polymer and carbon composite for key parts of the rifle."

STK 40AGL Mk2 delivers accurate and intense firepower against enemy personnel and light armoured vehicles.

SAR21 was adopted by the SAF in 1999 and sold to many countries. After SAR21, the small arms team developed the 40mm Lightweight AGL in 2000 and the 9mm Compact Personal Weapon in 2005. Mr Chin Nan Sang, Senior Principal Engineer, now leads the team and they continue to introduce new upgrades like the 40AGL MK2 and U100 MK8, and new weapons like the family of 5.56 Bullpup Multirole Compact Rifles (BMCR).

Said Nan Sang, "The BMCR is a modern assault rifle designed for urban missions. Its compact and light bullpup design allows enforcers to manoeuvre around small areas and tight corners, and the forward ejection system enables ambidextrous firing. The rifle is fully integrated with advanced soldier systems such as ACMS and ARIELE to support the next generation fighting forces."

The ambidextrous BMCR, one of the world's shortest bullpup rifle is designed for integration with advanced soldier systems such as ACMS.

From Forestry to Military

Some new products are developed in earnest while others are discovered by chance. Such is the case with the hydro-mechanical infinitely variable transmissions (HMX), produced by Kinetics Drive Solutions (KDS), an ST Kinetics subsidiary. KDS started out as a forestry equipment manufacturer in Langley, Canada, and along the way, became a significant military transmission producer, with a total of 23 patents awarded for the HMX family of transmissions.

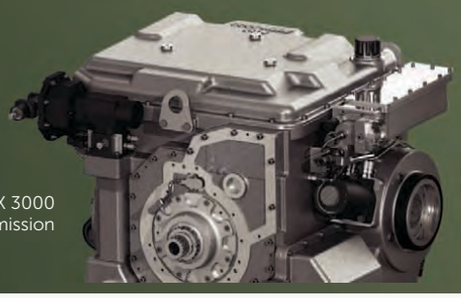
KDS's transmission technology was borne out of its long history making off-highway vehicles for the logging industry since 1989. Mah Chi Jui, ST Kinetics' Senior Vice President recalled, "We were interested in the company's capability to design hydraulic drives that could operate efficiently without overheating. After ST Kinetics invested in the company in 2000, we started KDS off with the development of a full hydrostatic drive prototype to target the M113 upgrade market."

Mr Paul Dries, Vice President Engineering of KDS remembered that during the development of the first prototype, the M113 steering response lags when driven at high speed. He said, "To rectify this problem, the hydraulic drive was modified to maintain power to both tracks during steering. This led to the successful launch of the HMX1100 in 2002."

In 2003, KDS developed another transmission, the HMX1600, for the Trailblazer that allowed the mine-clearing vehicle to creep at a constant low speed while maintaining sufficient power to spin a mine flail.

With success from these two products, KDS embarked on the development of HMX3000 for the next generation AFV in 2007. Mr Gerald Dyck, Vice President of R&D, said, "The HMX3000 made use of another KDS innovation, the compact and modular Integrated Pump Motor (IPM) to provide the hydraulic power. The IPM uses advanced digital controls to match transmission ratio and engine performance with output demands. This innovation is significant for future generation of high power density HMXs."

In 2015, Science Applications International Corporation decided to incorporate HMX3000 in its proposal for the upgrade of the US Marine Corps' Assault Amphibious Vehicles (AAV) and was subsequently awarded the project. "The US Marines wanted an AAV with a higher payload, which would require more power. HMX3000 was not only able to deliver that power, it could run the water jets and the tracks simultaneously during a beach landing operation," Paul said.



HMX 3000 transmission

Enabling Autonomous Navigation

IMU-S1 Tactical Grade Inertial Navigation Unit

ST Kinetics' SMART Systems has been in the business of integrating and maintaining guided munitions for the past 20 years. Realising the potential of Micro-Electro-Mechanical Systems (MEMS) technology for more applications as the technology had matured and its cost reduced, SMART Systems decided to move up the value chain in 2010 by first diversifying into the manufacturing of Inertial Measurement Units (IMU), and over time, to build up relevant capabilities in ruggedised embedded systems design, sensors integration and navigation algorithm development.

> "An IMU is essentially an electronic module that can compute the angular velocity and linear acceleration using a combination of gyroscopes and accelerometers. A MEMS-embedded IMU is not only robust, it is compact, and can be used in inertia navigation systems (INS) of a variety of vehicular and aerial platforms, like unmanned aerial vehicles and autonomous vehicles. SMART Systems is developing Singapore's first lightweight and cost-effective INS for ground navigation. We expect this to greatly expand market opportunities for ST Kinetics as it moves into the autonomous and unmanned space.
>
> **Tung Yui Kee**
> *General Manager of SMART Systems (2005 to 2010, 2014 to 2017)*
> *Deputy Chief Engineering Officer, ST Kinetics*

Advancing Material Science

At ST Kinetics' CTO office, engineers are exploring the use of novel materials like nano-ceramics, and advanced techniques like cold spray and spark plasma sintering to create new materials as well as to improve the properties of traditional materials. The team, led by Dr Kwok and Head of Emerging Technologies Mr Jimmy Chan, has made significant progress in several areas. One of them is developing a flame-resistant magnesium alloy that is 30% lighter and has a higher mechanical strength than aerospace aluminium, making it ideal for making aircraft seats and air cargo containers. Another area is in the use of cold spray to repair aircraft components and coat ceramic to enhance durability. By adopting a practical approach to solve real-world problems, the team has not only secured research grants and won several innovation awards, but also put ST Kinetics firmly at the forefront of advanced materials research.

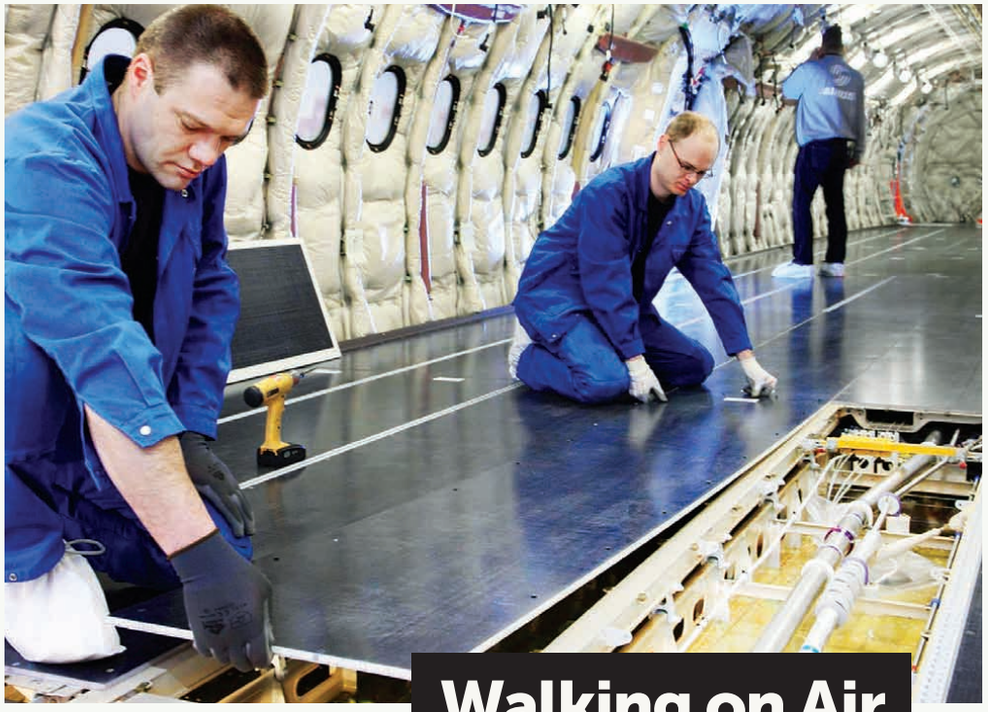
Flame-resistant magnesium alloy

STAYING RELEVANT TO MODERN AVIATION

"To stay competitive and to remain a leader in the aerospace industry, we have to continually look into providing services that add more value to our customers. As digital transformation finds its way into airline operations, we are leveraging ST Engineering's competencies in areas like data analytics and artificial intelligence, and working with airline customers to incorporate technologies and introduce services that are relevant to their needs.

A good example is 3D printing for aircraft parts to reduce the need to keep inventory and improve turnaround time. Other examples are in the use of data analytics to predict and pre-empt parts failure, the development of robots for aircraft maintenance, and process automation to improve turnaround time. We have been expanding our offerings in adjacent areas like the development of passenger seats and carbon fibre-reinforced plastics (CFRP) floor panels to move up the value chain."

Lim Tau Fuie
Chief Technology Officer, ST Aerospace



Walking on Air

Whenever you fly in an Airbus plane, you would have stepped on a floor panel made by Elbe Flugzeugwerke (EFW). EFW is an ST Aerospace-Airbus joint venture based in Dresden, Germany. Besides aircraft heavy maintenance, EFW also specialises in composite manufacturing and special lightweight panels, and is the sole supplier of floor panels for all current Airbus aircraft.

"In 2009, Airbus approached us to develop a new concept floor incorporating full CFRP that would allow flexible arrangement of cabin interior monuments," said Mr Torsten Kuehn, EFW's Chief Engineer and Head of Design Organisation. "This was one of the most ambitious civil Airbus programmes. We had to develop new techniques to manufacture the CFRP components in a vacuum-assisted process (VAP). The new CFRP floor panel design was used in the A350 aircraft family. We were able to scale the VAP for mid-sized volume production later on. It was a true testament to EFW's technical capabilities."

Said Dr Andreas Sperl, President & CEO of EFW, "We took the decision to be a risk-sharing partner of Airbus for the A350 Programme. This gives EFW the opportunity to develop its breadth of technical capabilities, which is crucial for it to expand its value chain and revenue potential beyond the aerospace industry."

The strategy worked. EFW saw an increase in demand for floor panels, and secured its first train and ship customers in 2009 and 2014 respectively. In 2016, EFW expanded its production capacity with a new factory in Kodersdorf, Germany.

Value Adding through Service Innovation

In 1996, VT Mobile Aerospace Engineering (VT MAE) found itself in a fix for one of its modification contracts. It was for a job to completely reconfigure and recondition 20 mid-life DC-9s that Northwest Airlines had acquired.

Said Mr Bill Hafner, President of VT MAE, who was brought in at that time to turn the programme around, "We were losing money because the man-day efforts were severely underestimated. Even back then, the DC-9 was considered an old model. Parts like the magnesium castings were no longer in production and costly to procure. I made the call to invest in a machine shop to manufacture the parts in-house. By the 12th aircraft, we managed to shift from purchasing the parts to making all of them in-house. That's where the margin was – in the materials."

The Northwest Airlines programme was a lesson in service innovation. VT MAE realised it would not be competitive as another maintenance, repair and overhaul (MRO) service provider. To succeed, it had to become a valued solution partner for the airlines. "Simply put, we needed to become better at MRO services than the airlines themselves," Bill said.

Bill believed that technologies would ultimately be a game-changer to raise the standard of services in aviation MRO. He cited VT San Antonio Aerospace which was already looking at the use of drones and lasers to detect surface defects and damages. "These are more accurate and faster than conventional methods using grids," said Bill. "At VT MAE, mechanics used tablets to access technical data without having to leave their work areas. Service innovations like these will enable ST Aerospace to set new standards for MRO services and keep aircraft flying safely."

Dennis Carr, machinist at VT MAE, using the multi axis CNC machine to build a fitting.

Next Generation MRO Hangar

Tomorrow's hangars could be drastically transformed by advanced technology, such as robotics, aerial inspection and data connectivity. Workplace safety, productivity and quality will be enhanced, while waste and inefficiency, as well as turnaround times and costs will be reduced. This is what ST Aerospace's future hangars could look like.

Digitised Work Flow
Using paperless processes, tasks are assigned, approved and monitored online. Images of defective parts are uploaded for direct assessment and approval of replacement parts.

Virtual Warehouse
Spare parts are 3D printed and assembled on site to shorten turnaround time and reduce logistics costs.

Wearable Connectivity
Augmented Reality (AR) glasses provide technicians with visual cues for each task while wrist-worn devices track the activities in real-time. The voice-enabled AR glasses allow technicians to directly log the inspection records.

Robotics
Drones equipped with 3D-Scanners and HD Cameras inspect the aircraft fuselage for defects. UGVs transport inventory from Automated Storage and Retrieval System (ASRS) for Just-In-Time (JIT) servicing. Robots work on fuselage paint sanding, while other robots inspect the fuel tanks and cabins for defects.

Automated Toolcribs
Tools are inspected to be serviceable before being pre-packed in toolboxes according to the work cards. The system alerts the technician of any missing tools at the end of the day, making Foreign Object Damage tool control checks a thing of the past.

SMART Hangar
Biometric iris scanner in AR glasses automatically clock technicians work schedules. Sensors within the hangar provide round-the-clock security. Data analytics is used to understand the information collected from the sensors, bots and other devices to optimise work flow and recommend predictive maintenance regimes for aircraft.

Turning Around an Aircraft in 18 Days

ST Aerospace Services Company (SASCO) has been supporting the MD-11 heavy maintenance for FedEx since 1997. In 2010, SASCO initiated a project to find ways to shorten the maintenance downtime for the MD-11 programme for FedEx. Mr Chan Chin Wah, SASCO's General Manager, who was then the Director, Planning & Production Control, was tasked to lead this process review, recalled assembling a cross-functional team of engineers, planners, procurement specialists and line managers to review the work flow and to develop a detailed proposal.

"We reviewed and streamlined the processes involved in the pre planning and maintenance activities such as work flow, work shift alignment, documentation, engineering dispositions process, material and toolings preparation. We also worked closely with the FedEx team to understand their maintenance programme requirements. More pre-planning and coordination were required between FedEx and SASCO to schedule the pre-draw parts and tools required for the added work in advance before the aircraft arrived at the hangar," said Chin Wah. The FedEx-SASCO team managed to reduce the maintenance downtime from 23 days to 18 days.

With the new maintenance regime in hand, both FedEx and SASCO adopted the new process for the MD-11 inputs till today. "The 18-day maintenance programme ran like clock-work. We achieved a significant reduction of 20% in down time – that's the same as having an extra aircraft available to FedEx for revenue flight!"

Proving our EcoPower

EcoPower is a revolutionary system for washing aircraft engines that was developed in 2004 by four aerospace engineers who were seeking an encompassing and environmentally-friendly solution to improve the performance, fuel efficiency and lifecycle costs of aircraft engines.

Mr William Welch is the President of EcoServices, a joint venture between Pratt & Whitney and VT Aerospace formed in 2011 to grow this proprietary solution. According to him, developing the solution was not the hard part. "The challenge was in convincing a customer to use EcoPower. Many aircraft operators were sceptical about the benefits of engine wash," he said.

Yet, EcoPower, being new, required hard operational evidence to show the economic advantage of the engine wash. "It took many months and our persistence paid off. We found our first customer, Hawaiian Airlines and convinced the Los Angeles Airport that the EcoPower procedures would be safe for the environment and the tarmac," William said.

The results were better than expected. More than 70,000 EcoPower engine washes had been performed since for over 200 customers, ranging from single aircraft operators to airlines and air forces. "I was most impressed with the team's unwavering focus despite the slow start. For me, that is passion – the difference between being relentless in the search for solutions and just showing up for work," William reflected.


Boeing 787 Trent 100 wash


A320 PW1100G-2M wash


Wash manifold

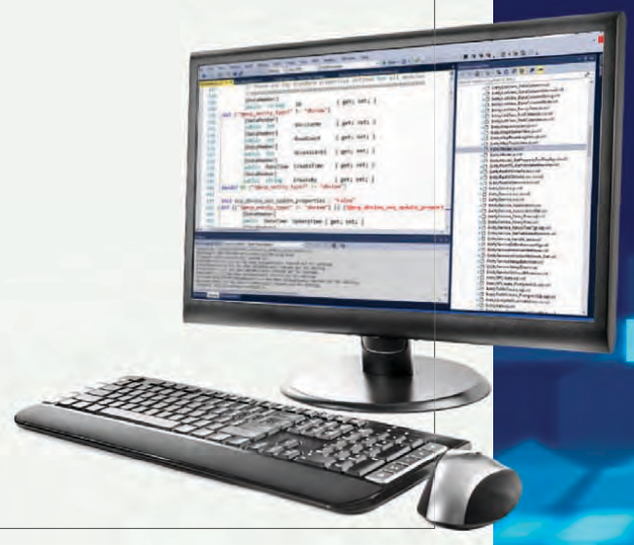
ENHANCING CONNECTIVITY IN THE DIGITAL AGE

“Digitisation is transforming industries at a furious pace. The Internet of Things (IoT) has unlocked the floodgates for smarter machines and it is no longer business as usual with the rapid advancements in super-computing, nano-technology and AI.

ST Electronics is in a unique position to develop focused capabilities for both defence and commercial applications, with interchangeable results. AI, for example, has transformed the landscape for business automation; unmanned and robotic technologies have become an important part of the hybrid workforce; while innovations like our Entity Code Production (ECP) have heralded encouraging breakthroughs in software development. We are improving Singapore’s in-country capabilties for cyber security with a calibrated suite of capabilities. We are also investing in neuromorphic engineering in collaboration with others. These are critical building blocks for the making of a smart nation.

Industry 4.0 will take digitisation to new heights. Ubiquitous sensors will soon become agents for supervisory control and data acquisition. With data convergence, demand for agnostic platforms that can provide smart contextual reasoning will increase. The speed of capturing, computing and contextualising content in real-time will be a key differentiator, and we can either embrace the digital disruption for exponential growth or fight it to our peril.”

David Tan
Chief Technology Officer, ST Electronics



An Express Way for Coding Software

One of the areas software developers can significantly increase productivity is in reusing software codes from similar systems. Yet, this is also one of the hardest things to do. All customers have their own business processes, and even the codes for the same function may be very different due to unique system configuration and legacy issues. "Simply put, a direct reuse of codes would not work," said Mr Ulf Pettersson, CTO of ST Electronics' Info-Software Systems.

This recurrent challenge prompted Ulf and his team to find a way to reuse codes in their projects. They conceptualised a software framework that could automatically generate codes and construct an operational web system based on the inputs provided by the programmer, while allowing new codes to be added to customise the programme for different customers.

Convinced that the concept would work, the team embarked on its development in 2015, and named the solution the ECP. Templates of codes were created to define commonly used functions, like model classes, database access protocols and visualisation. These templates and codes were thoroughly tested for security, robustness, quality and stability before they were introduced into the ECP.

"ECP solves the issue of reusability of codes. A software developer can now define the entities, including their relationships, properties and attributes, and ECP will automatically piece together the templates into an executable web system. The software developer will then customise the software to the exact customer requirements," said Ulf. "ECP is able to greatly speed up the generation of entity-specific codes."

In 2016, the ECP was used for the first time by a project team working on a Command and Control (C2) operations centre system for Singapore's Ministry of Communication and Information (MCI). Ulf's team developed the templates for the web-based C2 systems and took the opportunity to add new features to the ECP.

According to Ms Annie Ng, Project Manager at MCI, ECP has enabled her to deliver the MCI project on time with less issues than other projects. She said, "ECP has significantly sped up project programming and helped the project to save two-thirds of the man-day efforts compared with using a conventional coding approach. Moreover, human errors were reduced as codes were generated from validated templates. This ability to do speed-coding is going to be a game-changer."

The ECP has since been applied in other projects and Ulf's team has used each opportunity to further improve the platform and build up the library of templates. For its innovation, the team has garnered several awards. Ulf believes that ECP would differentiate ST Electronics' software development capability from the competition. "With ECP, software development teams could do more with fewer members in a shorter time and with better results. They will be able to engineer customised solutions and produce best-of-breed end-user features on the fly," he added.

Straight-through Access at Train Stations

As part of its effort to champion hands-free fare collection, ST Electronics has developed the sleek and intuitive Next Generation Automatic Fare Collection (AFC) System. The front end, comprising the Interactive Traveller Terminal and the Advance Fare Gate, uses facial recognition technology, which allows pre-registered commuters to walk through the fare gates without having to tap in or out with their fare cards. The Next Generation AFC was launched at the Singapore International Transport Congress and Exhibition 2016.

"The Next Generation AFC is able to work with multiple payment systems. Besides the traditional contactless smartcard, commuters can opt for open payment methods like credit cards or mobile Near-Field Communication payment without having to purchase tickets the way we are doing today," said Mr Andrew Mak, a software manager at ST Electronics' AFC Division.

According to Mr George Goh, Vice President of ST Electronics' Transport Business, the new AFC solution would provide multiple benefits, including unprecedented convenience to commuters as well as increased throughput and tighter security at train stations. He added that the AFC innovation was part of ST Electronics' continuous efforts to harness technology to meet the growing demands of public transport in today's cities.

Command on the Move

Mobile C4 centre

Over 40sqm of internal working space is available in the mobile centre, more than twice its size in a closed configuration.

ST Electronics' CETRON Mobile Command Hub (MCH) features a breakthrough vehicular design that has transformed the way incident management is conducted. With a sophisticated mechanism that enables the vehicle to be expanded up to three times its size, and all its internal consoles rapidly deployed, all it takes is 20 minutes – and the push of a button – to set up the MCH as an operational command centre, saving precious time for rescue personnel during emergency situations.

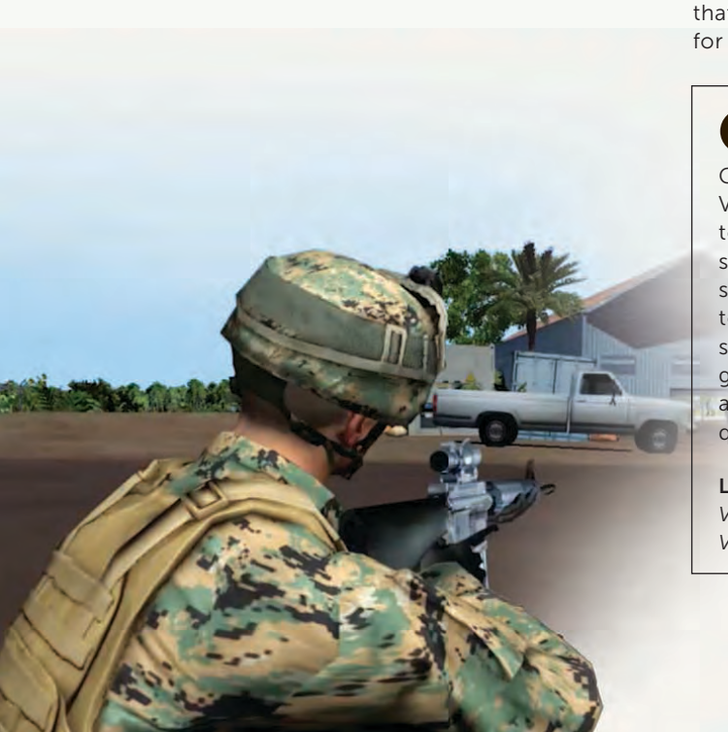
> "Engineering is all about thinking out of the box and creating solutions that solve problems and make a difference in the lives of others. When we started designing the CETRON MCH, it was simply meant to be a mobile platform with emergency response systems that could be quickly set up. By leveraging advanced technologies in info-communications, electronics and mechanical engineering, we were able to develop a solution that enables multiple MCHs to be deployed, forming a fully interconnected and operational command centre for large-scale operations. Our patented vehicular design can even be customised to meet different operational requirements of public safety agencies!
>
> **Han Tyng Chour**
> *Chief Design Engineer of the MCH, ST Electronics (Info-Comm Systems)*

Affordable Simulation Becomes a Reality

In the early days of computer simulation, it was common for government units to build simulation engines for their training systems. However, these systems tend to be large and complex. They could not be shared between departments, and were inefficient on smaller projects. That was when VT MÄK, which reports into the Electronics sector, saw the opportunity for a simulation platform designed with compatibility in mind. The team started to develop commercial off-the-shelf products that could deliver unprecedented efficiencies for the customer.

> “What resulted was a solutions suite that included powerful Computer-Generated Forces programmes like VR-Forces. We became one of the first to develop an extremely customisable, scalable, interoperable and affordable simulation solution that can be tuned to any programme or requirement. The simulations can even be linked for larger group exercises – and that has brought about a massive improvement in the quality of training.

Len Granowetter
Vice President of Products & Solutions, VT MÄK



Staying Connected in the Air

Behind its humble model number, iDirect’s CX780 satellite router holds great promises as it enables passengers flying in an aircraft to stay connected on broadband. Mr Andy Hefner, a Principal Engineer at VT iDirect, calls it a “generational leap” from the company’s earlier offering. Apart from expanded features, the CX780 has a faster processing speed and is built on iDirect’s Velocity platform, an IP-based satellite communications system engineered to deliver high-quality broadband connectivity.

> “The CX780 satellite router is the latest product in the Velocity line targeting the commercial aviation market. It was first launched in 2016 as a core module of Honeywell’s JetWave, the world’s first in-flight broadband solution. In the world of wireless connectivity, air travel represents the last frontier. In-flight Internet access, if it’s available at all, is seldom fast or reliable. CX780’s ability to provide uninterrupted and seamless connection 10km above the ocean and travelling at close to supersonic speed is astounding. It is the long-awaited in-flight broadband!

Andy Hefner
Principal Engineer, VT iDirect

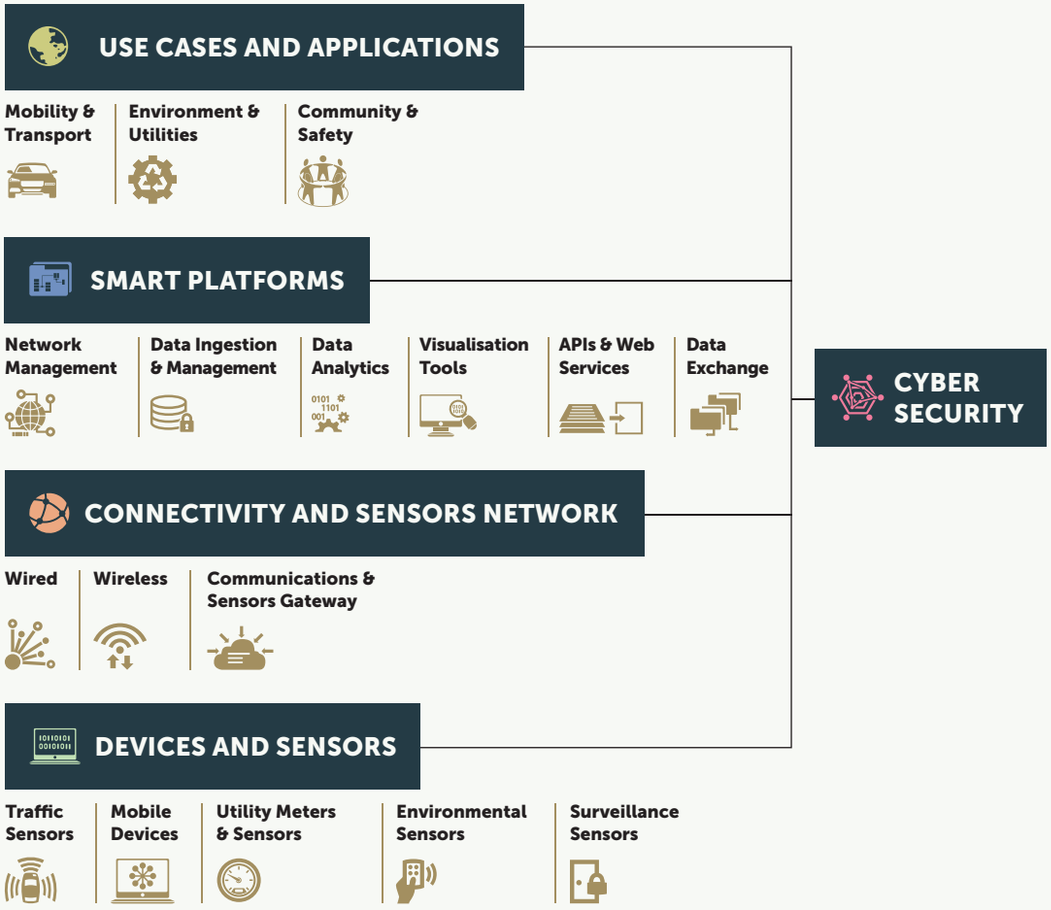
The Internet of Everything

ST ELECTRONICS' IOT REFERENCE ARCHITECTURE

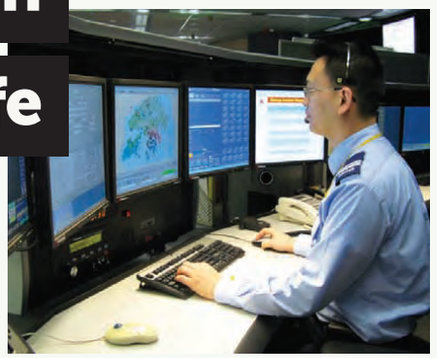
These days, more and more things are connected to the Internet, from public amenities like bus stops and streetlights, right down to air-conditioners and water meters at home. What has made this possible is the IoT, a concept where different web-enabled devices can send and receive data and 'talk' to one another. This is all thanks to wireless sensors, networks and platforms that provide the infrastructure for seamless connectivity.

"IoT is the backbone of smart cities," said Andrew Chow, President of ST Electronics (Info-Comm Systems). "We build the smartness into devices and sensors to collect information such as brightness, utility levels or movements. The data is then relayed to backend network management systems, where they can be analysed and used for predictive maintenance."

Some examples of ST Electronics' machine-to-machine IoT solutions that have improved the quality of people's lives include smart street lighting, advanced metering readers, energy conservation at home, and intelligent transport management systems. As demand for IoT continues to grow, many of ST Electronics' innovative solutions have been implemented in large-scale smart city projects in Singapore, Brazil, Canada, France, Israel, New Zealand, United Kingdom and the US.



Enabling Technology in Everyday Life



Emergency Response Operational Centre

ST Electronics has implemented numerous infocomms technology (ICT) solutions for governments and commercial enterprises. In 2015, it started to market these solutions under SERIS to create a unified product brand that would differentiate ST Electronics from the competition. "We wanted an impactful brand that could carry our products internationally. The Corporate Planning and Business Development team did a thorough review and identified a suite of solutions that would contribute to the objective of 'shaping a safer tomorrow'. We wanted the staff to own the solutions suite. So, we invited them to propose and vote for the name, and SERIS, short for Secured Emergency Response Information System, was chosen," said Mr Jeremy Foo, President of ST Electronics (Info-Software Systems).

SERIS comprises a suite of integrated solutions that include smart city solutions for seamless tracking and digitally locking of resources; Smart Analytics solutions to address cyber security issues; Public Safety solutions for homeland security; and Smart Maritime to monitor and track movement of vessels as well as identify illegal maritime activities.

Since its launch, SERIS has secured many new projects for ST Electronics. For instance, SERIS' Air Traffic Simulator Common Application Platform is used by aviation authorities in Singapore, Vietnam and Ecuador. SERIS' Intelligent Airport System is used by Singapore's Changi Airport Group for its airport management while SERIS' Smart City solutions, such as smoking detection, people counting and crowd monitoring, were used in Singapore's Jurong Lake District testbed. In Public Safety, SERIS' Third-Generation Mobile System is used by the Hong Kong Fire Services Department, and its Smart Maritime solution by Singapore's Police Coast Guard for real-time coastal surveillance.

"Working on SERIS has given me valuable hands-on experience in the implementation of new technologies like big data analytics, and smoke detection algorithms," said Mr Edwin Lee, a SERIS software developer. "With the mission to deliver the best solutions, we are constantly scanning the horizon for new technologies that can make cities smarter and life better with tech-enabled solutions."

SERIS-Maritime enables monitoring and tracking of sea vessels for any illegal maritime activities.

> "As part of Singapore's Smart Nation initiative, Aggregation Gateway Boxes are currently put on trial by ST Electronics at the Jurong Lake District's Yuhua housing estate, to pilot and consolidate the nation's sensor needs while providing secure Internet connectivity for these sensors. We are glad to continue to collaborate with industry partners to develop our capabilities in pervasive connectivity and build the infrastructure to enable citizens, businesses and government agencies to leverage technology to make lives better as a Smart Nation.
>
> **Dr Tan Guan Hong**
> *Senior Director, Smart Nation Systems and Solutions, GovTech Singapore*

> "Smart infrastructure, like ST Electronics' Central Management System for streetlights, will give our residents greater confidence in Southend-on-Sea's Council to meet its goals on reducing energy costs and CO_2 emissions. We hope to align this with other IT applications, such as future ICT-based procurement and cloud computing, to realise further savings and benefits from its smart characteristics.
>
> **Paul Mathieson**
> *Group Manager, Southend-on-Sea Borough Council, United Kingdom*

ADVANCING INNOVATIONS

Connecting Securely

ST Electronics provides a wide range of innovative cyber security solutions, many of which are developed in-house. Its ventures into information assurance can be traced to the early 1990s, when a small division under the former CIS provided customised encryptors for its customers.

In 1999, the division was incorporated as DigiSAFE to manage the growing business of information assurance. Propelled by a 'Dare to Think Big' culture, the team developed many of its own information assurance products, including end-to-end network security solutions, communication links, internet, ethernet and storage media. It also enhanced secure imaging through digital authentication under its DataMark brand and pioneered Singapore's first Virtual Private Network for secure data transmission.

In 2006, the DigiSAFE solutions were marketed overseas, opening up new markets in Asia, Africa, Middle East, Europe and the US. The following year, DigiSAFE was renamed as ST Electronics (Info-Security) to reflect its core capability in cyber security. "Pioneering Singapore's information assurance business had given us a head start in cyber security. We are able to leverage more than three decades of experience in providing cyber security solutions to government agencies and large enterprises, establishing ST Electronics as one of the world's leading cyber security solutions provider," said Mr Goh Eng Choon, General Manager of ST Electronics (Info-Security).

"Every employee is ingrained with a strong security mindset – we live and breathe security. You will need this level of commitment to stay on top of the latest technology development and ever-evolving cyber threats so as to respond quickly and develop solutions to protect networks from cyberattacks," added Mr Koh Sze Liat, Group Head of Cyber Security Solutions Group. "In recognition of our innovative efforts, we have won numerous awards, like the International CES Innovations Design and Engineering Awards in 2010 and 2012 for DigiSAFE DiskCrypt Mobile and DiskCrypt respectively."

The advent of the IoT and Singapore's Smart Nation agenda have also seen an increased demand for cyber security expertise. In 2014, ST Electronics set up the first Cyber Security Centre to provide cyber security training in support of Singapore's National Infocomm Competency Framework. In 2016, it became the first training provider in Singapore for the $(ISC)^2$ Systems Security Certified Practitioner (SSCP) Common Body of Knowledge that incorporates advanced cyber range exercises.

Said Mr Victor Yeo, Deputy General Manager of ST Electronics (Info-Security), "We are the first training centre in the world to introduce cyber training and development with advanced cyber range exercises for the SSCP course. Trainees can acquire the latest cyber security skills in a state-of-the-art virtual training environment. Organisations can also use the cyber range to simulate corporate Security Operations Centre environments as well as scenarios for training and evaluation purposes. We have also provided advisory and consultancy services to the Sri Lanka government for the implementation of its first National Cyber Security Operations Centre."

To ensure that it stays ahead of the cyber defence technology curve, ST Electronics set up the ST Electronics-SUTD Cyber Security Laboratory in 2016. Mr Lee Fook Sun, former Deputy CEO of ST Engineering and President of ST Electronics, announced at the facility's opening that with the vision of accelerating the pace of cyber security technology development incorporating cross-sector applications, the new laboratory would have the capacity to attract and bring cyber security experts and capabilities together under one roof.

"The ST Electronics-SUTD Cyber Security Laboratory will help Singapore advance new frontiers in cyber security technologies and develop the next generation solutions to address future cyber threats and challenges," he added.

ST Electronics built and operate the 24/7 ST Engineering Cyber Security Operations Centre to monitor the cyber security status of some 10,000 users.

Hotbeds for innovation

At ST Engineering, the skills and entrepreneurial instincts of engineers are honed through a variety of internal competitions. Regular events like ThinkOut, ThinkerSparks and InnoChamps have provided the catalyst for many innovative products and solutions.

Engineers from across sectors at a brainstorming session during ThinkOut 2014.

"THINKOUT OF THE BOX"

Every two years, ThinkOut brings together entrepreneurial and creative problem solvers from across the business sectors to tackle engineering challenges and generate ideas for business adoption.

"The idea came about after the Little India riot in 2013, when we read in the news that police vehicles could not access the riot area promptly due to road congestion. This could've been avoided if the law enforcement team had access to real-time situation awareness, and so we pooled our knowledge on UAVs and smart networking systems to develop a riot monitoring and control solution that could expedite their operations. The smart networking systems can process video images from the UAVs and other data, and then notify the ground troops in advance of roadblocks as well as provide an optimum ingress route for their vehicles so that time is not wasted in traffic congestion. It's exciting to be able to combine ST Engineering's various competencies to come up with a practical solution!"

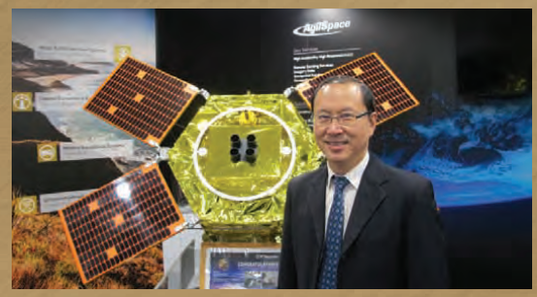
Lee Wai Leong (ST Aerospace) (pictured above, 2nd from left), Team spokesman, ThinkOut 2014 Winner
Team members: (from left of Wai Leong) Eric See (ST Electronics), Nicholas Tseng (ST Kinetics), Tho Wee Hong and Ng Chee Koon (ST Aerospace), Koh Wee Yung (ST Marine) and Dr Jake Toh (ST Dynamics)

"It was the sight of food wastage and elderly folks clearing used crockery left behind by hawker centre patrons that got us thinking about developing a food waste management solution made from affordable electronics components. Our innovation also serves to alleviate issues such as hygiene and poor working conditions at food centres. Using data analytics, we can predict consumers' food preferences and enable hawkers to prepare the right amount of specific foods to minimise wastage. We can even derive useful insights on calorie consumption patterns to improve public health and encourage the return of food trays with incentives such as priority seat allocation. Our hope is that the hawker centre experience will be one that Singaporeans from all walks of life can be truly proud of.

Leong Jenn Chuan (ST Marine) (pictured above, 1st from left), Team spokesman, ThinkOut 2016 Winner
Team members: Ong Gim Hoe and Yacob Mokti (3rd and 4th from left) (ST Marine), Mun Meng Wai (ST Dynamics), Karen Ng (right) (ST Electronics), Keith Toh (ST Kinetics) and Ong Shee Yin (ST Aerospace)

RECOGNISING OUR INNOVATORS

Hotbeds for innovation



IGNITING CREATIVITY THROUGH THINKERSPARKS

The annual ThinkerSparks Idea Competition allows employees to present innovative ideas or eco-friendly solutions with good business potential.

"We are always striving for the next breakthrough in material technologies, and our winning idea was a lightweight, high-performance boron carbide ceramic material that could enhance the protection, mobility and fuel-efficiency of platforms. We actually make the material in-house and they yield excellent hardness with tough mechanical properties. We've also incorporated amorphous aluminium into the alloy so that 3D printing using this improved material can be made possible. With this, we are ready to develop more business ideas for the aerospace and automotive sectors.

Jimmy Chan (ST Kinetics) (pictured above, left), Team spokesman ,ThinkerSparks Idea Competition (2016) Winner
Team members: Sim Zhen Hao (middle) and Eric Lim (right)

"The Space Systems team started out in 2014 with no software development experience. After co-opting a software engineering colleague and hiring two others, we decided to conceptualise our own geospatial portal instead of acquiring one through open tender. This resulted in the AgilSpace GeoPortal, which enabled the high-quality imagery captured by our first commercial Earth Observation satellite, TeLEOS-1, to be transacted over the Internet. We then struck up reciprocal arrangements and built linkages to our partners' satellite imagery portals to expand our marketing reach. Thanks to the ThinkerSparks competition, we were spurred to further our R&D efforts. Today, we have an experienced multidisciplinary team, and collaborations with world-renowned partners for the AgilSpace business.

Seah Peng Hwee (ST Electronics) (pictured above), Team spokesman, ThinkerSparks Idea Competition (2015) Winner
Team members: Dr Robin See and Maverick Tan

NURTURING TRUE "INNOCHAMPS"

The annual InnoChamps competition creates a platform for the recognition of ideas and concepts that have transited into successful products and services.

"I see engineering as a profession to build and create things to add value to people's lives. Amongst my patented innovations, Inno-Grinder is the most meaningful as it not only attains business gains for my company, but more importantly, it brings about substantial employee welfare. Inno-Grinder is an automated grinder that has transformed a highly labour-intensive task into a simple procedure. By redesigning the work processes, the Inno-Grinder has enabled older workers to remain gainfully employed even in the harsh foundry environment. To me, there is no giving up in engineering, especially in the pursuit for innovation. While passion drives us to dream, true success only comes through perseverance.

Liu Yong Wee (ST Aerospace) (pictured above, middle)
InnoChamps Innovation Competition (2016) Winner

"Innovation can be an uphill task especially when working with something unfamiliar. The Airbitat Smart Cooler project was a good example. We taught ourselves to approach problems from new angles and fresh perspectives, allowing ourselves to fail fast but learn quickly, until our envisioned product has materialised in the ideal form. We built eight prototypes in 18 months – it's amazing how much innovation we have achieved since our first prototype. As engineers, it's great to have passion, to debate hypotheses and turn dreams into reality. However, it's when people's lives are touched by our work that the iterative efforts become intensely rewarding.

Dr Li Fuyun (Innosparks) (pictured above, 2nd from right), Team spokesman, InnoChamps Innovation Competition (2016) Winner
Team Members: Gareth Tang (far right), Timothy Ang (left), Tracy Yee (2nd left), Clifford Cheung (3rd left) and Nyi Myo Aung

"As engineers, we are trained to always think out of the box, and the InnoChamps award has been a great encouragement and affirmation of our work as designers. It fostered a stronger innovation culture amongst our team working on the 155mm Red Phosphorus Smoke Projectile, to increase its modularity and flexibility of construction. It has also motivated us to constantly think of innovative ways to improve safety, efficiency and quality at every stage of the developmental process, and to apply this valuable experience into all our future programmes.

Yew Tian Geng (ST Kinetics) (pictured above, middle), Team spokesman, InnoChamps Innovation Competition (2016) Winner
Team Members: Huang Kede, Stanley Teo, Eugene Teo, Louis Lim, Chew Yee Leng and Fong Kok Chung

RECOGNISING OUR INNOVATORS

Building Intellectual Assets

ST Engineering's Intellectual Property (IP) initiative dates back to 1999 when Mr Boon Swan Foo, then President & CEO, saw the growing importance of intellectual property rights (IPR) to create higher value-add to differentiate itself from the competition. He tasked Dr Richard Kwok to spearhead the initiative for the Group. When Tan Pheng Hock took over in 2000, he further defined the targets to generate at least four patents from each business sector and to expand IP by 20% each year.

Richard took up the challenge. With just one patent on record, he began to establish the patent application process first by setting up an IPR Committee to guide the Group, establishing annual patent application targets and rapidly scaling up IP competency through engaging consultancy and training. Through these efforts, ST Engineering gradually overcame the inertia towards patenting and became recognised as an IP best practice company in Singapore with an innovative culture. Several of the IPR members now sit in national IP committees to advise corporations on IP and position Singapore as a bustling IP hub in Asia.

From left: Sze Swai Ming, Yeang Say Feng, Tomoyuki Yoshimura, Xiao Cai Yong, Zheng Guo Ying, Yip Siew Ming, Charles Baz, Gn Wende, Chong Yong Qi and Cheng Siang Ann

"The challenging technical and regulatory environment of the aircraft seat industry spurred us to innovate and enhance seat design for the safety and comfort of passengers. We would carefully review each idea many times before coming up with new features for the seat pan, headrest and structural frame that would provide the desired level of comfort. We also worked with the production and maintenance teams to ensure the design would be cost effective to produce, and simple to install and maintain. It is truly satisfying to see our inventions contributing to safer and more comfortable air travel.

Dr Zheng Guo Ying
Engineering Director, ST Aerospace Aircraft Seats, ST Aerospace
Six patents granted and another four patents pending

Transporting municipal waste underground is a brilliant concept if not for the bulk and size of waste that would often choke the vacuum pipeline. This problem was always on my mind. One night, the idea suddenly came to me to reduce the size of the waste. I stayed up late to work out a detailed design, and the next day, with the help of a colleague, created a 3D schematic of what I called a 'Discharge Extruder'. This is a device with a pair of hardened blades to cut and compress waste to reduced size. Realising its potential for applications in any pneumatic waste collection systems, we filed a patent for it. I would never have imagined when I first set out to solve a problem that I would end up becoming an inventor with a patent to my name.

Yacob Mokti
Assistant Principal Engineer, STSE Engineering Services, ST Marine
First patent filed for a pneumatic waste collection system

When I first joined the company in 2000, there was a big party. It was not to welcome me but to celebrate the granting of a US patent on the 40mm mechanical self-destruct fuse. It was a more reliable fuse as there were no shelf-life limiting components, which meant lower chance of duds. That event inspired me as a young engineer to explore new areas for product innovation. In 2006, my first patent was filed for a coupling adaptor for the 40mm projectile and propulsion unit. This was followed by another two patents. Since 2000, the 40mm design team had filed more than 56 patent applications and made ST Kinetics a global leader in 40mm munitions.

Yak Chee Keong
Senior Principal Engineer, Advanced Material Engineering, ST Kinetics
Three patents granted on 40mm munitions

From left: Low Keng Choong, Tan Thiam Siong and Andrew Mak from the AFC Team

Several years ago, we had to withdraw a proposal to supply a solution for Platform Screen Door (PSD) for a rail project because the idea we had proposed was already patented by someone else. Since then, we have been filing for patents on the PSD as well as the AFC systems to protect our IP and business interest. While patents will remain important in protecting our business interest, what has become even more rewarding for the company is the vibrant and innovative culture we have fostered among the engineers, through the patenting process, to strive towards better product designs that would make a better travel experience for commuters.

Bernard Chow
Senior Vice President, Transportation Business Unit, ST Electronics
Four patents granted and another four patents pending, including one for a revolutionary hands-free next generation AFC system that uses facial recognition and long range RFID technology

Meet Our 'Oscar' Winners

Every year, MINDEF's Defence Technology Prize (DTP) is awarded to worthy scientists and engineers in recognition of their contributions to strengthening Singapore's defence capabilities.

For those in the local defence eco-system, this prestigious accolade is the equivalent of the Academy Awards for engineers. Since the DTP was established in 1989, ST Engineering has garnered four individual prizes and 21 team awards together with its collaborators in the Defence Technology Community.

These achievements continue to inspire younger generations of engineers to excel at what they do, take risks and pursue their dreams – no matter how impossible they may seem.

"ST Engineering is integral to our defence technology ecosystem. It spearheaded the development of many innovations that contributed to the third-generation SAF's cutting edge such as the Terrex Infantry Carrier Vehicle that enhanced the Army's networking and fighting capabilities and the Navy's unmanned systems for mine countermeasures. Moving forward, it is critical for ST Engineering to continue to be proactive, forward looking and relentless in its innovation drive for it to remain distinctive, competitive and a key partner in sharpening the cutting edge for Singapore's defence.

Quek Tong Boon
Chief Defence Scientist and ST Engineering Board Director (2008 to 2016), during which he was also the Chairman of its Research, Development and Technology Committee

DR RICHARD KWOK
Executive Vice President and CTO, ST Kinetics
2002 DTP Individual (Engineering) Award

An avid tinkerer with an uncompromising work ethos, Richard has contributed his insights and ideas to every major project from the AMX upgrade and Bionix development to advanced materials and smart ordnance. His innovative approach and undaunted attitude towards problem solving have inspired many and directly contributed to various successes, particularly in the fields of ordnance, weapon development and armoured vehicles.

On his advice to young engineers:
"You must dare to dream. Too many of us are afraid to fail and make mistakes. You can't come up with great ideas by doing the same thing or staying in the comfort zone. Start by building trust with all the stakeholders. Learn from the pioneers who have established excellent professional relationships with our customers, partners and even competitors. This has enabled us to get things done."

LOH HENG FONG
Vice President and Head of Tracked Mobility Centre, ST Kinetics
2010 DTP Individual (Engineering) Award

Heng Fong has contributed to the development of tracked vehicles and armoured defence capabilities over the last 35 years. His projects have included the upgrading of the AMX-13 tanks, to the design and development of Singapore's very own Bionix Infantry Fighting Vehicle, Bronco All Terrain Tracked Carrier and Trailblazer Countermine Vehicle.

On the attributes of good engineers:
"With innovation, one must be prepared to take risks. There's always a first time – so young engineers must learn to overcome the fear of failure, take ownership, and believe in themselves. Also, none of my projects could have been accomplished without the support of a strong team. For me, the DTP individual award is really a recognition of team effort."

TEO CHEW KWEE
Vice President and Chief Engineer of Weapon Systems, ST Kinetics
2015 DTP Individual (Engineering) Award

Chew Kwee is the undisputed authority on Singapore's artillery weapons. He has worked on almost all of Singapore's artillery projects, starting from the development of the FH2000, the world's first 52-calibre 155mm howitzer, to the innovative self-propelled howitzer Primus, the heli-portable Pegasus and the 120mm Super Rapid Advanced Mortar System.

On what motivates him in his job:
"Being the frontrunner of technology development often means that there are plenty of unknowns. It is important to learn from our failures and build on these experiences towards successful outcomes. For me, the satisfaction comes from seeing each project through from concept to execution. You feel a great sense of pride when your guns are mentioned alongside other top artillery systems in the world."

LEE YOKE MING
Distinguished Member of Technical Staff Advanced Technology Research Centre, ST Kinetics
2014 DTP Individual (R&D) Award

Since 1990, Yoke Ming has been involved in the research and development of propellants and explosives. Her expertise in these domains has enabled her to make significant contributions to the development of new weapon systems and special explosives that enhance the SAF's capabilities.

On overcoming challenges at work:
"In my area of research work, we come out with a lot of new ideas. One of the challenges I face is convincing customers to try out these new technologies. Making sure that every product is safe and effective is always our foremost consideration. And this is where I find alignment of stakeholder interest critical to bringing an innovation from prototype to production."

RECOGNISING
OUR
INNOVATORS

Our Defence Technology Prize Awards

2015
DTP Individual
(Engineering) Award:
Teo Chew Kwee
ST Kinetics

2014
DTP Individual
(R&D) Award:
Lee Yoke Ming
ST Kinetics

2014
DTP Team (Engineering) Award:
Missile Corvette Upgrade
(DSTA, RSN,
ST Electronics & ST Marine)

2010
DTP Individual
(Engineering) Award:
Loh Heng Fong
ST Kinetics

2010
DTP Team (Engineering) Award:
Comprehensive Maritime Awareness
(DSTA, DSO, RSN &
ST Electronics)

2010
DTP Team (Engineering) Award:
G550-AEW
(DSTA, DSO, RSAF,
ST Electronics & ST Aerospace)

2010
DTP Team (Engineering) Award:
Guided System
(DSTA, DSO & ST Kinetics)

2010
DTP Team (Engineering) Award:
Terrex Infantry Carrier Vehicle
(DSTA, Army & ST Kinetics)

2009
DTP Engineering Award:
Countermine Vehicle
(DSTA, Army & ST Kinetics)

2009
DTP Engineering Award:
Mini UAV
(DSTA, DSO, Army &
ST Aerospace)

2008
DTP Engineering Award:
Mission Computer
(DSTA, RSAF &
ST Aerospace)

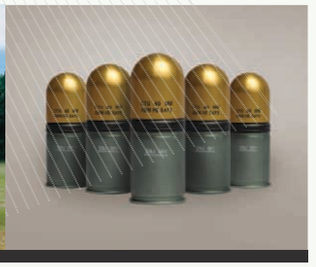
2008
DTP Engineering Award:
Air Power Generation C2I System
(DSTA, RSAF & ST Electronics)

2007
DTP Engineering Award:
Formidable Class Stealth Frigate
(DSTA, DSO, RSN, ST Electronics & ST Marine)

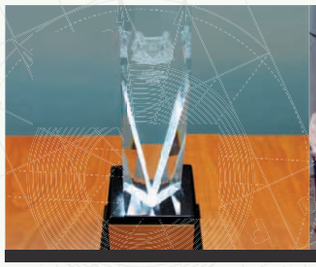
2007
DTP Engineering Award:
Classified
(DSTA, DSO, RSAF & ST Aerospace)

2006
DTP Engineering Award:
Specialised Marine Craft
(DSTA, DSO & ST Marine)

2006
DTP R&D Award:
Pegasus Singapore Lightweight Howitzer
(DSTA & ST Kinetics)



2004
DTP Engineering Award:
40mm Air Bursting Munition System
(DSTA, Army & ST Kinetics)



2003
DTP Engineering Award:
Enterprise C2I System
(DSTA & ST Electronics)

2003
DTP Engineering Award:
Datalink Network
(DSTA, DSO & ST Engineering)

2002
DTP Individual (Engineering):
Dr Richard Kwok
ST Kinetics

2002
DTP Engineering Award:
Air Command and Control Hub
(DSTA, DSO, RSAF & ST Electronics)

2001
DTP Team Award:
SAR21
(DSTA, Army & ST Kinetics)


Photo courtesy of DSTA

2001
DTP Team Award:
Landing Ship Tank
(DSTA, RSN, ST Electronics & ST Marine)

2000
DTP Team Award:
Bronco All Terrain Tracked Carrier
(DSTA, Army & ST Kinetics)

1999
DTP Engineering Award:
F5 Upgrade
(DSTA, RSAF & ST Aerospace)

1999
DTP Engineering Award:
E2C Upgrade
(DSTA, RSAF & ST Aerospace)

1997
DTP Team Award:
Bionix Infantry Fighting Vehicle
(DMO, Army & ST Automotive)

OPPORTUNITIES AND OUTCOMES

ST Engineering's steady growth is supported by the relentless pursuit of opportunities at home and abroad. From our strategic investments in new capabilities, to our successes at clinching major international contracts and growing our global footprint, we have ventured outside our comfort zone and made significant strides to stretch our horizon across four continents.

We have established strategic collaborations with leading partners, learnt from both challenges and successes, and gained a global reputation as a leading technology, defence and engineering group. From major airlines and public transport operators, to governments and military forces, ST Engineering has earned its stripes as a partner of choice.

TURNING OPPORTUNITIES TO OUTCOMES

Opportunities in Diversity

Photo courtesy of Pensacola News Journal

General (Ret.) John G. Coburn
Chairman and CEO, VT Systems, Inc.

Vision Technologies Systems (VTS) was set up in 2001 to be the US headquarters of ST Engineering. General (Ret.) John Coburn, who had just retired from the US Army Materiel Command at that time, was hired to be VTS' Chairman and CEO.

He recalled, "When VTS was first established, there was just one other person and me. We shared one desk in a small office, and there were no phone calls for weeks – no one was interested in us, no one knew who we were. So, we decided to move closer to Congress and the Pentagon, near the centre of activities in DC."

"The first building we found was 44 Canal Center Plaza in Alexandria, Virginia. We soon learnt it was a bad choice in numerology when the paperwork took a long time to be processed. With the advice of a Singaporean colleague, we moved down the block and got another address at 99. This time, we got the approval without a hitch," John laughed. 99 Canal Center Plaza has remained VTS' head office since.

VTS at AUSA Annual Exposition & Symposium.

He continued, "One of our earliest pursuits was the US Army's Interim Armoured Vehicle programme. Although our Bionix armoured fighting vehicle was shortlisted, it did not make it to the final round of selection as the US Army decided to go for a wheeled platform instead. The experience, however, gave us a good understanding of the US government's highly structured procurement system, and the participation in such a high-profiled programme allowed ST Engineering to make its mark globally. Today, the US Department of Defence knows us very well. We've demonstrated our capabilities and proven our mettle."

In 2002, ST Engineering reorganised its subsidiaries in the US to come under the VTS structure. This decision immediately strengthened the Group's collective presence and network in the US that would prove invaluable for its subsequent growth in North America and beyond.

That same year, two companies were bought out of bankruptcy to expand the US footprint. "One of them was the Dee Howard Company in San Antonio – their conspicuous orange hangars are now a prominent part of VT San Antonio Aerospace (VT SAA). The other was Halter Marine. We rebuilt it into a world-class shipyard and kept the name for its strong legacy of trust and quality," John said.

"We knew there would always be demand for reliable vessel repair services. That's why we got into ship repair in Mississippi. Halter Marine did not have a dry dock at that time, so we had to acquire one. We eventually found one far away in Vietnam and bought it for a great price. We floated it to the Philippines for maintenance, put it on a heavy sealift ship and brought it around the Horn of Africa all the way to Mississippi," said John. VT Halter Marine went on to find success in major projects such as the Egyptian Navy contract for four fast missile craft, ships for the US Navy and other commercial vessels.

EcoPower performed more than 60,000 EcoPower Engine Wash for over 180 customers since 2011.

As for VT SAA, besides its core capabilities in Maintenance, Repair and Overhaul (MRO), it founded AERIA Luxury Interiors in 2012 to handle VIP aircraft maintenance and interior completions. In 2013, it expanded into composite repairs with the acquisition of TurboMach. Eyeing opportunities from the shortage of commercial pilots, it also established the Aviation Academy of America in Hondo, Texas in 2014.

Leveraging VTS' presence and extensive network, ST Engineering gradually built up a strong portfolio of businesses in aerospace, electronics, land systems and marine in the US through a dozen subsidiaries. Several of these companies have transformed into world-renowned brands and industry leaders, like iDirect in satellite communications, Miltope in ruggedised solutions and EcoServices in engine wash.

VTS continues to expand and strengthen these "building blocks", as John calls them, to create the versatility necessary to take advantage of future opportunities. He said, "VTS did not initially set out to be an international company. Yet, we now have offices in Abu Dhabi and Sao Paulo. We intend to drive business growth in the various niche areas and where we can, find areas of synergy where the businesses can collaborate and strengthen integration."

He continued, "Jet engine wash is a good example. A joint venture with Pratt & Whitney was established to grow this operation in 2011. The aviation industry was sceptical about the effectiveness of engine wash, and not many saw a future in the business. That gave us a head start to become a market leader."

Likewise, when American Airlines conducted the first round of base maintenance visits for its Boeing 777-300s, it wanted a regional MRO to service this fleet. Although VT MAE had lots of MRO experience, it had never redelivered a Boeing 777 before. So, it teamed up with SASCO in Singapore to set up the capability. John said, "SASCO sent a team over to guide and oversee the first maintenance check, and gave a guarantee to provide backup support. VT MAE secured the contract, and in 2015, became the heavy maintenance service provider for American Airlines' fleet of Boeing 777-300 aircraft."

On the Land Systems front, VT Hackney was one of the companies down selected by the US Postal Service to deliver mail truck prototypes. In Electronics, VT iDirect has taken advantage of the world's constant need for connectivity and is today the leader in internet protocol hubs, commanding more than half of the global market share.

None of these achievements would have been possible without ST Engineering's commitment to the US market. John emphasised, "The fact that a small country like Singapore could successfully bid and win major US government programmes fascinates people. That the Terrex 2 was down selected by the US Marine Corps in 2016 just goes to show how far we've come since the Bionix days."

"For 16 years, our diversity has been the source of resilience and innovation that grew the Group's US operations, which now contributes about 25% to Group revenue. It will, no doubt, continue to drive our growth in the Americas and carry us far into the future," John said.

VTS management meeting.

TURNING OPPORTUNITIES TO OUTCOMES

STAYING FOCUSED DESPITE SETBACKS

Barely three years after being acquired by VTS in 2006, VT LeeBoy went through one of the worst recessions in America since 1929. Sales dropped by more than 70% and persisted for five years before there was any sign of a turnaround. We had to let some of our people go. It was a difficult decision.

What pulled us through was the solidarity within LeeBoy. The management voluntarily undertook a pay adjustment together with the staff and all of us had to double up on our roles. We went into survival mode – doing everything we can to innovate, finding ways to acquire new customers and doing things differently and better.

The result was a leaner, more productive and more cohesive LeeBoy when we finally turned the business around in 2015. That year, we achieved a record sales growth of more than 20% compared to the period before the 2009 financial crisis. More admirably, profitability improved by more than 30% due to our stronger foundation.

I believe strongly that a company has the responsibility to take care of its employees and also their families. During the crisis, I saw employees who lost their homes. Some were even forced to live in their cars. This really touched me and it became clear to me that it was my job to run the business well so that we could keep everyone employed.

Kelly Majeskie
President and CEO, VT LeeBoy

FAMILY CULTURE

The number of repeat customers at VT Halter Marine, in my view, is the strongest testimonial on the quality of our vessels, our track record for vessel deliveries, and the integrity and dedication of our people.

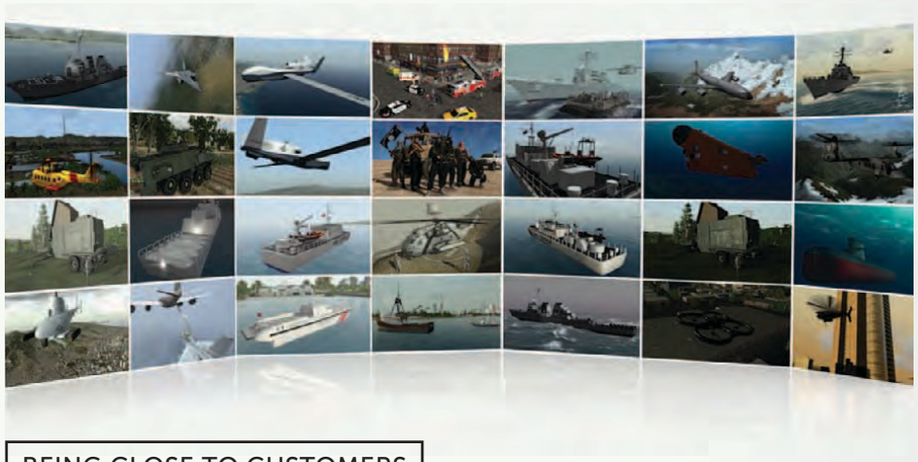
Our employees have included many multi-generation families – fathers, sons and grandsons who have all worked at our facilities. And because VT Halter Marine has provided jobs that supported these families, there's a certain allegiance from our shipbuilders to make sure the company is successful.

As a result, we've been fortunate to have experienced shipbuilders with long tenures, including many in the senior management who have risen through the production ranks. We owe this achievement to the family culture that binds our organisation.

I'll never forget how ST Engineering supported us after Hurricane Katrina left the Pascagoula yard six feet underwater in 2005. That was the costliest natural disaster and one of the five deadliest hurricanes in the history of the United States. We were greatly encouraged by the visits from the Chairman of ST Engineering and senior management of ST Marine.

We decided then and there to replace the expensive equipment damaged during the hurricane. Purchase orders were issued immediately and that proved to be the right decision because while all the other shipyards were scrambling to replace damaged equipment, we were the first to be back in full production.

Paul Albert
President and CEO, VT Halter Marine



BEING CLOSE TO CUSTOMERS

The story of VT MÄK is a classic tale of entrepreneurial success that started in a basement. As the world leader in modelling and simulation software developed for virtual networks, our innovations have always been rooted in a genuine desire to create real and practical customer value.

One of the ways we've done this is to give customers direct access to our software engineers. It's a service promise I call 'the engineer down the hall', which MÄK customers clearly appreciate as it significantly shortens the rectification time for any technical or software integration issues.

From a business standpoint, it has been advantageous for our engineers to be able to 'eat their own cooking'. Because they have to handle technical support, our engineers get to hear the joy and feel the pain. It encourages them to listen to the customer, incorporate more rigour and improve the product development process.

These days, customers walk into trade shows asking to see or consult their favourite MÄK engineers. I think the recognition speaks volumes about the competency and professionalism of our people.

Continuous efforts to incorporate advancements in virtual reality (VR), web-based and gaming technologies into its software products is the other winning factor. In the past, costly hardware like simulation domes had to be built to create immersive training environments. Nowadays, high-fidelity VR goggles are available at a fraction of the price, and we're staying ahead of the curve to factor such developments into our programming work to deliver pragmatic advantages to our customers!

Dan Schimmel
President and CEO, VT MÄK

STAYING AHEAD OF THE MARKET

VT Miltope is in the business of ruggedising sensitive electronic equipment to withstand the harshest environmental conditions. With over 40 years of engineering expertise, we set the benchmark to qualify for the term 'reliable in the extreme'.

There is great opportunity in equipment ruggedisation. Our mission is to become a leading player in this niche market. Furthermore, we're able to leverage synergies from intra-Group collaboration to deliver improved customer value and more robust solutions. The possibility of developing ruggedised packaging for satellite modems for VT iDirect would be a good example.

To maintain VT Miltope's position as a frontrunner of the industry, we are paying close attention to delivering solutions that are valuable and sustainable for the customer. Technology is evolving so quickly that we must always think one step ahead to adapt for upgrades and improvements, and to make a good solution even better!

Not surprisingly, there is great passion among our leadership to nurture innovation. We even share ideas and inputs with local universities to enhance the content of engineering courses to keep pace with industry trends and market demands. Internally, our engineers are actively engaged in broadening our expertise through new technologies, so we make sure we offer the challenges and opportunities to help people grow. It has enabled us to capture new market opportunities and kept us on top of our game.

Ed Crowell
President and CEO,
VT Miltope

TURNING OPPORTUNITIES TO OUTCOMES

PLANTING OUR FLAG IN BRAZILIAN SOIL

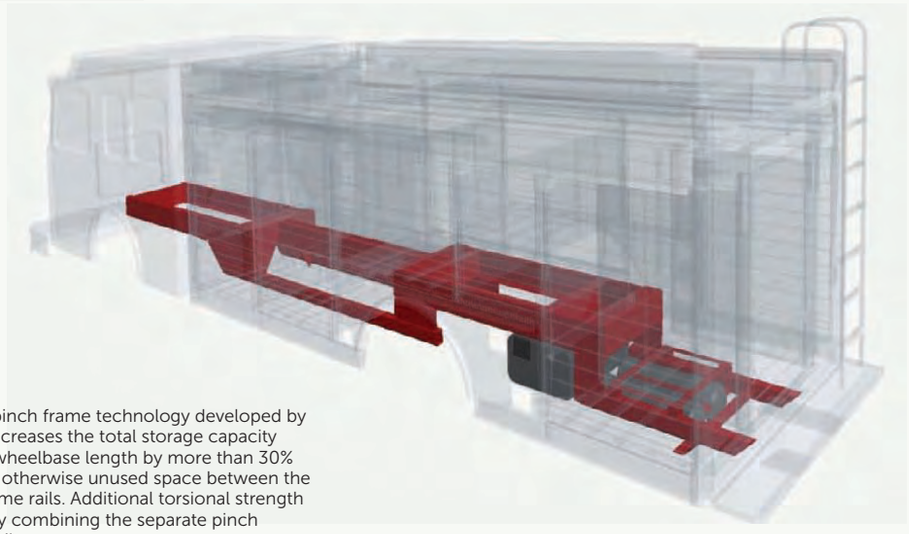
In July 2013, ST Kinetics acquired a majority stake in Technicae Projetos e Serviços Automotivos Ltda (Technicae), an automotive service company, to establish a foothold in the Brazilian defence market. Brazil was selected as it was the biggest economy in South America and a natural springboard into the rest of Latin America; the choice of partner in Technicae was based on the strong engineering knowledge and vast military MRO experience of its founding Executive Director, Mr Roberto Pina.

Since the acquisition, Technicae had won several contracts with the Brazilian Army, including the modernisation of 6x6 armoured vehicles, trucks and command and control shelters. Projects with other government agencies include vehicle maintenance for Brasilia's Fire Brigade and Military Police, and the upgrade of Sao Paulo Fire Brigade's fire trucks. In December 2016, it won its largest tender to date for the supply of diesel additives to the Brazilian Army. Technicae is next setting its sights on modernisation programmes for the armies of neighbouring countries.

Revitalised fire trucks for the Brasilia Fire Brigade.

> "We have achieved very good progress since 2013 but this did not come easy – we had to overcome many different challenges. Brazil's weakened economy was one; cultural and process alignment with the Group was another. There was also the need to win the trust of people to build honest and strong partnerships. The reason we have come this far and can go much further is because of the unfailing support and access to the full capabilities of ST Engineering.
>
> **Roberto Pina**
> *Executive Director, Technicae*

BECOMING AMERICA'S RESCUE LEADER



The drop/pinch frame technology developed by Hackney increases the total storage capacity in a given wheelbase length by more than 30% by utilising otherwise unused space between the original frame rails. Additional torsional strength is gained by combining the separate pinch and drop rails.

VT Hackney is home to "Hackney" and "Kidron", two trusted brands in America's transport industry whose aluminium beverage truck bodies and refrigerated aluminium trailers are commonly used in food and beverage delivery trucks owned by world-recognised brands.

VT Hackney is also America's leading builder of emergency support vehicles, operated by fire and rescue departments across the US. According to Mr Ed Smith, Director of Emergency Vehicles Group, who has been with the company since 1994, the one thing that has kept him going is the passion for making the company 'America's Rescue Leader' – an honour it has held for over 15 years.

An important feature of VT Hackney's design is the 'Pinch Frame' technology, which allows unused space beneath the frame of a truck to be converted into valuable storage. This provides a big advantage for both food and beverage distributors and emergency workers, who now have one-third more capacity for storage.

"The brutal attacks on September 11 was a turning point for the rescue agencies, who began to recognise the merits of extra storage capacity when they found themselves waiting hours for supplies and replenishment to begin the lifesaving missions. I'm proud that we've been able to offer solutions that fit the agencies' requirements perfectly. I consider myself very fortunate to be in a company that is delivering positive impact to society," Ed said.

TAPPING THE POWER OF THE TEAM

For Steve Miller, President of VT Hackney, being passionate at work is to care intensely about getting the job done well. "I've seen many at our Hackney and Kidron divisions, who exemplify this principle by placing the company's goals before their own interests," he said.

Take for example, the tender for six new prototype mail trucks by the US Postal Services to be delivered in 2017. When the company was down selected to develop the prototypes for trials and data collection, VT Hackney pulled together its resources in record time.

> "Everything happened in a whirlwind. Within two months, we set up a design centre in front of the office and reconfigured the factory floor to build the prototypes. Everyone recognised the importance of this project because of the substantial logistics tail that would ensue. Kidron was co-opted and they participated without hesitation even though this might compromise their performance in the short term. This is teamwork at its best.
>
> **Steve Miller**
> *President, VT Hackney*

READING
TRENDS

Building MRO Business from the Ground Up

> "When I arrived in Mobile in 1994, I was told that the company was in a precarious position. MAE had only one customer, FedEx, and if we failed to expand the business, we might have to close down the operation. None of us were ready to throw in the towel yet, so we would huddle around a small white bench outside the office every day, pondering how to tap the US markets.
>
> One of the right decisions we made was to hire more technical personnel with a deep understanding of the US aviation industry and culture. That convinced FedEx to let us do more PTF conversions as well as other heavy maintenance work on the Boeing 727s.
>
> We had to work really hard to prove that we had the right mettle and capabilities to be the logistics giant's new PTF conversion and maintenance service partner. The industry norm at that time for Boeing 727 PTF conversions was 120 days. We did it in 75 days. The business took off after that. Today, VT MAE supports FedEx in heavy maintenance for its fleet of A300, 757, 767 and MD-10 aircraft."
>
> **Stephen Lim**
> *President, VT Aerospace,*
> *President, VT San Antonio Aerospace*
> *and ST Engineering's longest-serving*
> *overseas postee*

While work from the RSAF continued to grow and was well supported through the efforts of Singapore Aerospace, the company aspired in the late 1980s to extend its existing capabilities to support the military MRO requirements of Asian and Middle Eastern countries. However, as opportunities in these areas were not significant then, Singapore Aerospace decided to venture into commercial narrow body and wide-body aircraft MRO, and thus began the journey of ST Aerospace becoming the largest airframe MRO player in the world.

The commercial airframe MRO business started in 1990 with the formation of SASCO. With limited experience in commercial airframe MRO, Singapore's Economic Development Board helped to persuade JAL and Singapore Airlines (SIA) to each take up a 10% stake in SASCO to give it a leg up. A group of technicians and managers, along with the systems and processes, from the then Singapore Aerospace Engineering Company (previously SAMCO and now STA Engineering) were transferred to SASCO to seed the effort. To strengthen its capability, SASCO started looking for overseas talent.

"As luck would have it, the British announced in 1991 that it was handing Hong Kong back to China in 1997. This resulted in a good number of highly experienced people joining us," said Mr Quek Poh Huat, the then President of Singapore Aerospace.

Although JAL and SIA provided some initial workload to SASCO, it was clear that the company needed a strong customer base to survive. "That break came with the Boeing 747 Section 41 work which involved heavy modifications to address a nose structure fatigue issue. While most MRO shops would take more than 60 days to complete the modification, we did it in 42," Poh Huat recollected. With each day of downtime equivalent to easily US$150,000 in lost revenue, '41 in 42' became ST Aerospace's key value proposition for many years onwards.

The next big gamble Poh Huat took was to set up Mobile Aerospace Engineering (MAE) in 1991. "The US had the biggest market for non-captive commercial aircraft which made it very attractive for third-party MRO shops. It also had a well-regulated aerospace industry," said Poh Huat. "We decided on Mobile, Alabama because it was a 'right-to-work' state and there were also several large hangers decommissioned by the US Air Force. The warm southern climate also allowed us to work on the tarmac all year round."

Mr Richard Liow, General Manager of SA Engineering, was put in charge of MAE. He was succeeded by Mr Bob Tan a few years later. Mr Lim Lu Hock, who was then overseeing MAE, recalled, "MAE was a nobody in those days, and we struggled to keep the company running in the midst of a global recession. When Bob took over, he had a strong sense of responsibility for the employees and worked very hard to keep them on the job. But the pressure was just too great at one stage, and we either had to let some of the staff go or pull out of the US entirely."

The project that spared MAE from a premature closure was FedEx's Passenger-to-Freighter (PTF) conversion work. "I remember it was a rather odd contract with a firm requirement to convert one aircraft and an option for another 11 planes," said Lu Hock. "The contract went to three companies, including MAE. We proved ourselves and were awarded the conversion for the rest of the fleet. As the requirement for PTF grew in the subsequent years, SASCO complemented MAE in carrying out some of the conversions."

With the workload at MAE stabilised, ST Aerospace decided to expand to another site to grow its aircraft MRO work. By 1997, the US MRO work had grown significantly to require a second facility. ST Aerospace purchased a facility at Dallas Love Field at an attractive price in 1997 and renamed it DalFort Aerospace (DalFort).

Said Mr Tay Kok Khiang, who was President of ST Aerospace between 2001 and 2010, "Over time, the drawbacks of DalFort began to show. Its limited capacity to take up to only six narrow-body aircraft hindered our ability to achieve the critical volume to become cost-effective. It was also located in a high-cost area and talent retention became a big issue due to keen competition for MRO personnel from the many major US airlines that operated in Dallas. In 2003, Dalfort was closed as it was not profitable and assessed to have limited potential even if there was a turnaround."

"We had also been considering the Dee Howard Company previously but did not proceed due to its high asking price. When the company filed for bankruptcy in 2002, we acquired the facility and set up San Antonio Aerospace (SAA)," Kok Khiang continued. "SAA had a large capacity but no work. ST Aerospace needed to secure a signifcant customer. At that time, UPS was looking for a strategic MRO provider to support its growing fleet. Management of UPS and ST Aerospace, struck a mutually beneficial agreement. It's a relationship that has continued to today."

Besides the US, the next concentration of civil aviation was in Europe. However, European airlines had largely operated on the basis of having its own MROs. With anticipation that European airlines would, in time, follow the outsourcing trend in the US to be more cost efficient, ST Aerospace decided to venture into Europe. "In 2002, we set up a joint venture company, Bournemouth Aviation Services Company (BASCO) with FR Aviation to provide heavy maintenance for commercial aircraft flying into the UK," said Kok Khiang.

"The challenge of securing MRO jobs was significant as European airlines had their own MRO shops and they were competent. While we had hoped the trend for MRO outsourcing would catch on in Europe, as it did in the US and Japan, it did not. We then took a decision to shut down BASCO in 2006 and re-prioritise resources to other growth areas."

Undaunted by its earlier experience in Europe, ST Aerospace continued to seek opportunities to expand its heavy engineering capabilities in Europe. This time, it leveraged its PTF capabilities instead of its MRO experience. In 2012, it took up a 35% stake in Airbus' Elbe Flugzeugwerke (EFW). This was increased to 55%, making EFW an ST Aerospace subsidiary in 2016.

China is another key market under ST Aerospace's radar since the early 1990s. Realising that the Chinese aviation market would hold great potential for airframe MRO, ST Aerospace set up Shanghai Technologies Aerospace Company (STARCO) with China Eastern Airlines in 2003. To maintain the high quality of standards expected of an ST Aerospace company, STARCO invested heavily in technology, infrastructure and training, and expanded its operations from Hongqiao Airport to Pudong Airport. ST Aerospace also set up ST Aerospace (Guangzhou) Aviation Services, a joint venture airframe MRO company with Guangdong Airport Authority in 2014. Besides serving Chinese airlines, ST Aerospace's other key focus is to serve foreign airlines operating into China. Many of these are ST Aerospace global customers who prefer to continue working with the company.

Said Mr Ang Chye Kiat, ST Aerospace's Executive Vice President of Aircraft Maintenance and Modification, "It has been almost 30 years since we first ventured into the commercial airframe MRO business. The pioneers had accurately anticipated the rising trend for outsourcing of airframe heavy maintenance by airlines and airfreight operators, and worked hard to capture the opportunity. It is our job to build upon their achievements, and most importantly, continue to keep our customers' aircraft flying safely."

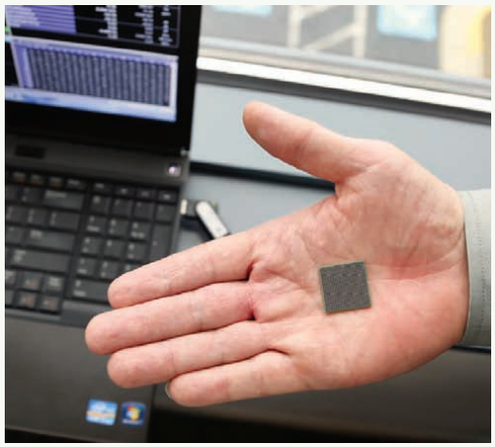
READING
TRENDS

Connecting the World

VSAT satellites atop VT iDirect's headquarter at Herndon, Washington D.C., US.

Not many would know that more than half of all Very Small Aperture Terminals (VSATs) installed on board ships are made by VT iDirect. VSATs are "mini ground stations" that receive and transmit satellite data. For cruise passengers, these devices ensure continued network access even when you are on the high seas.

It all started in 1994 when VT iDirect developed an IP-based system (IP or Internet Protocol is the method where data is sent from one computer to another) to relay satellite data over the Internet. This breakthrough made it possible to connect with anyone regardless of how remote the location is. This makes the VSAT a valuable communication asset for aviation, emergency, scientific, military and offshore operations.



Revolutionary new ASIC chipset that redefines performance and efficiency levels for satellite networks.

The real turning point came in 2010 when VT iDirect secured a US$60 million deal to provide Ground Network Infrastructure (GNI) and end-user terminal technology for Inmarsat's multi-billion dollar Global Xpress (GX) satellite service.

"Inmarsat was looking to shake up industry benchmarks on pricing and delivery. They needed a reliable partner with the competencies to develop a fully integrated ground platform that would support their new Ka-band network and allow them to deliver a global, high quality service," recounted Ms Mary Cotton, VT iDirect President & CEO (2007 to 2017). "Although we were relatively small at that time, Inmarsat came to us because they saw in us the passion and drive to deliver the best solution. We were extraordinarily focused on ensuring that Inmarsat was successful."

The contract put VT iDirect on the forefront of a new satellite technology. Its satellite terminal modules would be the go-to solutions for any GX service provider. "As GX started calibrating protocols to our equipment, iDirect naturally became the industry standard," she proudly added. "The contract affirmed iDirect's leadership role in the satellite industry. It is a great responsibility, and we are very respectful of the opportunities we have been given."

Having stepped up to the challenge with an engineering headcount that went from 100 to 350 in eight months, Mary can attest to why fast growth can be tricky business, especially

when it involves mindset change. "Because of technology shifts over the last 10 years, we've had to move from hardware to software development. It didn't make sense to create more hardware variants or replace terminals in the field, when upgrades were being tackled at the software level."

The hardest part about the transition? Convincing personnel who were accustomed to building hardware that software is a thing as well! "Obviously, we've had to bring in more skills and experience as part of our expansion; but we're also extremely mindful to give people the space to learn and practice what they observe. People would naturally contribute if you give them a chance. We can't expect any real change just by telling people to do so," she shared.

According to Mr Kevin Steen, the Chief Operating Officer who took over Mary as President & CEO, it would be "interesting times ahead" with 5G networks and the Internet of Everything becoming more pervasive. "The prices of satellite bandwidth will become a fraction of what they were, thanks to new entrants like Google and Facebook. We're excited by the changes, and believe there are plenty of opportunities for us to innovate and expand our offerings. iDirect will continue to make a difference in this industry," he said.

A TRAILBLAZER IN HER OWN RIGHT

Having started her career in finance, Mary never imagined a future in satellite communications. Not only has she been successful, she is also one of the few female leaders in the business.

"I don't think there's any particular challenge for women coming into this business. You've still got to do your work and build the relationships. For me, the energy and creativity behind making technology that has an impact on people and markets – that just keeps me going. If anything, I've seen women who have impeded themselves because they feel a need to be better than everyone else.

Mary Cotton
President & CEO, VT iDirect (2007 to 2017)

8 OF THE TOP 10 MARITIME SERVICE PROVIDERS (by revenue)

use iDirect

MORE THAN 50% OF ALL VSAT REMOTES

deployed on vessels are made by iDirect

7 OF THE TOP 10 MARITIME SERVICE PROVIDERS (BY UNIT)

rely on iDirect as their platform of choice

SATELLITE OPERATORS

Inmarsat, Intelsat and Telenor launching HTS constellations targeted at maritime using iDirect

READING TRENDS

Running Man

> A high level of reliability, availability, maintainability and safety are critical to SMRT Buses' ability to launch buses on time, every time and to keep downtime in the workshop to a minimum. I am pleased with the after-sales support as well as sound technical advice on parts and inventory management provided by ST Kinetics.
>
> **Tan Kian Heong**
> *Managing Director of SMRT Buses & Road Services*

ST Kinetics has a long relationship with Germany's MAN Truck and Bus (MAN). It has been MAN's exclusive importer in Singapore for more than 30 years, starting with the after-sales support for MAN trucks to MINDEF, and the sales of commercial MAN trucks and buses in 2008.

Mr Vincent Kee, Manager of Kinetics Automotive Services, recalled the MAN bus business taking off after SMRT's city bus trial in 2010 that led to the first order by SMRT for 200 units of the single-deck city bus and the subsequent purchase of another 202 optional units.

"With the success of the single-deck buses, we introduced MAN's 'Bendy' articulated buses to the market and initiated the development of a right-hand drive double-decker with MAN in 2015. We won several heavily contested tenders called by SMRT and Land Transport Authority (LTA). Both bus types were delivered between 2014 and 2017. Of SMRT's fleet of 1,400-over buses, more than half are MAN buses supplied by ST Kinetics," said Vincent.

In 2015, ST Kinetics won a LTA tender to develop a future concept bus to improve commuter flow, carrying capacity as well as the safety and comfort of commuters and driver. The prototype, with its three doors and two staircases, was displayed at the LTA Bus Carnival. In 2016, ST Kinetics also designed and built a 3-door single-deck concept bus with similar objectives to improve capacity and commuter flow at peak hours. The single-deck concept bus was showcased at the Singapore International Transport Congress Exhibition 2016 and won the accolade as 'the Jewel of the Show' from a Hong Kong bus magazine.

Said Vincent, "By working with our partner, MAN, to offer better bus design and lower total cost of ownership to customers, ST Kinetics is the only bus supplier to offer a full range of city bus platforms in Singapore."

Vibrating driver seat.

Information display panels.

BUS SERVICE 143

In 2017, a 3-door bus prototype designed by ST Kinetics using a MAN chassis was put on road trials by LTA to improve commuter flow and travelling experience. Bus Service 143 had an additional staircase to facilitate commuters from the upper deck alighting from the third door. Other unique features included USB charging points, information display panels and a vibrating seat to keep the driver alert.

USB charging port.

Pram & wheelchair bay.

IDENTIFYING
NEW
BUSINESSES

Engineering a Cleaner Future

ST Marine's subsidary, STSE Engineering Services (STSE Engineering), was set up in 1996 to capture new opportunities in land-based engineering services. Early focus was on port automation, transportation, environmental engineering and energy. An example was supplying light-weight blast shelter doors for public flats built by the Housing and Development Board, as part of Singapore's civil defence programme.

Taking stock of the growth opportunities in environmental, renewable energy and offshore subsea markets in 2007, STSE Engineering leveraged its systems integration and marine engineering background to branch into environmental engineering projects. The ambition was to provide turnkey solutions in the design and development of plants and installations aimed at cleaner environments.

The first environment-related contract was secured in 2007 for the design and supply of a waste transfer station in Doha, Qatar, for Keppel Seghers. A transfer station is a facility where waste is treated and compacted before movement to landfills or incineration sites, thereby significantly reducing transportation costs and resources. Today, STSE Engineering has delivered projects relating to waste management and logistics, as well as water and wastewater treatment in countries such as Brunei, India, Thailand and the United Arab Emirates.

Backed by its successes, STSE Engineering broke into the China market in 2010. Through its subsidiary, ST Environmental Services and Technology Ltd (STE&T), which specialises in the handling and treatment of municipal solid waste, it has delivered a design-and-build contract for a refuse transfer station in the Wuhan Donghu High-Tech Zone, and a design, build, operate and transfer contract for a pneumatic waste collection system in Sino-Singapore Tianjin Eco-city. The solutions by STE&T have increased the efficiency of waste transfer from residential homes to waste collection points. Contact between waste and the environment during transportation has been reduced and the quality of air in the surrounding area has improved.

On the home front, the expansion of the Kranji NEWater plant for the Public Utilities Board in 2016 was a significant project for Singapore. Through STSE Engineering's design-and-build solution, the national water agency was able to increase its volume of NEWater production by five million gallons per day.

Sungai Paku Engineered Landfill in Brunei.

An integrated Waste Management System was successfully delivered to the Brunei Economic Development Board in 2016.

> “Working on environmental engineering and infrastructure projects has filled me with a sense of satisfaction. My role allows me to develop sustainable solutions with a positive impact on society. As engineers imagining the environment for the future generations to come, I am thankful to be placed in a profession that can change our world – not just study it.
>
> **Ong Xiang Rong**
> *Senior Engineer (Projects), STSE Engineering*

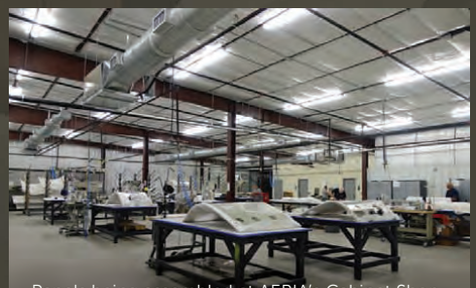
SUSTAINABLE ENVIRONMENTAL SOLUTIONS FOR BRUNEI

The Integrated Waste Management System (IWMS) for the Brunei Economic Development Board (BEDB) can be counted among STSE Engineering’s landmark projects. It comprises a waste transfer station at Sungai Akar, a specially constructed landfill at Sungai Paku, and a suite of supporting facilities and components. The facility was completed in 2012 and handed over to the customer in 2016 after a four-year operations and maintenance period. Today, the transfer station compacts up to 500 tonnes of municipal and commercial waste from Bandar Seri Begawan and the surrounding Muara district. At the engineered landfill, the waste is further compacted into cells lined with geo-synthetic liners to contain odour and leachate, protecting the environment.

Acknowledging the significance of the IWMS, Dato Paduka Timothy Ong, Acting Chairman of BEDB, said, “This project will contribute to a cleaner Brunei in line with the wishes of His Majesty’s government for Brunei to be a model of environmental good practice.”

IDENTIFYING NEW BUSINESSES

Launching into Cabin Interiors



Panels being assembled at AERIA's Cabinet Shop prior to installation on a VIP aircraft.

If you ever fly JAL, ANA, Air Canada or AirAsia X aircraft, there is a good chance the aircraft interiors were fitted out by ST Aerospace. Said Mr Chang Cheow Teck, former President of ST Aerospace, who led the company to branch into the cabin interior business in the early 2010s, "In looking for ways to provide more comprehensive services with higher value content to airline customers, we found airlines competing to refresh cabin interiors with greater frequency so as to deliver better flight experience to passengers in their class of travel. We saw the potential to become a strong player in cabin interior modification with our deep engineering design capability, and we could also add a new line of customers to our MRO business."

Initial projects by VT SAA had involved the conversion of single-classed Boeing 737s and Airbus A320s into business-and-economy class configurations or vice versa. In 2011, VT SAA acquired DRB Aviation Consultants Inc., an FAA-designated Airworthiness Representative focusing on supporting VIP modification. The following year, it acquired Volant Aerospace, a company specialising in Boeing interior parts. This led to more extensive turnkey modification projects involving design, engineering, customisation, fabrication, certification and

ST Aerospace has performed VIP completions for more than 50 Boeing and Airbus aircraft.

installation of cabin interior parts ranging from space and ceiling panels to overhead bins and lavatories.

Ms Huang Liyan, ST Aerospace's Head of Cabin Interiors, has found it rewarding that her engineering work has provided passengers with safe and comfortable journeys. "Cabin modifications are just like home renovation projects but with a very stringent certification process. Besides meeting airlines' requirements, all alterations, right down to the material selection and testing, must comply with the aviation regulations," she said.

CABIN INTERIORS FIT FOR A KING

Mr Ron Soret, Vice President and General Manager of AERIA Luxury Interiors at VT SAA, is the expert on the lifestyles of the rich and famous when it comes to luxury aircraft furnishings. VT SAA's big orange hangars were where the first Boeing 747-300 jumbo jet belonging to the King of Saudi Arabia had been retrofitted in the mid-1980s, when the facility belonged to the Dee Howard Company (DHC), which established the legacy of VIP completions for narrow- and wide-body aircraft. DHC was acquired by ST Aerospace in 2002 and became VT SAA, before the VIP interior business was re-launched as AERIA in 2012.

"Launching AERIA has allowed ST Aerospace to elevate its position in the competitive VIP completions and refurbishment industry. Over the last few years, we have upsized our infrastructure and grown to more than a hundred highly skilled personnel," Ron said. AERIA also owns one of the largest and most technologically advanced 3D printers in the industry. This has helped to expedite the development and fabrication of mock-ups, proofs of concept modelling, production parts, as well as intricate decorative features in a highly productive and cost-efficient manner.

In 2016, an AERIA Singapore division was set up at Seletar Aerospace Park to cater to rising demand for bespoke cabin interiors from Asian and Middle Eastern customers. The new facility enabled AERIA to provide a one-stop service for maintenance, refurbishments and completions outside of the US.

SIT TIGHT AND BUCKLE UP

Not all seats are made equal, especially aircraft seats. Built to keep passengers safe during flight, aircraft seats are required to clear a number of certification checks before they can be installed in an aircraft. For Dr Zheng Guo Ying, Director of Engineering, ST Aerospace Aircraft Seats, the foremost criteria for a good aircraft seat are: safety, comfort and a lightweight design.

"We subject our seats to a series of rigorous safety inspections, otherwise known as 'crash and burn tests'. The seat structures must be able to withstand at least 16G of stress, while the fire-resistant materials used must not emit smoke that can foil an evacuation attempt," Dr Zheng elaborated. For extra passenger comfort, ergonomic features like adjustable lumbar support and a unique teardrop-shaped headrest are incorporated into the design. Durable lightweight composites are used to reduce the overall payload and cost of each flight, particularly for the long-haul routes.

"As one of few companies with authorisations from the aviation authorities in China, Europe and the US in cabin interiors modifications, it's time to take our offerings upstream with our superior cabin interior products and go the extra mile to exceed our customers' expectations," Dr Zheng added.

> "Our engineers have worked so closely with AERIA that we established a satellite office inside their hangar. The co-location has helped ST Aerospace to grow in this exciting industry with a strong local legacy by drawing on our track record in engineering and certification for VIP and corporate aircraft completion.
>
> **Steve Chapman**
> *Vice-President, VT DRB*

Staying on Track with the Rail Business

In 1984, ST Electronics made its first foray into commercial business, leveraging the knowledge and technologies it had acquired as a defence contractor. The ability to offer solutions for effective and efficient public transportation systems was one of the areas where it has found success.

The development of Singapore's Mass Rapid Transit (MRT) system around the same time created the impetus to move into rail electronics. While the initial capabilities were focused on project management, systems installation and maintenance in Singapore, the engineers from ST Electronics relentlessly worked their way up the value chain to become systems integrators by 1992.

The breakthrough arrived in 1993 when ST Electronics secured its first overseas rail contract for communications systems for Taipei MRT's Nankang and Panchiao Lines. More projects and opportunities would ensue in Taiwan and the Philippines that by 2001, ST Electronics had commenced productising its railway electronics solutions.

It was the Singapore experience that enabled ST Electronics to pitch its products against those of well established international product houses and to emerge equal, if not better, in terms of quality and reliability. It drove the team to further develop its capabilities for overseas growth.

ST Electronics made its foray into the rail electronics business when it secured the contract for Singapore's first MRT communication system.

In fact, the focus on capability, product and technology developments, coupled with process improvements, has remained at the heart of ST Electronics' business strategy. Project engineers are constantly updated and exposed to best practices and the latest technologies.

"While we seized every opportunity to expand rapidly to more cities, efforts were ongoing to train our engineering teams and localise our design skills to meet the requirements of our overseas entities and long-term partners. To stay competitive, we had to be cost-effective and yet, quick and efficient with our customer support. That was how we managed to move ahead in this highly challenging yet exciting journey," reflected Mr Yong Thiam Chong, President of Large-Scale Systems Group (LSG), ST Electronics from 2002 to 2010.

Today, ST Electronics is one of few companies in the world with a full suite of rail electronics solutions. It has moved up the ladder from delivering individual systems to managing billion-dollar electrical and mechanical turnkey projects in partnership with rolling stock, power, track work, depot and signalling suppliers. Its track record has expanded by leaps and bounds with projects delivered in 34 major cities from Asia to America.

Undaunted by the lightning pace of technological changes, ST Electronics is committed to greater product differentiation with higher value-add to stay ahead of the curve. "The rail electronics business was built up over three decades from very humble beginnings. I attribute our success as a leading player in the regional market to the wisdom and foresight of our past business chiefs, the sheer determination and perseverance of all staff, and the continued support of our customers and partners. The best way of showing our appreciation to all stakeholders is to strengthen the foundation that's been laid, create greater value for our customers and take our rail business to a new level," enthused Mr Wong Loke Hin, President of LSG, ST Electronics.

RAIL PROJECTS IN 34 CITIES OUTSIDE SINGAPORE

> "In retrospect, two factors have combined fortuitously to enable the initial success with our earliest contracts for the Singapore MRT lines. Firstly, our experiences in the Changi Airport Building Automation Project convinced our partners that they made the right choice; and secondly, our then General Manager Mr Chong Kok Pan kept his faith with us and cleared many of the impediments along the way.

Siow Keng Cheng
General Manager, LSG (1997– 2002)

> "As an important partner to our efforts since 2009, ST Electronics' experience and capabilities in implementing the Automatic Fare Collection system for the BTS Sukhumvit and Silom extension lines have made a difference in our ability to execute BTS projects on schedule and to meet the performance standards expected of us.

Manit Techaapichok
Former Managing Director,
The Krungthep Thanakom Co., Ltd

> "ST Electronics has consistently demonstrated that it is aligned with the goals of its customers, pursuing excellence at all times while meeting the varied needs of the project and maintaining rigorous discipline to work safely under demanding circumstances. I am glad to congratulate and commend ST Electronics for their significant contributions to the achievement of providing a safe and reliable rail transport system for the commuters of Singapore.

Ong Boon Ann
Former Director (Electrical & Mechanical)
Circle & Downtown Lines, LTA

IDENTIFYING NEW BUSINESSES

TeLEOS-1

Near Equatorial Orbit (NEqO)
Earth observation satellite

TeLEOS-2

The next-generation
Earth observation satellite

TeLEOS-1:
Singapore's first commercial Earth observation satellite launched into a 550km NEqO for remote sensing applications.

- Electro-optic camera
- Clear weather, daylight imaging
- On-board recording: 32 GB
- Downlink transmission: 300 Mbps
- Mass: 400 kg

TeLEOS-2:
The satellite will carry a made-in-Singapore Synthetic Aperture Radar payload capable of providing 1m resolution data. It provides round-the-clock and all-weather imaging opportunities and is able to penetrate thick cloud cover.

- Synthetic Aperture Radar
- All-weather, day & night imaging
- On-board recording: 500 GB
- Downlink transmission: >800 Mbps
- Mass: ~750 kg

Space for Growth

The TeLEOS-1 Earth observation satellite is one of the most complex and challenging engineering systems ever developed in Singapore. It was developed by ST Electronics (Satellite Systems), a joint venture between ST Electronics (Satcom & Sensor Systems), DSO National Laboratories (DSO) and Nanyang Technological University.

TeLEOS-1 was successfully launched into orbit in end-2015. It is the first commercial Earth observation satellite in a near equatorial orbit that is designed and developed in Singapore and has had been in operation since. Its near equatorial orbit allowed it to transmit high resolution images to the ground control station in greater frequency and under more varied sun-lit conditions than was possible with other satellites of its class.

Ms Grace Parn, a senior engineer in the TeLEOS-1 structure and mechanical team, recalled the moment when the satellite was launched, "There was a deep sense of quiet pride and personal victory in each of us as we watched the rocket gradually vanish into the sky. I would never have imagined I could ever participate in a major project like this when I first took up engineering."

The successful development and operation of TeLEOS-1 was a major milestone in ST Electronics' efforts to build indigenous capabilities in satellite systems. "Behind every successful satellite launch is a series of what-ifs that must be addressed so that every component and every part work perfectly as one. The margin for error is incredibly low. And that accounts for only half of the success. The other half is in the satellite's ability to survive first the launch and then the harsh environment in space to operate for the next five years or more. All critical sub-systems, for instance, were designed for redundancy to make the satellite resilient against failure as we will not be able to go up there to make any kind of repair. Not yet anyway," said Mr Ong Kien Soo, Vice President & General Manager, ST Electronics (Satellite Systems).

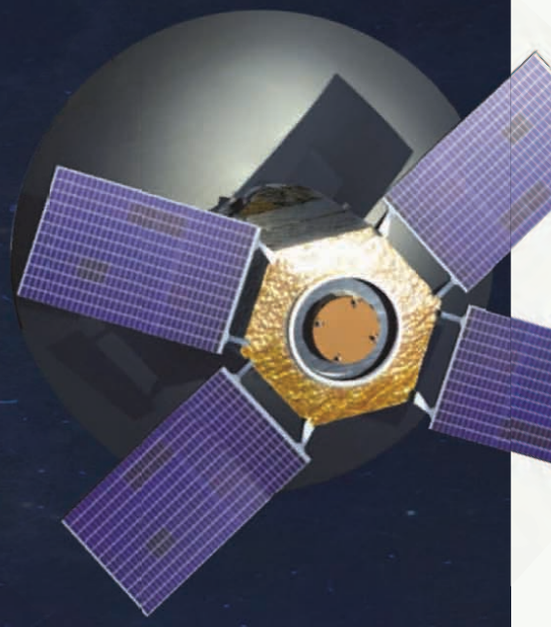
The challenge fell on the team to factor reliability into the satellite's systems and to minimise the chance of failure. Every part of the satellite was carefully designed and developed using high-fidelity modelling and simulation before it was subjected to rigorous functional and environmental testing.

"We have to ensure there were no weak links in the sub-systems that could compromise the satellite's overall performance or its lifespan. A set of stringent quality assurance processes was put in place and we adopted industry best practices in the design, implementation and validation of the satellite," said Kien Soo. "At the integrated satellite system level, we subjected the design and implementation to a variety of rigorous tests. Vibration and acoustic tests were conducted to certify the satellite would be fit for launch, and thermal vacuum and auto-compatibility tests were done to ensure the satellite could operate in the harsh environment of space."

For the team's innovative efforts, it was awarded the prestigious President's Technology Award in 2016 and became the first engineering team to receive this top honour from Singapore President Tony Tan.

Said Mr Tang Kum Chuen, Deputy President of ST Electronics, "The successful operation of TeLEOS-1 is a testament to ST Electronics' capability in precision engineering design and development of complex system. Space is often reckoned as the final frontier and this engineering feat epitomised the ever-exploring, never-say-die spirit of our engineers. We are now ready to take on more challenging engineering tasks to create value for our stakeholders."

Engineers installing star trackers - primary attitude determination system - on TeLEOS-1.



TeLEOS-2

In 2017, ST Electronics partnered with the Defence Science and Technology Agency (DSTA) to develop the next-generation Earth observation satellite, TeLEOS-2. The satellite would carry a Synthetic Aperture Radar payload capable of providing images in all-weather conditions during day or night to support the satellite imagery requirements of government agencies, including the Civil Aviation Authority of Singapore, Maritime and Port Authority of Singapore, National Environment Agency, MINDEF and Ministry of Home Affairs. The development of TeLEOS-2 will enhance ST Electronics' commercial satellite imagery services, providing multi-modal and high responsiveness features to its customers.

SELLING TO THE WORLD

Going Global

ST Engineering's international achievements in recent decades can be traced back to the formative years. Behind the glorious tales of marketing trips and international exhibitions is a story of perseverance in an extremely challenging industry dominated by few players.

Uniquely Unicorn

Top: Lai Chun Loong with Paul X. Kelley, then Commandant of the US Marine Corps.

Middle: Demonstration of Ultimax 100 Light Machine Gun.

Bottom: Loh Chuk Yam and Lai Chun Loong with former Sultan of Johor and Goh Chok Tong, former Prime Minister of Singapore at Asian Aerospace.

Top and Bottom: Photo courtesy of Lai Chun Loong

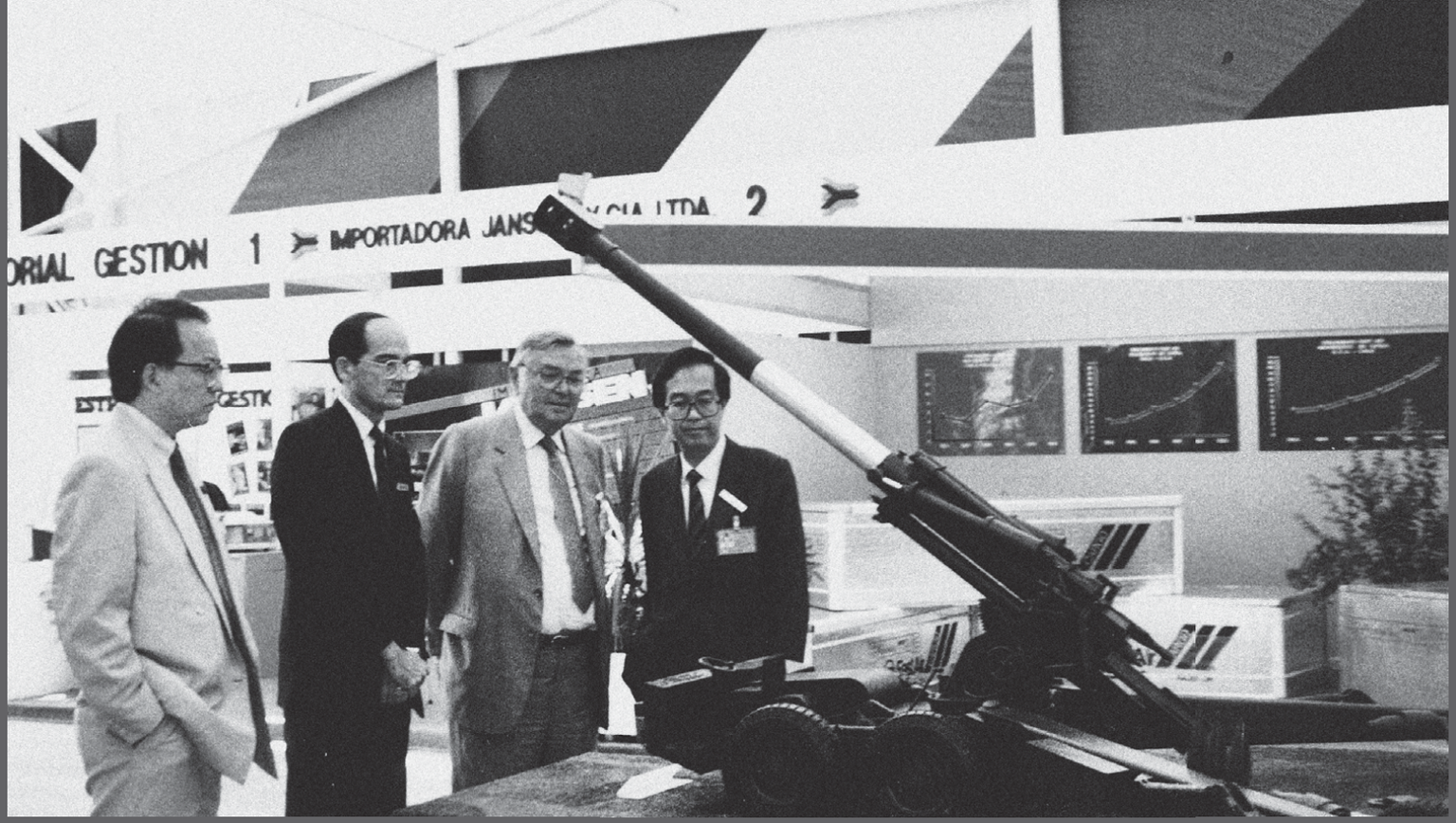
Around the time when the defence industry was achieving breakthroughs in design and development, a business unit named after a mythical creature was making waves overseas. Unlike its sister companies, Unicorn International (UI) was not known for its engineering prowess. Rather, its role was to market Singapore's defence solutions abroad and to source for defence capabilities required by MINDEF and the SAF.

Incorporated in 1978, UI was the brainchild of Dr Goh Keng Swee. As pointed out by Mr John Chiew, General Manager of UI from 2003 to 2005, "Many ST Engineering companies have had their names changed in the past, but not Unicorn! Our name was retained to honour the late Dr Goh, who bestowed it."

Dr Goh had tasked Mr Kua Hong Pak, the Managing Director of Sheng-Li, the forerunner of Singapore Technologies, with the responsibility of setting up UI. Its first mission was to handle the export and after-sales support for Sheng-Li's six main companies, namely Chartered Industries of Singapore (CIS), Ordnance Development Engineering (ODE), Singapore Shipbuilding and Engineering (SSE), Singapore Electronic and Engineering (SEEL), Singapore Automotive Engineering (SAE) and Singapore Aerospace Maintenance Company (SAMCO).

"It was challenging doing defence business internationally in the early years. We had to participate in defence shows, prove our products and make marketing trips to all corners of the world – no one's heard of a Singapore defence industry back then," John continued.

In many ways, ST Engineering's global marketing successes today were preceded by these earlier efforts to make inroads into every continent. Mr Stewart Yen, General Manager of UI from 1988 to 1999, added, "I remember when we were exporting mortars and ammunition in the



Stewart Yen, John Chiew, Carlos Honzig & Lai Chun Loong at FIDAE International Exhibition, Chile.
Photo courtesy of John Chiew

1980s and 1990s to government customers in the Middle-East, Africa, Asia Pacific and South America. Our marketers sailed the seven seas in search of markets, organising product demonstrations in faraway exotic places. The exports helped us achieve economy of scale in our production, and at the same time, allowed us to battle-test our equipment."

According to Mr Cheng Tee Yeow, General Manager of UI from 2005 to 2013, "UI's past Board of Directors included prominent public figures like the late President S R Nathan, and top civil servants such as Mr Philip Yeo and Mr Peter Ho. It was through their leadership and foresight that UI was able to venture overseas to make a name for the Singapore defence industry. Their pioneering spirit continued to impress and inspire me and my team when I was managing UI."

In fact, the entrepreneurial spirit of UI's pioneers is evidenced by the numerous business ventures and start-ups, ranging from a flight leasing subsidiary dealing with military tow target and air ambulance services, to hotel management and commercial security products and services.

Photo courtesy of the National Archives of Singapore

Progressively, some of these activities were handed over to other entities within Singapore Technologies.

Through corporate restructuring over the years, UI's responsibilities have evolved. Since 2002, the role of international marketing has come under ST Engineering's Head of International Marketing, who works with the respective marketing teams from the four business sectors. Subsequently, UI has been focusing on agency representation and specialising as a sourcing and consultancy house for military, homeland security and healthcare products. It partners with prominent global companies to deliver a wide range of cost-effective solutions for air defence, firepower, mobility, protection and robotics.

Said Mr Jimmy Mak, General Manager of UI since 2013, "Dr Goh's vision has inspired us to constantly excel and serve our customers well. We will continue building bridges with our partners and customers, and innovate with other business units to strengthen our core to serve our customers in MINDEF, the Ministry of Home Affairs and the Ministry of Health better."

SELLING TO
THE WORLD

Earning our Stripes among the Big Boys

Demonstration of Bionix at Fort Knox USA for the US Army Interim Armoured Vehicle Programme.

Mr Patrick Choy stepped on board ST Engineering just in time to spearhead its marketing bid in the US with the Bionix Infantry Fighting Vehicles. The former Executive Vice President of International Marketing (IM) remembers his dilemma at that point, before any of the Group's automotive platforms had witnessed any global success, "How do you gain access to global markets when you've got nothing to show?"

He resolved that ST Engineering would have to make a name as a global defence contractor that could help customers to develop their own capabilities for specific requirements. "That was the key difference in forming IM. To me, it was no longer enough to just make and sell arms.

"We didn't win the US programme, but we gained tremendous visibility as a credible contractor, and that had been strategic to proving ourselves in a developed market – just like the big boys. Quite frankly, if we're good enough for the US to take notice, the rest of the world would too," explained Patrick, who is now Executive Vice President for Strategic Programmes.

Photo courtesy of TheNational.

Patrick Choy and the Crown Prince of Abu Dhabi at IDEX 2015.

The STK 40mm Automatic Grenade Launcher has been sold to over 15 militaries around the world.

Thus began the focused quest to "create our own unique selling propositions", as Patrick puts it. "Our experience in engineering solutions like the Landing Ship Tank and FH2000 artillery gun that required low levels of manning became a winning factor. We also banked on our design philosophy, which has been honed through efforts to unburden fighting forces. For example, we leverage advanced materials, robotic and smart technologies, as well as greater connectivity to equip forces for a 'multiplier effect'. These capabilities empower the troops to operate with greater efficiency, and to communicate in real time with fellow users, adjacent units and higher commands. This has drastically shortened decision cycles, which is crucial in the battlefield," the retired brigadier-general added.

When pressed to share one of his many marketing war stories while serving as the Head of IM, Patrick revealed, "When Mr Boon Swan Foo was the P&CEO, he insisted that I arranged for him to see the US Secretary of Defence as part of our Bionix campaign. We fought tooth and nail, like pit bulls, acquiring connections and making these things happen. We even gate-crashed a constituency tea party once, just to see a senator in Washington DC!"

In a way, it is IM's role to create access for the marketing teams from the four business sectors. "There are many more stories involving private audiences with kings and sheiks, and courtesy calls on presidents and prime ministers that have paved the way for subsequent successes at the business sectors!" he hinted.

Patrick attributes the Group's defence export success to several elements. "Customer-centricity is definitely one, given our experience in 'cradle-to-grave' services – from customised solutions, through to maintenance support and upgrading. With defence, however, some customers prefer to co-own the development, which means we must be prepared to explore technology transfers, set up localised production and even establish bigger local presence."

ST Engineering has come a very long way to become a recognised global player. Today, it has a proven defence export track record in over 40 countries, as well as battle-proven products such as the Warthogs for the British Army, 40mm family of munitions, Super Rapid Advanced Mortar System, Landing Platform Dock and Offshore Patrol Vessel. "As markets mature, we will have to move up the value chain to demonstrate continued commitment as a long-term defence partner. It's the only way to stay on the customer's radar," Patrick concluded.

When asked about his vision for international marketing, Mr Chew Men Leong, ST Engineering's Chief Marketing Officer, said, "We will continue to build on the successes in ST Engineering's journey in internationalisation. As we mature as a Group, we will further grow both commercial and defence exports in a bigger way and break into new territories on top of our traditional markets. We are putting in place a more robust marketing framework to strengthen collaboration across the four business sectors and offer comprehensive and integrated solutions to our customers. We have identified strategic markets and domains where we want to focus our resources on and will continue to explore and develop invaluable partnerships in both the public and private sectors to augment our offerings."

> "Singapore Technologies Holdings was the first local company to go regional without anybody knowing it. We had offices in Kuala Lumpur, Hong Kong and Bangkok, at a time when all the GLCs in Singapore just stayed at home.
>
> **Philip Yeo**
> *Board Member (from 1980) and Chairman of Singapore Technologies Holdings (1987 to 1993)*

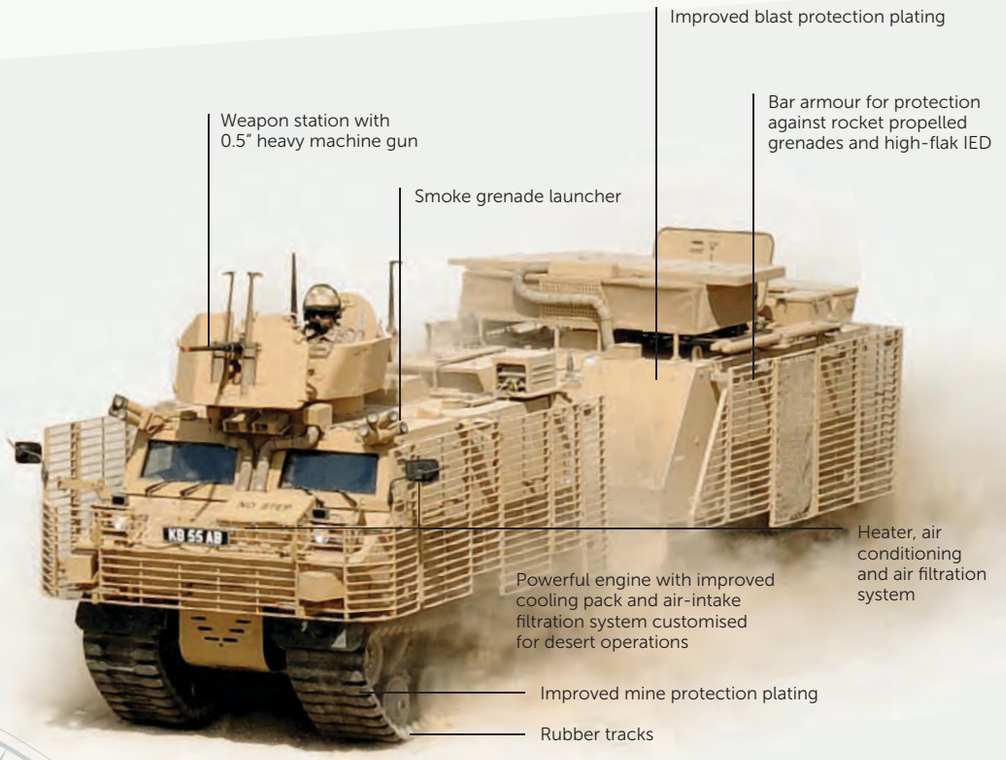
Endurance-class Landing Platform Dock built by ST Marine for the Royal Thai Navy.

Protecting the Lives of British Soldiers

Warthog is the first Asian-built armoured vehicle to be deployed in military operation by a Western army. The 20-tonne variant of the Bronco All Terrain Tracked Carrier was customised to support British operations in Afghanistan. Its superior off-road ability was subsequently proven in operations with the swift and safe mobilisation of the British troops on the war-torn landscape.

The vehicle was designed to withstand heavy firepower from any direction, with an under-body armour that was able to deflect explosive forces away from the vehicle and protect the lives of the soldiers in it. When several Warthogs were hit by large Improvised Explosive Devices (IED) in Helmand while providing perimeter defence for the Royal Engineers, all the soldiers onboard survived the explosions.

ST Kinetics was awarded the contract by the UK Ministry of Defence in 2008 to make over 100 units of the all-terrain vehicle, and the first unit was delivered within a record nine-month production period. The Warthogs have travelled more than 500,000km in Afghanistan since, during which they had encountered numerous IED and mines and safeguarded every soldier's life.



> "You can put Warthog into places you would not dream of with other armoured vehicles as it has very low ground pressure giving us the ability to move around the battle space in a completely different way. Literally we can go over ditches, swim rivers or go up ravines getting right in behind the enemy where they least expect us. We run on them at speed and before they know anything, we are right on top of them.
>
> **Major James Cameron**
> *Squadron Commander,*
> *2nd Royal Tank Regiment*

Quote courtesy of The Telegraph

THANK YOU
FOR SAVING MY LIFE!

Lance Corporal William Reeks was on routine patrol duty in Afghanistan when his vehicle ran over a booby trap made of 50kg of explosives. The 27-year-old soldier from the Royal Tank Regiment suffered internal injuries, a broken vertebrae and blast damage to his legs. But he survived the ordeal, all thanks to the armoured vehicle designed and produced by ST Kinetics – the Warthog.

The family is grateful that he is alive. His mother, Mrs Anita Lee, credits the Singapore-made armoured vehicle for his survival. "It is thanks to the (British) army changing over to Warthogs, which are bigger, stronger vehicles," she told The Welwyn Hatfield Times, a community newspaper in Hertfordshire, UK. "He's a very, very lucky boy!"

SELLING TO THE WORLD

Leading the World in 40mm Munitions

When Mr Henry Cheong first saw the M113 armoured vehicle in 1982, his initial thought as CIS' Director of Engineering was how to make the vehicle provide better covering fire for the soldiers during an assault. The idea stayed with him. In 1986, Henry gathered a team of young engineers and started the development of the 40mm Automatic Grenade Launcher (AGL) and 40mm munitions.

In 1992, the team successfully developed the 40mm AGL and munitions for the M113 Ultra upgrade programme. The same 40mm system would also be mounted on the Bionix 40/50 variant. The 40mm team continued to develop its knowledge in 40mm design and production. In 1999, the team made a breakthrough with the world's first 40mm self-destruct (SD) round with a unique built-in mechanical SD mechanism. The patented device ensured detonation should the round fail to explode upon impact.

Mr Philip Ou, ST Kinetics' Vice President of Marketing, who spearheaded the 40mm munitions marketing efforts in Europe, said, "We secured early success in 2000 with Sweden when the SD rounds were launched. As the 40mm weapon became more widely deployed later on, other European countries like the UK, Finland, Ireland, Slovenia and Spain also started ordering from us."

In 2004, the team went on to develop the 40mm Air Bursting Munitions System (ABMS), another first in the 40mm market, to allow soldiers to engage enemies behind cover. The fuse could be programmed to detonate over the target. In 2010, the ABMS was enhanced to compensate for muzzle velocity, which improved the accuracy of each round fired.

Other innovations over the years included the 40mm Low Velocity Extended Range (LVER) munitions that could be fired using conventional low velocity grenade launchers like the M203; the Soldier Parachute Aerial Reconnaissance Camera System (SPARCS) Compass round that could launch a camera into the sky for instant aerial visual; and the Enhanced Blast Insensitive Explosive (EBIX) round that improved handling safety while providing a greater blast effect when activated. More than 56 patents were filed in different countries for the 40mm munitions, and the ST Kinetics team has won numerous awards for its innovation and contributions to defence technology.

Mr Aw Cheng Hok, Vice President of Engineering at ST Kinetics, was involved in the 40mm munitions development from the start. He recalled, "We have come a long way since. I am glad to have worked alongside a team of innovative and passionate engineers and put ST Kinetics on the world map as a leader in 40mm munitions. We have close to 40% of the world market, and the broadest range with 53 variants to meet the wide spectrum of operational, peace-keeping and training needs of military and para-military forces."

Besides Singapore and Europe, ST Kinetics sold the 40mm munitions to customers in Asia Pacific, the Middle East, Latin America and North America. "In 2013, we were awarded a major 20-year licensing contract to supply 40mm munitions to the Canadian Department of National Defence through General Dynamics Ordnance and Tactical Systems (GD-OTS Canada) and to transfer the technical data package to GD-OTS Canada," said Mr Lim Beng Lee, General Manager of ST Kinetics' Advanced Material Engineering (AME).

Mr Rene Blouin, General Manager of GD-OTS Canada, was particularly impressed with ST Kinetics team's "solid technical support and continuous dedication" which he believes contributed to the success of the programme. He shared, "The Canadian customer was very pleased with the final result and completely satisfied with the professional work performed by AME and GD-OTS team."

World's First Light Vehicle-Mounted Mortar System

120mm SRAMS.

In 2004, Mr Teo Chew Kwee, Head of ST Kinetics' Weapon System Centre, proposed to develop a mortar system with a Middle Eastern partner. The system would comprise a 120mm Super Rapid Advanced Mortar Systems (SRAMS) and a fire control system mounted on a four-wheel drive light truck, to demonstrate the superior shoot-and-scoot capability of the combined system.

Although the SRAMS was already in service with the SAF by then, involving the mortar in such a configuration would be a world's first. The SRAMS team, led by Mr Ang Teoh Hwa, an experienced weapon designer formerly involved in a few 155mm field howitzer programmes, had developed several patented innovations. This included a recoil mechanism and a self–compensating spade that radically reduced the recoil force of the SRAMS to less than 20 tonnes, allowing the SRAMS to operate from a vehicle. The recoil forces of a conventional 120mm mortar would not only break the vehicle, its vibration would affect the accuracy of subsequent rounds.

The integrated SRAMS system was successfully tested and showcased at overseas defence shows. It attracted interest from several potential customers, one of whom requested the SRAMS to be mounted on a mine-resistant wheeled platform for enhanced protection. The system was successfully trialled, and subsequently deployed for in-theatre operations.

Mr Loh Khye Lim, Director of Regional Marketing at ST Kinetics, noted that bringing a product to market could be a long-drawn process, even for a superior solution like the SRAMS. He said, "It took us six years and many firing trials to secure the customer. A great solution will still need persistent marketing to turn the opportunity into a positive outcome."

SELLING TO THE WORLD

Tiger Tiger, Burning Bright

The F-5 Tiger fighter is a highly versatile and reliable military aircraft that has served air forces well since the 1960s. A fleet of F-5E/Fs was operated by the RSAF since the 1970s and upgraded by ST Aerospace in the 1990s to give the Tigers a new lease of service life. The modernisation programme redelivered to the RSAF a fleet of advanced multi-role F-5 fighters with enhanced air-to-air and air-to-ground capabilities.

ST Aerospace started chasing for F-5 upgrade opportunities overseas in the late 1980s and secured its first overseas contract with the Venezuelan Air Force (VAF) in 1990. Apart from technical challenges, the F-5 team had to learn to deal with diverse issues working overseas, from managing cross-cultural expectations to complying with foreign regulations and practices. It proved to be an enriching and unforgettable experience for the engineers.

After the VAF programme, ST Aerospace went on to win F-5 modernisation contracts from other air forces including the Turkish Air Force in 1999 and the Brazilian Air Force in 2001, among others. Today, ST Aerospace is recognised as the foremost contractor for the upgrades of the F-5.

> “When the test range for bomb scoring was closed due to the wet season, VAF constructed a temporary test range near the airbase. They got us to help them clear the field and paint the bull’s-eye for the F-5 bombing. It turned out that with the make-shift bomb range located near to the airbase, we were able to save on travelling time and carry out more sorties, which greatly helped to shorten the trial duration. It was an incredible feeling standing on the runway as our upgraded F-5 flew past and hit the bull’s-eye made by us. We found out years later after we’d left that the bull’s-eye was still in use by other squadrons for bomb scoring and exercises.
>
> **Chai Kean Keat**
> *VP GM STAR, ST Aerospace; then Flight Test Engineer*

> “The VAF F-5 upgrade was a rare opportunity for us to be involved in an overseas programme that went through a complete cycle of design, development, prototyping, testing and production. The project team, though young and new to working for foreign air forces, rose to the occasion and delivered the upgraded aircraft within schedule and budget to a delighted customer.
>
> **Goh Poh Loh**
> *Executive Vice President, Component Total Support, ST Aerospace; then Avionics Manager*

Reborn Hercules

ST Aerospace has been actively supporting the C-130 Hercules military aircraft and its civilian version, the L-382, for many international customers, such as Lynden Air Cargo, Indonesia Air Force, Tunisia Air Force and Royal Air Force of Oman (RAFO).

ST Aerospace's partnership with RAFO goes way back to 1988 with its first project to repair RAFO's Bell 205 helicopter components. Over the years, the services were extended to airframe and engine MRO as well as aircraft modernisation, when RAFO engaged ST Aerospace in 2012 to upgrade three C-130 Hercules. The upgrade included putting in a new cockpit and a suite of avionics that would meet civil airspace regulation requirements. The first aircraft was redelivered within just seven months, well ahead of the industry's average turnaround time by several months, and the other two aircraft were redelivered in an equally short time frame. The C-130 modernisation programme did not just upgrade the capabilities of the RAFO's Hercules, it also extended the service life of the aircraft.

"The Royal Air Force of Oman has selected ST Aerospace because it is a one-stop centre with extensive capabilities for the C-130 aircraft. ST Aerospace's ability to undertake depot level maintenance and cockpit modernisation simultaneously is especially advantageous to us as it minimises downtime and improves aircraft availability.

Air Vice Marshal Matar Ali AL-OBAIDANI
Commander, Royal Air Force of Oman

"The C-130 upgrade went smoothly, but just before the flight test, the monitor started to give the wrong display of the engine parameters. It turned out to be a complex aircraft integration issue with obvious safety implications. The design team had to work closely with the equipment supplier, our test and calibration shops and the production crew to resolve the problem before the C-130 was assessed safe to fly. It was the team's collective and proficient knowledge on engine MRO and system safety as well as everyone's commitment to meet the customer's urgent operational need by working during the festive period that we were able to recover the aircraft so quickly.

Tan Yen Ping
Director Programme, Military Business Unit ST Aerospace; then Programme Manager, Military Business Unit

"I remember flying in the Charlie-130 as part of the field service support team. When the plane approached the Khasab Airport, the pilot had to descend into a narrow valley for the landing. I could feel my heart in my throat when the aircraft was less than a hundred feet from the ground and airstrip was still nowhere in sight! The plane suddenly took a sharp turn and the runway finally revealed itself. I only found my breath again after the skillful RAFO pilot had landed the plane safely. The experience, though terrifying, had also attested the superb performance of the upgraded Hercules."

Jackson Hoon
Assistant Principal Engineer, ST Aerospace; then Senior Engineer

SELLING TO
THE WORLD

In a Class of Its Own

ST Marine has been servicing marine engines for navies in the Middle East since 2000. In 2009, when the RNO announced that it would be acquiring a new class of Patrol Vessels to replace the aged Seeb class Patrol Vessels that had been in service since the 1980s, ST Marine decided to go for the bid.

Said Mr Bernard Yeo, ST Marine's Senior Vice President / Head of Defence Business, "ST Marine has built up its capabilities in design, building and integrated logistics support services for naval vessels over the past five decades. We have deep experience in the Fearless Class Patrol Vessels (PVs) that we have conceptualised, designed and built for the RSN in the 1990s. We knew from the start that it would be a mega project with many challenges downstream but we were confident we had the in-house expertise, processes, systems and supply chain support to undertake this significant endeavour."

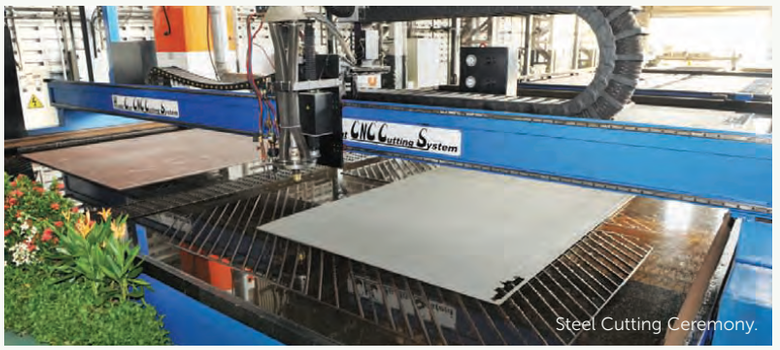
A project team was formed, led by Mr Ng Sing Chan, President of ST Marine, to pursue this opportunity. He was then Deputy President and President of Marketing & Business Development, to pursue this opportunity.

"The 75m Fearless Class PV was customised to meet the RNO's requirements. We had countless sleepless nights and passionate debates as we worked out the tender proposal, all with the intent to build a world-class vessel that could effectively support and protect the waters around the Gulf of Oman and the Arabian Sea," said Mr Nicholas Leow, then Senior Manager (Project Office).

"In April 2012, we beat keen competition to sign a historic contract with the Ministry of Defence of the Sultanate of Oman for the delivery of four PVs," said Sing Chan. The PV contract was the largest export order for ST Engineering as a group as well as the first naval platform programme from a Southeast Asian nation to a Middle Eastern Country.

In 2015, ST Marine delivered the first of the four vessels to RNO after successful trials in Oman. "The trials were perhaps the most challenging phase of the contract. We had to endure the punishment of the scorching sun in order to perform the weapons integration and live firing trials in the open seas. It was rewarding when everything went according to plan and the ships were successfully delivered," said Mr Steve Wong, Director of Weapons & Electronics and System Integration.

The RNO named the fleet the Al-Ofouq Class, which means 'horizon', and the four vessels after the coastal cities of Al-Seeb, Al-Shinas, Sadh and Khassab. The fourth and final vessel was delivered in 2016. This fleet of four vessels now patrols the waters of the Sultanate of Oman, carrying out maritime surveillance and a range of homeland security missions.



Steel Cutting Ceremony.


Keel Laying Ceremony.


Launching Ceremony.

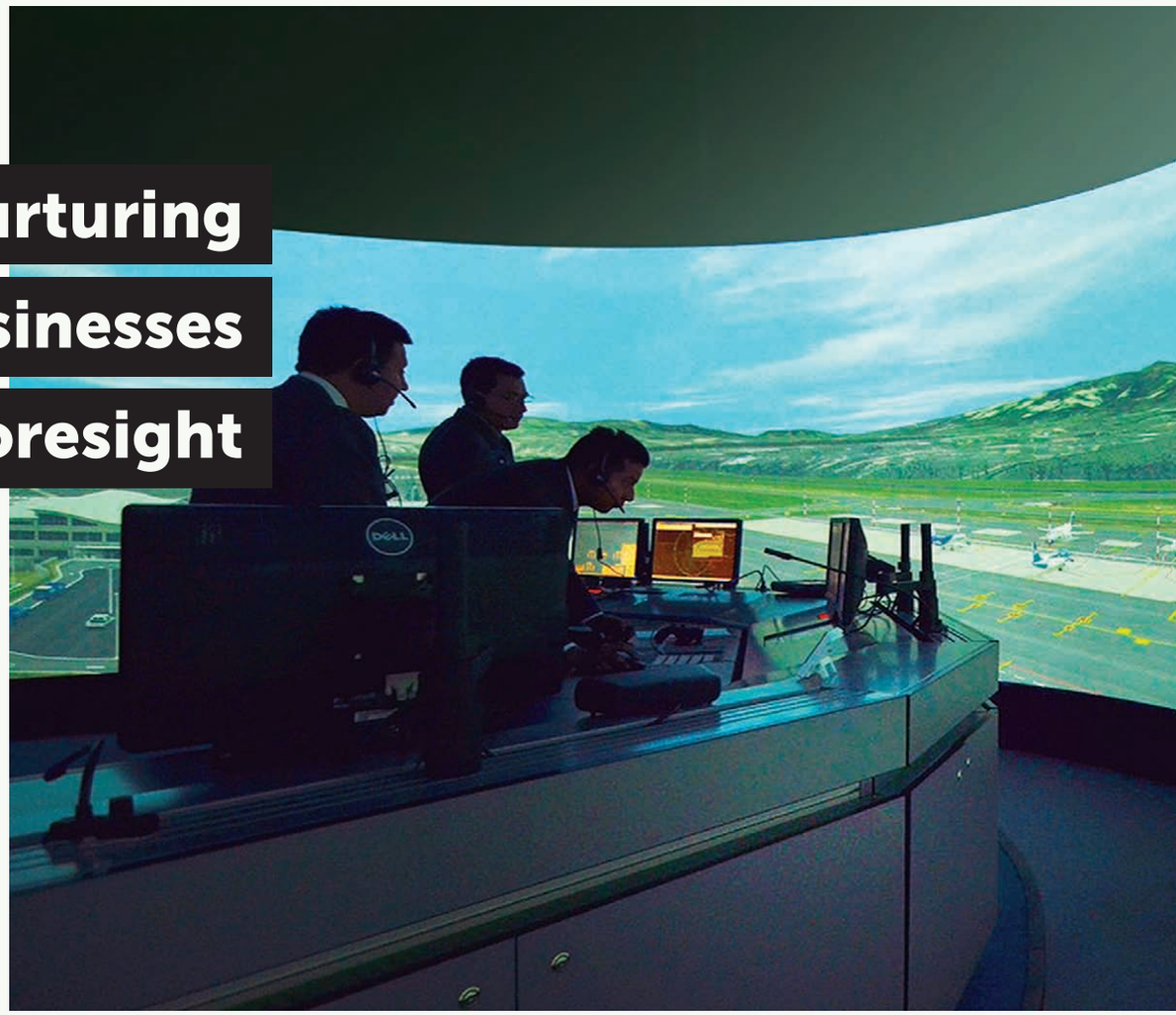

Naming Ceremony.

NATURE AND NURTURE

As a corporate citizen, ST Engineering strives to operate in a responsible and sustainable manner. Concerned by climate change and environmental impact, we are passion-driven to leverage our engineering expertise in service of our environment and communities.

The development of current and future generations of technical and management talent is a key priority in our sustainability objectives. We nurture the passion of our employees to excel and engineer for good, so that ST Engineering can continue to make meaningful contributions that are beneficial to societies and mankind at large.

Nurturing Repeatable Businesses from our Foresight



ST Electronics' Air Traffic Control Simulation System.

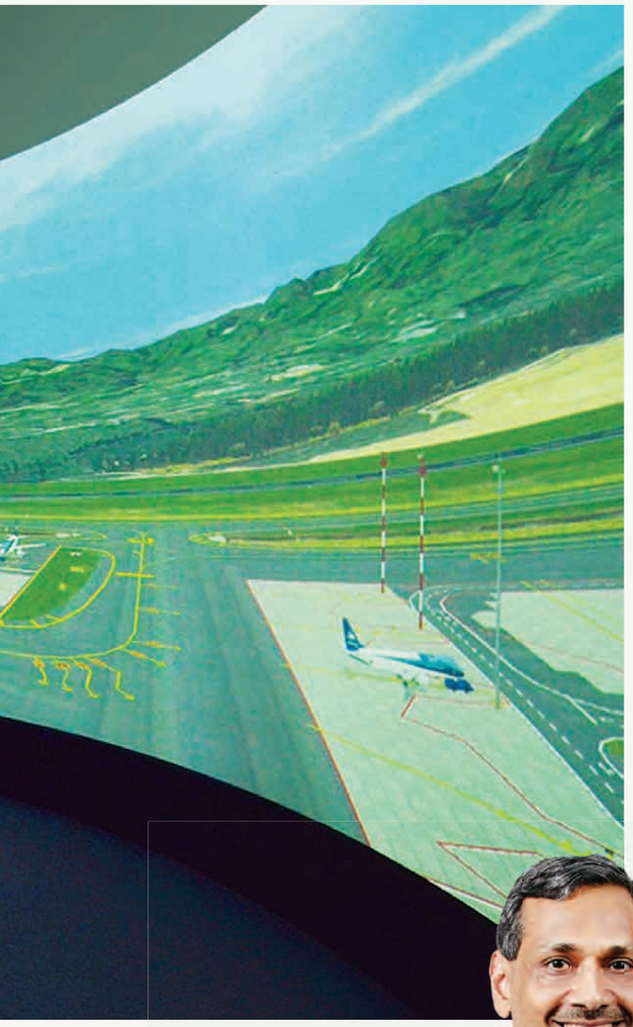
It is the stuff legends are made of.

From a small system integration house, the Electronics sector of ST Engineering has grown phenomenally over the years to cross the S$1 billion revenue mark in 2007; and is now approaching its next billion-dollar mark. Net profitability has been consistently in the double digits and growth continues despite several periods of weak global economic conditions.

When Mr Lee Fook Sun, Deputy Chief Executive Officer of ST Engineering (2014 to 2017), and President of ST Electronics (2009 to 2016), was asked about his secrets to sustaining business longevity, his answer was simple: Repeatability.

"It's nice to win large contracts but if the sector is unable to develop the kind of capabilities that will give it a good chance to secure more similar projects in the long run, it does not make for sustainable business," he said. "It'll just be a flash in the pan."

Then, there is the challenge of the new digital economy and the incredible speed of change. "The running joke in the industry is that the technology would have become obsolete



Depot Command Centre for the North East MRT Line in Singapore.

before it reaches the market. So, how do you even begin to meaningfully invest in anything at all?" Fook Sun asked.

Yet, the Electronics sector has managed to develop two highly successful lines of business, which it calls Globally Competitive Businesses (GCBs), amidst the keen competition and technological uncertainties. One of them is satellite communications (satcom) and the other, urban rail.

In satcom, the Electronics sector is the world's largest enterprise Very Small Aperture Terminal (VSAT) systems vendor by revenue, with its iDirect solutions commanding over 36% in market share. In urban rail, where any downtime would immediately translate into productivity and economic loss, the market demands are for reliable solutions and rigorous maintenance. Such exacting customers' expectations have allowed ST Electronics to quickly establish strong footholds in Asia, the Middle East, Latin America and the US with its good track record in timely delivery and excellent aftersales.

According to Fook Sun, to build repeatable success in a vibrant industry where innovation and disruption are the norms requires doing the right things well every time. "You will need to consider everything, big and small, from building up the right skillset and knowledge to deliver outcomes valued by customers, to managing cost efficiently and better than the competition," he said.

Ravinder Singh
took over from Fook Sun on Jan 2017 as President, ST Electronics

Lee Fook Sun
President, ST Electronics (2009 to 2016)
Deputy CEO and President, Defence Business, ST Engineering (2014 to 2017)

SCANNING THE HORIZON

The ST Engineering Business Foresight Committee (BFC) is led by Mr Ravinder Singh, President of ST Electronics to engage government agencies, venture capitalists and other stakeholders on issues relating to technologies, markets and business development. BFC also scans the global trends and emerging business opportunities regularly and advises ST Engineering on the appropriate strategies to leverage these opportunities for sustainable growth.

Nurturing Repeatable Businesses from our Foresight

Airbus Helicopter H135 simulator.

"Take the TeLEOS-1 for example. The rocket science is no longer just in the rockets but also in the engineering of the satellite. The module must first survive the rigours of the launch, before setting itself accurately into an orbit where it will be taking high-resolution images from an altitude of 550 metres above the equator over the next few years. A lot of planning and innovation have gone into perfecting the system while keeping the project on schedule and within budget. This is the level of competency and dedication that our team possesses," said Fook Sun proudly.

For Fook Sun, preparing the sector for the uncharted future requires the same adeptness and adaptability. He said, "Many people think that IT and ICT is a sunrise industry with a pot of gold at the end of every rainbow. What they don't realise is the intense competition within the industry and the substantial risk of investing in new technology to maintain the lead. The stakes are high – there is no guarantee of success and we have to stay on our toes at all times."

Having people in the team with the right skillset and mindset is vital. Leaders must have the drive and motivation to help their teams succeed and to continually seek ways to build stronger teams. "We want people who are obsessively curious in our team. With inquisitiveness comes the urge to learn, to look forward and to come up with better ideas," said Fook Sun.

Mastering these three components – focused business lines, reliable world-class solutions and deep technical knowledge – have enabled ST Electronics to establish itself internationally. Going the next lap would require the sector to stay ahead of market disruptions that characterise today's digital economy. In fact, Fook Sun sees these challenges and opportunities as different sides of the same coin. Overcoming a challenge would present an opportunity for innovation, and at times, disruption. "And in our line of business, it's better to be the disruptor than the disrupted," he added candidly.

To this end, ST Electronics is venturing into exciting new fields that could become future market disruptors, like neuromorphic computing, machine intelligence and cyber chips that are capable of protecting the motherboards from malwares. It is considering the development of promising technology from ongoing projects into profitable businesses in areas such as unmanned surface vehicles and autonomous underwater systems. In its core IT businesses, like data centres, training and shared services, ST Electronics is expanding its offerings and deepening its capacity to meet increasing customer demands for higher value-add services.

The sector is also looking at creating more GCBs to support the needs of smart cities in areas such as security systems, intelligent buildings and machine-to-machine (M2M) connectivity. It has ongoing IoT projects in major cities all over the world, and new concepts and solutions are coming from the innovative use of communications technology.

Agilis' Mobile Earth Station provides high quality satellite communications wherever required.

TeLEOS-1 Earth observation satellite model.

Mr Ravinder Singh, who was handed the baton as President, ST Electronics in 2017, is excited about the future. "ST Electronics is a very strong company from technology, product and marketing points of view. Fook Sun has set us on a strong trajectory. Our continued priority will be on scaling more of our businesses internationally while remaining cognisant of our role in the local Total Defence eco-system.

"Urbanisation and digitalisation present unlimited growth opportunities for ST Electronics. There will be increase in demand for smart cities solutions leveraging the proliferation of sensors and availability of data, and for robust security to counter increased threats to our physical and cyber environment. Engineering is our core and we will continue to innovate and utilise technology to create value for our customers. We will have to strengthen our talent pool, build more synergistic alliances and strategically invest in technologies and market access to become globally competitive," Ravinder added.

Summarising the lessons from his time at ST Electronics, Fook Sun, who retired on 30 June 2017, advised, "Apply your knowledge to help customers solve their problems. Turn that success into a sustainable service and offer it to other customers with a similar set of problems. In other words, succeed and then replicate the success."

STAYING AHEAD OF THE DEMAND CURVE

In 2008, ST Electronics acquired Telematics Wireless, a company offering capabilities in M2M applications and wireless telemetry to gain a foothold in the emerging vehicular telematics and M2M markets. Soon after the acquisition, M2M applications and devices began to skyrocket, driven by global demands for smart city and IoT solutions, and ST Electronics was ready to bring to market its M2M and wireless sensor network solutions to the fore. Mr Andrew Chow, President of ST Electronics (Info-Comm Systems), pointed out, "Investing in M2M before it became an obvious trend has given ST Electronics a strategic advantage. With more than 15 million wireless devices, sensors and communications nodes already installed for smart city applications worldwide, we are now in a leading position as a smart city solutions provider."

BECOMING A BIG PLAYER IN VSAT SYSTEMS

ST Electronics was producing satcom radio frequency equipment and carrying out systems integration of large-scale satcom networks under its established Agilis brand when it decided to grow the business and become a leading global satcom player.

"From the onset, we knew we needed to expand into satellite remote modems and hubs, and access the US which has the biggest satcom market," recalled Mr Tang Kum Chuen, ST Electronics' President of Satcom & Sensor Systems Group. "We started searching for a good complementary company in 2003. It took us two years before I received a proposal for the sale of iDirect Technologies (iDirect) while I was in transit at Washington DC Dulles Airport. I read the document with great interest and immediately recommended to Mr Seah Moon Ming, who was the President of ST Electronics at that time, that we buy over the company."

The acquisition of iDirect in 2005 extended the Electronics sector's presence in the US and propelled it to be a leading global satcom solutions provider, with a comprehensive product offering of iDirect's satcom network equipment and Agilis' satcom front-end transceivers.

PROTECTING
OUR
ENVIRONMENT

Friends of the Environment

Earth Check at Gardens by the Bay.
Photo courtesy of Gardens by the Bay

From advocacy of environmental standards and water and energy efficiency, to active involvement through activities like tree-planting and beach clean-ups, ST Engineering believes there is no action too small in environmental protection. It continues to invest in public education, contribute engineering expertise and encourage all staff and business units to step up to this worthy cause.

OUR EARTH, OUR CHOICE

Earth Check and +5 Degrees in the Cloud Forest at Gardens by the Bay are exhibits sponsored by ST Engineering from 2013 to 2021. The two exhibits use digital technology to educate the public on their role in preserving the environment for future generations. Mr Wu Tzu Chien, Chairman of ST Engineering's CSR Committee, who secured the corporate support to sponsor this project, said, "We wanted to use these exhibits to raise public awareness on the impact of climate change, and encourage individuals to adopt pro-environment habits."

The exhibits offer an immersive multi-media experience that takes the audience through space and time to observe the adverse effects a few degrees of change in temperature could have on Earth.

+5 Degrees at Gardens by the Bay.
Photo courtesy of Gardens by the Bay

Earth Check at Gardens by the Bay.
Photo courtesy of Gardens by the Bay

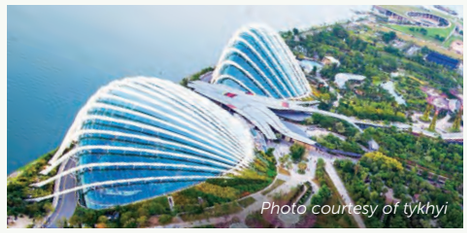


Photo courtesy of tykhyi

"Earth Check and +5 Degrees are two key multi-media exhibits in Cloud Forest, because they convey the importance of environmental conservation to our visitors. This is a message with increasing urgency, especially since real cloud forests around the world are extremely vulnerable to climate change. We are glad to have the support of ST Engineering, which helped us craft a more impactful message to inspire visitors towards making a difference to our world.

Dr Tan Wee Kiat
Chief Executive Officer
Gardens by the Bay

THE TREE ON THE FIVE-DOLLAR NOTE

Pull out a Singapore five-dollar bill and you will find a majestic Tembusu tree with a characteristic low and outstretched branch featured on the reverse side. At more than 200 years old, this iconic tree situated in the Singapore Botanic Gardens, Singapore's first UNESCO World Heritage Site, would have witnessed Singapore's transformation from a small, unknown fishing village in the backwaters of Southeast Asia into a global metropolis.

The low hanging branch of the Tembusu tree was supported by wooden structures that were installed in 1992. Worried that the rigid structures would restrict the tree's movements and cause it to lose the ability to carry its own weight as it grew heavier, National Parks Board (NParks) approached ST Kinetics in 2013 to seek its advice on developing a dynamic support system that could adjust to the growth of the tree and allow the branch to move freely in the wind.

Deeming it a worthy cause to preserve Singapore's heritage, ST Kinetics agreed to sponsor the project as well as the time and expertise of two of its engineers, Mr Yeap Khek Teong and Mr Ng Zhenxian, to design and build the first-of-its-kind dynamic support system for the Tembusu tree.

"It took us 11 months, from a thorough study of the tree, its movements and soil conditions to the design, fabrication, installation and testing of the dynamic support system," said Zhenxian, Assistant Principal Engineer who volunteered his time for the project. "I am glad to have this rare opportunity to apply my engineering expertise in the conservation of the Heritage Tree."

(Top) The dynamic support system props up the branch at three points, allowing it to gradually adjust to wind conditions and regain strength to support itself. (Bottom) Ng Zhenxian (left) assisting President Tony Tan at the launch of the dynamic support of the iconic Tembusu Tree at Singapore Botanic Gardens.

GREEN FINGERS

A nature lover, Mr Yeap Khek Teong, Vice President and Head of Management System and Processes at ST Kinetics (pictured below), embarked on his green journey in ST Engineering in 2008 when he was asked to lead the Group's Plant-a-Tree programme in Singapore. That year, a record 2,008 trees were planted in Admiralty Park, and in 2009, another 1,000 trees were planted in Punggol Promenade.

Khek Teong went on to set up five community gardens in ST Kinetics premises that provided the staff a place to grow vegetables, herbs and flowering plants. These efforts were recognised by NParks with Khek Teong winning a Platinum award every year since 2010, and ST Kinetics being awarded the Best Garden in the Organisation category in 2012 and 2016. With more than 18,000 trees and shrubs planted since 2009, ST Kinetics has been transformed into a factory within a garden.

Outside of work, Khek Teong has been leading community gardening groups to create show gardens at the biennial Singapore Garden Festivals. In 2016, his team's show garden won the Gardener's Cup, the highest NParks award at the festival. Khek Teong has been recognised as Community in Bloom Ambassador by the Prime Minister in 2010 for his personal contribution in greening Singapore.

Said Khek Teong, "My father inspired my interest in gardening. The joy of watching the plants grow and blossom got me hooked on gardening. I'm glad to have beautified the surroundings where we live, work and play, while mitigating the impact of greenhouse gases in our environment. Being involved in greening for almost 10 years in ST Kinetics, I've got to know more like-minded people, build friendships among colleagues and share my passion with others."

Planet, People, Profit

As a responsible business, ST Engineering is committed to sustainable operations through a range of initiatives from recycling and reducing carbon footprint to managing waste and conserving water and energy. Regular talks are organised to encourage employees and business partners to adopt eco-friendly practices. ST Engineering started participating in the Carbon Disclosure Project in 2014 after spending a few years preparing the groundwork and has taken steps to monitor and reduce greenhouse gas emissions.

Solar panels installed atop ST Kinetics facility at 249 Jalan Boon Lay, Singapore.

TAPPING THE POWER OF THE SUN

One of the areas identified to reduce the Group's carbon footprint is the use of solar energy to supplement its energy needs. In 2015, a solar energy pilot was started at ST Kinetics in Singapore to evaluate the effectiveness of photo-voltaic (PV) systems and their impact on operations. With encouraging results from the trial, more PV systems were implemented in stages on the rooftops of the buildings at ST Kinetics and ST Aerospace. By 2018, these solar panels are expected to provide more than 8GWh per year of clean energy – enough power to light up more than 1,700 four-room flats annually – and reduce 3,300 tonnes of carbon dioxide equivalents of emissions for the Group. There would be more energy savings and carbon reduction when the rest of ST Engineering comes aboard the solar energy initiative.

UPPING POWER EFFICIENCY

As a Group, ST Engineering has progressively expanded its efforts to improve energy efficiency in its daily operations. In 2013, it appointed energy managers, who are trained under the Singapore Certified Energy Manager programme, to monitor and manage energy use and greenhouse gas emissions. The Group's Singapore operations have been certified to ISO 50001 (Energy Management System) since 2015.

The energy efficiency initiatives it has embarked upon include implementation of building management systems to monitor energy consumption, deployment of motion detectors in low-use areas like toilets and car parks to conserve energy, and optimisation of equipment, such as furnaces and blasting chambers, to minimise wastage. An example of an optimisation initiative is the use of two small air compressors instead of a larger air compressor to support surges in demand at an ST Aerospace facility. In addition, the workshop roofs of both ST Kinetics and ST Marine in Singapore were fitted with skylight panels to let in more natural light, and incandescent fluorescent tubes were gradually replaced by energy-saving LED lights.

> "Climate change is severely affecting the environment. As an engineering company, we rely heavily on electricity to power our operations and maintain a conducive workspace for the employees. As an energy manager, besides implementing energy efficient initiatives to lower our carbon footprint, I am also exploring hybrid energy solutions that tap on free and clean energy to supplement grid power and meet our internal pledge to cut carbon emissions.
>
> **Wee Yu Hen**
> *Energy Manager, ST Kinetics*

THE SAND SHARK WITH AN APPETITE FOR TAR SAND

On 20 April 2010, Deepwater Horizon, BP's rig platform drilling at the Gulf of Mexico, exploded. For nearly three months, oil spewed from the well into the Gulf and contaminated the surrounding coastlines in the worst marine oil spill in history. Responding to the crisis with BP, engineers at VT LeeBoy conceived, designed and converted a force feed loader into a high-efficiency beach cleaner prototype within just four weeks. The product was aptly named the Sand Shark for its voracious appetite for tar sand and ability to clean depths of half a metre of sand in a single pass compared to less than 8cm by the conventional method. BP subsequently bought six units of Sand Shark, which have helped to clean up hundreds of kilometres of beachfront.

Employees pledging support for World Water Day 2014 and 2015.

MANAGING WATER USAGE

The Group's operations in Singapore rely on municipal water supplies for use in production, cooling, cleaning and general sanitation. These include both potable water and NEWater. According to Mr Ivan Ho, Vice President of Business Excellence in ST Electronics, who also oversees water conservation for the Group, ST Engineering has embarked on many initiatives to improve water efficiency. Employees are regularly reminded to practise water conservation during toolbox briefings, staff briefings, productivity projects and water campaigns like World Water Day.

"At our facilities, we have installed digital water meters and water-saving devices like water thimbles and flow-reducing valves. We are recycling water where we can, and using reclaimed water, like NEWater, for industrial processes and cooling towers. The ST Marine shipyard, for instance, uses industrial water for some of its operations like washing and wet blasting of the ship's external hull, ship ballasting and toilet flushing," Ivan added.

REACHING OUT

Engineering for Good

Showcasing the Spider New Generation Light Strike Vehicle at National Engineers Day 2014.

"ST Engineering has long supported CSR, even before the words corporate social responsibility became fashionable," said Mr Wu Tzu Chien, Chairman of the Group's CSR Committee. Although the committee was only formed in 2007, in reality, the various business sectors have been giving back to their communities since they were incorporated.

"Many of these activities take place at the neighbourhood charity homes and with little fanfare. We always have willing volunteers doing what they can to make a difference," recollected Tzu Chien. Today, the Group's CSR efforts are guided by two key thrusts: 'Enriching Lives through Education' and 'Touching Lives through Engineering'.

Engaging students at National Engineers Day 2014.

According to Tzu Chien, the Education focus has taken many forms, from simple book prizes to full scholarships for tertiary education and sponsorships at National Day Parades as part of the Group's support for National Education. "We believe that good education provides our youth with a strong foundation for personal growth and success in life."

"In fact, ST Engineering is one of few organisations known to offer non-bonded engineering scholarships in top Chinese and Indian universities for their own nationals. We're investing in future talent and people network by providing the means for talented students to complete their tertiary education in their own country. At the same time, we are promoting Singapore as a career destination," he explained.

The Engineering focus, on the other hand, challenges the Group to leverage its core expertise to do good for the community. "This includes engineering-based competitions to encourage innovative thinking in solving societal problems such as ageing-in-place, and empowering people with disabilities to lead more independent lives. A good example would be the ST Engineering Enabling Technology Centre, where engineering skills can be channelled into practical applications like assistive devices and technology," elaborated Tzu Chien.

"Our engineering solutions have also been put to good use in times of emergencies," he continued, referring to ST Electronics' Infrared Fever Screening System and the Contact Track and Trace System during the SARS outbreak; VT LeeBoy's Sand Sharks that were commissioned by BP to clean up the beaches along the Gulf Coast after the Deepwater Horizon oil spill; and VT iDirect's satellite networking solutions for a remote Haitian village. "These are non-conventional CSR areas where we've been able to make a real difference," he added.

ST Engineering has also combined its education and engineering outreach at the Assumption Pathway School. "By having our engineers volunteer to teach the kids to build and race remote-controlled cars as part of the school curriculum, we've not only made them excited about engineering but also gotten them more interested in school work," beamed Tzu Chien.

"Some of us see CSR as a chance to come together for a good cause. It is that, and more. ST Engineering has an obligation and a duty to care for the communities in which it operates – it is something we strongly believe in. It is the right thing to do," he concluded.

GIVING BACK TO SOCIETY

The ST Engineering CSR Committee is chaired by Wu Tzu Chien and guided by the objective to be active and exemplary citizens in communities where the Group operates in. By emphasising social values in the Group's business decisions, the CSR Committee strives to achieve positive and sustainable outcomes for all stakeholders including business, employees, and the community at large.

UPPING THE TECH FACTOR

Organised by ST Electronics, the Tech Factor Challenge (TFC) promotes innovation and seeks to address real-world challenges through a technology competition. The year-long programme offers seed funding, mentorships, prototyping lab access, test-bedding opportunities and attractive prizes. The theme for each TFC is set to respond to different industry needs, such as 'Robotics in Civil and Security Applications' for the inaugural TFC 2013, 'Robotic Waiter' for TFC 2014/2015 and 'Ageing-in-Place" for TFC 2016/2017.

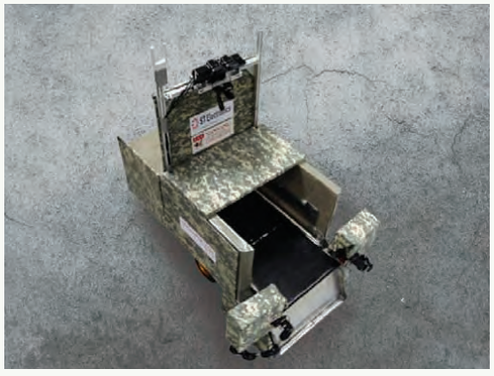
"We wanted to inspire final-year engineering students to discover creative uses of robotics that can solve real-world problems. For instance, in 2014, we partnered SPRING Singapore to challenge tertiary students and start-ups to develop robotics and applications that can support ageing-in-place. These can either improve mobility for the elderly, make their homes safer, or monitor their health for quicker intervention. ST Electronics recognises the importance of developing budding engineers and helping them to fulfil their dreams," said Mr Jeremy Foo, President of ST Electronics (Info-Software Systems).

> "Participating in TFC was rewarding beyond expectations. We had to develop a robotic waiter prototype and put it to work in an actual restaurant for judging. My team valued the opportunity for our solution to be validated by the industry and the exposure for growth beyond the competition.
>
> **Hansen Goh**
> *Co-founder of robotic start-up Sybo Tech Singapore and winner of the TFC 2014/2015 Grand Prize*

PAST TFC WINNERS

Grand Prize Winner 2014/2015

Team OBYS from Sybo Tech Singapore impressed the judges with a multi-functional robot that could function as a waiter or usher, and even distribute flyers for the food and beverage sector.



Platinum Award Winner 2013/2014

The Autonomous Battlefield Extraction Robot from NTU stood out for its ability to evacuate casualties remotely using a combination of unmanned and virtual reality technologies. The avatar-controlled robot mimics the rescuer's body movements to assist the wounded during emergencies.

MAKING A DIFFERENCE WITH ASSISTIVE TECHNOLOGY

Down at the Enabling Village, an integrated community space for persons with disabilities (PWDs) and their caregivers in Lengkok Bahru, Singapore, there is a Tech Able facility set up to help PWDs live and work independently. The facility has two centres: one focusing on information technology and the other on assistive technology (AT). The AT centre is named the ST Engineering Enabling Technology Centre (ETC) after its sponsor.

At the launch in 2015, former President & CEO Mr Tan Pheng Hock said, "As an engineering group, we know how big a difference technology can have on our daily lives. Through the ETC, we want to help those in our community with disabilities to get the right assistive technologies so they too can lead full and productive lives at work, home or leisure."

Indeed, ETC aims to provide a one-stop shop for PWDs to try out different ATs that could improve their quality of life. AT specialists and therapists are on hand to assess the needs of the PWDs and advise on the most appropriate AT. Caregivers and employers of PWDs can learn about ATs and their limitations as well.

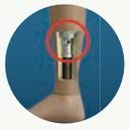
ST Engineering engineers have been engaging ETC and PWDs to identify areas where they could leverage their engineering capabilities to develop useful AT devices. Ideas have included an innovative assistive device that could significantly improve the mobility of wheelchair users.

REACHING OUT

From left: Richard Oh, Wong Liang Zhong and Ken Peh.

Ring tabs can be recycled into components for prosthetic limbs which are lighter and cheaper

The component used in a prosthesys



A LEG-UP FOR A GOOD CAUSE

Since 2013, ST Electronics has been participating in a local effort to collect ring tabs from drink and food cans that are then recycled to make parts of prosthetic limbs by the Thai Prostheses Foundation of H.R.H. the Princess Mother. These artificial limbs are given free to beneficiaries who cannot afford to purchase prostheses for themselves. Ring tab collection booths were set up throughout ST Electronics' premises, encouraging staff to participate in the movement. With 3,000 ring tabs weighing a kilogram, required to make a pair of prosthetic limbs, ST Electronics had over the past four years collected enough ring tabs to make more than 170 pairs of prostheses.

SARS CONTACT TRACKING AND TRACING

In April 2003, during the Severe Acute Respiratory Syndrom (SARS) epidemic, Singapore's Ministry of Health (MOH) approached ST Electronics, along with two other companies, to urgently develop a system to track and trace people who could have come into contact with SARS patients. A team was immediately assembled and a functional prototype was developed within a few days. The ST Electronics solution was shortlisted and eventually selected by MOH for trial at Alexandra Hospital.

Within the next few days, the team developed the radio frequency identification tag registration system, and wired it up to the sensors network at Alexandra Hospital's Accident and Emergency (A&E) Department. A database server and contact mapping system were installed and the complete Contact Track and Trace (CT&T) system went live in early May 2003, within a week of activation by MOH. The team also implemented the CT&T system at the National University Hospital's A&E Department the following week. Both systems were closely tested, monitored and refined throughout the deployment period to improve system performance.

> "Our families and friends were worried about us as we had to work at the A&E Departments to implement the CT&T systems. But there was a deep sense of purpose and camaraderie among the team members, and we found courage and strength in one another amidst the fear and distress. We knew the well-being of Singaporeans depended on the success of our project and that gave us the determination to plough on.
>
> **Ng Yew Liam**
> *Director R&D and Technology,*
> *ST Electronics (Info-Comm Systems)*

GOING PINK TO RAISE BREAST CANCER AWARENESS

In 2016, VT LeeBoy painted one of its pavers pink to raise breast cancer awareness and US$100,000 for the American Cancer Society in Charlotte, North Carolina. The idea first came to HR Generalist Ms Tamara Helderman of VT LeeBoy when she was looking for a custom-painted green asphalt paver for a customer. She thought a pink paver could help to generate awareness and inspire others to join in the fight against breast cancer.

"I didn't really expect the idea to take off like it has. Every department pitched in. When you can get everybody excited about a cause and support it, it speaks volumes about the family-like atmosphere here at LeeBoy," Tamara said. The pink paver has since been sold and put into service in Mifflintown, Pennsylvania, where it is busy paving roads and rallying support against a dreaded disease.

ENABLING DISTANCE LEARNING FOR HAITIAN CHILDREN

In 2014, Helping Haitian Angels (HHA), a non-profit organisation, opened the doors of its Kay Anj Village School located in Cap-Haitien, Haiti, to 91 children from the Kay Anj D'ayiti (Angel House of Haiti) and the local community. HHA knew that education was key to changing the lives of the young children, and that Internet access would help in reaching this objective.

When VT iDirect found out about this cause, it donated a VSAT system to provide broadband connectivity, and rallied LBiSat, its partner in satellite Internet services, to provide the bandwidth and other services to enable distance-learning for the school children. Satellite is a key enabler for this region since it is easily

deployable, provides a reliable connection and is cost-effective when compared with other access technologies.

Today, 129 students from Kay Anj Village School have access to quality educational resources from around the world that will help them succeed and thrive in the workforce and aid in the social and economic development of Haiti.

Lim Serh Ghee, President of ST Aerospace (left) and Helen Koh (right) at the THK Home for the Disabled@Eunos.

DOING WELL AT DOING GOOD

The Thye Hua Kwan (THK) Home for The Disabled@Eunos is one of ST Aerospace's adopted charities. Besides annual donations, ST Aerospace has organised regular visits to the home by its employees for almost 20 years. Many ST Aerospace volunteers have formed lasting friendships with THK's residents. Ms Helen Koh, an Occupational Health Executive, has been organising activities for the home for the past 17 years. She shared, "I remember our first visit in 2000 to the River Hongbao event during Lunar New Year. It was a rare treat for the residents to enjoy the city skyline at night from Marina Bay. For the volunteers from ST Aerospace, it was a wonderful feeling celebrating Lunar New Year with colleagues and residents from the home."

Nurturing Overseas Talents

As ST Engineering expands globally, it is also doing its part to promote engineering as a profession and Singapore as a place to build a career in, through bond-free scholarship awards. The scholarship scheme started in 2006, awarding students from Shanghai Jiaotong University, Fudan University, and Zhejiang University in China, and was later extended to students from the Indian Institute of Technology in Madras, New Delhi and Kharagpur. The scholarship programme includes a six to 12-week internship in Singapore at one of the business sectors. Several of the students have since decided to pursue a career at ST Engineering while many have remained in touch, adding to a growing network of contacts for future collaborations.

Shahin Shah Kozhimadam, India

2014 Batch
Joined ST Aerospace in 2016

"I chose to do my internship at ST Aerospace as my seniors who did their internship there were raving about its safe and friendly work environment. It was the right decision. The internship gave me great confidence to pursue a career in aerospace. Today, I'm a Stress Engineer at ST Aerospace working on the A330-300 Passenger-to-Freighter programme. I find my job fascinating as it allows me to put my studies to good use and work with various analytical software. ST Aerospace has played a significant role in shaping my career.

Ujjawal Chauhan, India

2012 Batch
Joined ST Marine in 2014

"I have always wanted a job where I can gain deep technical knowledge through hands-on experience. On my first day of internship, I was deeply inspired by the company's futuristic outlook in engineering. That sense of awe in creating solutions that could serve millions of people spurred me on to become a good engineer. I joined ST Marine upon graduation. Even though I was new, there was a lot of trust and support from my supervisors and their mentorship strengthened my aspiration to be an intrapreneur in ST Engineering.

Xu Shan Shan, China

2010 Batch
Joined ST Kinetics in 2013

"ST Engineering has given me a precious opportunity by supporting my studies financially and providing me a job in Singapore after graduation. As a Senior Process Engineer, I'm responsible for designing heat treatment process instructions critical to the safety and performance of the systems developed by ST Kinetics. Work has been challenging but deeply satisfying. I have developed a strong bond with my teammates and a deep sense of pride working for a great company.

Wang Shuliang, China

2009 Batch
Joined ST Electronics in 2012

"I remember being thrown into the deep end of the pool upon joining ST Electronics. As a software developer specialising in embedded firmware and Android applications, I was immediately assigned to a team working on a secured door access system for the Singapore Prison Service. Fortunately, my team members were helpful and supportive. They taught me how to manage urgent projects responsibly and to work as a team. I have also learnt to enjoy the exhilarating rush from working in a fast-paced environment.

Inspiring Future Engineers

ST Engineering's Young Engineers Programme (YEP) was started in 2012 to inspire junior college students to take up an engineering career. It is a continuation of ST Engineering's tradition of nurturing talents in science, technology, engineering and mathematics in support of the Singapore economy.

Students selected for YEP would spend part of their school holidays learning from practising engineers. They will also learn about the Group and the operations at the four business sectors. Since its inception, YEP has benefitted some 100 students.

"I decided to sign up for YEP as I was mesmerised by the world of engineering since young. The stint broadened my exposure to the various fields of engineering, and the visits to different business sectors affirmed my passion in engineering. I was eventually offered an opportunity to study Naval Architecture at the Newcastle University in the UK under the ST Engineering Overseas Scholarship. The eight-week internship with ST Marine prior to my undergraduate study enabled me to better appreciate what would later be taught by the university.

Fan Jun Wei
ST Engineering YEP 2012 Recipient
ST Engineering Overseas Scholarship 2015 Recipient

Building a Pathway to Success

ST Engineering has a financial assistance programme for qualified students undergoing secondary education at the Assumption Pathway School (APS). Wu Tzu Chien, Chairman of the CSR Committee, believes that the scheme will help youths acquire useful knowledge and set them on the path to successful adulthood. The programme has supported more than 110 students with financial support totalling over S$100,000 from 2013 to 2016 and has since been extended to 2019. In addition, two awards are given out each year – the ST Engineering Achievement Award and the ST Engineering Best Progress Award to motivate and reward the students.

A Radio Control (RC) Car Club was also set up as a co-curricular activity to teach the students to build and race RC cars. Mr Ray Lan, a Principal Engineer at ST Kinetics, was a volunteer for the programme. He was delighted with the opportunity to reach out and hoped that RC car racing would inspire the students to take up a career in engineering.

Mr Christopher Neo, Executive Director of APS, was deeply appreciative of ST Engineering's contribution to enhance the students' co-curricular learning experience. He said, "Since the RC Car Club started in 2014, our students are able to express their creativity and be exposed to the world of mechanics. You can see their enthusiasm in learning how to assemble the parts into a working machine, which they get to play with at the end of the project. Learning is greatly enhanced when the students enjoy the process."

NURTURING TALENTS

Defining our X Factor

Lim Jit Chek, Chief HR Officer, ST Engineering.

"The raison d'être of ST Engineering in the early years was to support a young and growing SAF. It spurred our founding fathers and motivated successive generations of engineers who dedicated their entire lives and careers to the engineering and defence of a nation. This calling still inspires us today, even as ST Engineering expands into the commercial space and internationally.

We're always cognisant of how this has made us who we are. It has shaped our thinking, attitude and culture. As an engineering company, we've learnt to respond swiftly to global trends and challenges so as to create stronger and better solutions for our customers. As a world-class solutions provider, we've not only kept pace with constantly evolving technologies, but we've also learnt to lead the change. Most importantly, as an employer, we've continued to pay attention to the development of our people. There would be no ST Engineering without them.

We have our roles cut out in HR to keep the Group's industrious and pioneering spirit alive. It's important to recognise and reward those who work hard and empower them to achieve their full potential. We create meaningful careers and forge environments that are conducive, where people can be intellectually, emotionally and functionally engaged. This is why teamwork and collaboration are so critical to ST Engineering's success.

Binding all these elements together is a strong, cohesive culture based on the five core values of Integrity, Value Creation, Courage, Commitment and Compassion, or IVCCC for short. This is how we're able to instil a common identity and unify our 22,000-strong family across 22 countries.

To groom the next generation of leaders, we're looking to offer more job rotations and overseas job postings, and to provide exposure to a wider breadth of work experience. We also have scholarship and sponsorship schemes in place to supplement the leadership pipeline.

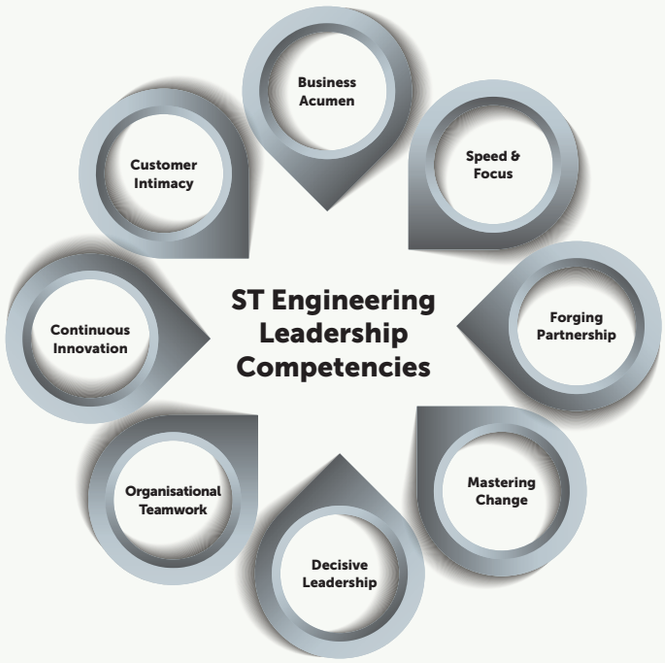
For our engineering pool to thrive and innovate successfully, coaching and mentorship would be essential. The reason we've been able to sustain a culture of "engineering with passion" is because our leaders have always been ready to invest time, effort and resources to this cause. It has enabled ST Engineering to differentiate itself in the marketplace. Our many achievements over the last 50 years will attest to that.

Lim Jit Chek
Chief HR Officer, ST Engineering

GROOMING LEADERS WITH EIGHT LEADERSHIP TRAITS

"We recognised the importance of having effective leaders in a fast-changing and increasingly competitive landscape. In 2004, a rigorous leadership framework was introduced to assess and develop our executives. Focus groups and numerous consultation sessions were held before the Eight Leadership Competencies framework was developed. The senior management has since been taking reference from this leadership model in evaluating the development needs of our executives. It was extremely satisfying for me to see the management's strong support in investing time and money on people development, including grooming future leaders and sponsoring staff for further studies and executive programmes. All these initiatives have definitely paid off, if you look at how much ST Engineering has grown over the years.

Tan Nga Kok
SVP/Director, HR (2000 to 2014), ST Engineering



GROWING THROUGH GLOBAL JOB ASSIGNMENTS

For ST Engineering to fuel its expansion as a Group, it is imperative that a growing number of employees be rotated through its business sectors both within and outside of Singapore. One who has benefitted from such rotations and overseas assignments is Mr Aw Kah Wai. The former Singapore Technologies scholarship holder graduated with an aerospace engineering degree and rose through the ranks in ST Aerospace before taking on an overseas assignment in 2007 at VT San Antonio Aerospace, and later at VT Mobile Aerospace Engineering in Alabama. He was appointed President of ST Aerospace Panama in 2011 and concurrently Vice President at VT Aerospace in 2012. Kah Wai made the boldest switch in his career in 2015 when he moved to the marine sector and assumed his current role as Vice President (Operations) at ST Marine's Tuas Yard a year later.

"It's always humbling to move from a familiar industry to a new sector outside one's comfort zone. You have to work harder to re-learn and re-build the network. Spending time overseas has helped me to look at ST Engineering from a different perspective. I could see what international customers value the most in us, and how we could step up to find a competitive path forward. It has given me much more confidence to venture forth. I'm also glad that I have been roped in for secondary duties like being the core team representative for ST Marine for Project Delta, the Group's shared services initiative. I encourage all colleagues to be open to overseas assignments, new roles and secondary appointments. See them as golden opportunities to expand your horizon and world view as well as to improve your resilience and adaptability.

Aw Kah Wai
Vice President (Operations) at Tuas Yard, ST Marine

Staying True to our Core Values

All great companies are shaped by guiding principles that determine how the organisation and its people are expected to behave. ST Engineering's core values are encoded as IVCCC, which stands for Integrity, Value Creation, Courage, Commitment and Compassion. "Over the past 50 years, ST Engineering has expanded and grown to become a global group. We now have operations in 22 countries spanning the US, Europe, Asia and Australasia. Our business landscape has undergone significant changes brought about by rapid technology advancements, globalisation and intense competition. Given these developments, it is ever more important that we remain rooted in our core values. They bind us in our day-to-day work – wherever we operate," said Mr Vincent Chong, President & CEO of ST Engineering.

GROUNDED IN INTEGRITY

When the project requirements for Saudi Arabia's Mass Rapid Transit Line were modified, the ST Electronics (Shanghai) team knew they would have to review the Power Supply Units (PSUs) that were purchased based on the earlier design. They had six weeks to modify and deliver the system, even though the work would have taken nine months. To uphold the company's culture of service and integrity, a decision was made to change the PSUs at a higher project cost to ensure long-term reliability. The modified system was delivered on time to the delight of the customer, who was highly impressed with the professionalism of the team and quality of the results.

MOTIVATED BY VALUE CREATION

ST Electronics' IFSS was the outcome of a request to manufacture a device that could detect fever in a fast and non-intrusive manner. The request arrived during the 2003 SARS outbreak amidst great urgency to curb the deadly virus. The project team raced against time to assemble, test and calibrate the system while adapting thermal imagers used in the military to meet the customer's specifications. The IFSS proved to be a winner by bagging several international awards and making it to TIME magazine's list of coolest inventions in 2003. The greatest satisfaction, however, came from bringing value to the society through a device that was subsequently deployed not just in Singapore but in many other countries.

UNDERWRITTEN BY COURAGE

In 2007, following a bold decision to refresh and grow VT LeeBoy's product line and take on new markets, a team from R&D, Engineering and Production accepted the challenge to redesign three core products: a Broom, Paver and Asphalt Distributor to be in time for the 2008 ConExpo international gathering for construction industries in Las Vegas, Nevada. At the same time, the team also took on the creation of a next-generation Paver and Grader, thinking outside the box to incorporate a new electronic control system. Undaunted by the tall order, the team rallied to get the job done, while the Purchasing team contributed by sourcing the test parts in record time. The courage and dedication to creating new possibilities paid off. The work was completed in four months, and the refreshed and new products drew much acclaim at the event.

DRIVEN BY COMMITMENT

For each Boeing 767 being converted into a freighter at ST Aerospace, there is a critical requirement to test the cargo system by positioning three large test pallets in the aircraft cabin. The labour-intensive and multi-stage process involves the use of a forklift and platform truck and can result in pallets toppling over during transportation, co-workers being hit and staff falling from height. Concerned about workplace safety and accidental damage to aircraft, a team was formed to review the processes. After analysing the requirements, the team came up with an innovative solution using man-portable modular pallets that can be easily assembled to the three different sizes as per the test specifications. This eliminated the safety hazards and avoided the use of a forklift and platform truck, thereby removing the risk of aircraft damage and raising productivity by over 80%. The team's commitment to improving the work processes has not only resulted in a safer working environment for co-workers but also created value for the company and customers.

MOVED BY COMPASSION

The devastation that swept through Mississippi, US, in the wake of the 2005 Hurricane Katrina was immense. Thousands of jobs were lost, and businesses and infrastructure were severely damaged or destroyed. The facilities of VT Halter Marine (VTHM) in Pascagoula were not spared. To help employees and their families tide over the difficult period, VTHM ensured that workers continue to be paid even though all shipyard work had halted. The move was unheard of in the shipbuilding industry, and the compassion for staff welfare was greatly appreciated. Yard workers, including office staff, returned to help with the repair and restoration of the premises, and VTHM became the first to resume regular operations in the affected areas.

Developing Talents, Nurturing Leaders

ST Engineering's technical and management leaders are groomed through a combination of talent development programmes, including scholarships, sponsorships and learning opportunities through their careers with us, as well as on-the-job trainings and job rotations. For young citizens and permanent residents with outstanding academic achievements, we provide scholarships to grow our talent pipeline. For staff who have demonstrated career potential, we sponsor them for part-time or full-time diploma, undergraduate, postgraduate or doctorate programmes. For senior staff with the potential to assume key leadership positions, we offer them executive programmes at prestigious universities. This has been the practice since the days of CIS and it has been followed since by the Group.

Ms Tracie Teo oversees a team of six as Planning Manager at ST Aerospace Engineering. She attained her Master and Bachelor of Science degrees in Industrial and Operations Engineering from the University of Michigan, Ann Arbor, under the Group's overseas scholarship scheme. Upon graduation, Tracie spent three years in ST Kinetics focusing on operational excellence, including improving the efficiency of the Terrex production line. She was then rotated into ST Aerospace. According to Tracie, it was the variety of opportunities and experiences present in ST Engineering's diverse business areas that drew her to apply for the scholarship. "Fun, challenging and eye-opening are how I would describe my journey with ST Engineering so far. Rubbing shoulders with the best and brightest at one of the world's best universities has helped me to develop intellectually. However, it was the exposure and opportunities for self-development that have provided the greatest fulfilment. Being able to contribute effectively in a male-dominated field has motivated me to do more, and to bring fresh perspectives to project discussions. I'd like to think that my contributions have led to better workflow, cost-savings and higher productivity in several projects!"

FINDING FULFILMENT THROUGH OPPORTUNITIES

THE PIONEER SCHOLAR

"I went to the University of California, Los Angeles for my Master of Business Administration in 1978. I remember when Mr Ong Kah Kok, Chairman of CIS, informed Dr Goh Keng Swee that I would be going for further studies, Dr Goh's response was, "What for? He already knew everything!"

When Kah Kok returned to the office, he hurried me to pack up and go immediately before the Old Boy – his fond moniker for Dr Goh, decide to stop my study for real. My wife was working for the Ministry of Education at that time and she had applied for a two-year sabbatical leave. I told Kah Kok that the application was still pending. He promptly picked up the phone and called Mr George Bogaars, the Permanent Secretary of the Ministry of Finance, for help. Mr Bogaars replied, 'Consider it done!' And just like that, I was off to the US. That was how fast decisions were made.

Lai Chun Loong, *who worked in CIS from 1968 to 1993 in a variety of roles, with the last being President, CIS and Chairman of ST Automotive*

Photo courtesy of Lai Chun Loong

ALWAYS READY TO LEARN

Mr Edwin Ang Wen Jun is an Engineer involved in the design of small- and medium-calibre ammunition at ST Kinetics – a role he landed after attaining a Bachelor of Mechanical Engineering degree from Nanyang Technological University under the ST Engineering Scholarship. Like many, Edwin was awed by the diversity of ST Engineering's businesses, and has always wanted to work for the biggest defence solutions provider in Singapore. "Defence equipment has captured my attention since I was young. Just in Advanced Material Engineering alone, we do everything from identifying operational needs to design, testing, qualification, production and providing technical support. There's always something new to learn every day. Being new has not deterred me, and I'm entrusted to be prudent with budgets, and to complete projects on schedule. I hope to deepen my technical expertise in ammunition design and to become a programme manager someday!"

GAINING NEW CONFIDENCE

Ms Jenny Yap is an Executive at the Group's Corporate Communications Department. While she has demonstrated her ability to take on greater work responsibilities, she lacked formal education in the advertising and marketing disciplines to be able to maximise her true potential. With the support of her supervisor at ST Electronics, Jenny applied for a Diploma in Marketing Communications at the Institute of Advertising Singapore under the staff sponsorship scheme. "Through the diploma programme, I got to understand the underlying principles of marketing, advertising, public relations and creative writing. And since I'm a member of the communications team, I have ample opportunities to put my newly acquired knowledge to practice. The skills upgrade has given me the necessary grounding to take on more challenging work. It has greatly bolstered my confidence, especially when I have to meet and deal with external parties."

Jenny (left) and her son, Wayne Koh (right)

NURTURING TALENT IS PARAMOUNT

"Being an engineering company, it is of paramount importance that we have good talents. When Singapore Aircraft Industries (SAI) was formed, one of my key priorities was to recruit the best people for the company. The SAI Engineering Scholarship Scheme was started in 1983 with an initial award to 13 scholarship recipients to study in either local or overseas universities. To ensure a strong talent pipeline, we continued to offer around 10 scholarship awards a year. The scholarship scheme was opened to all employees, children of employees and the general public who are citizens or permanent residents. Many of these scholars have stayed on with ST Aerospace well beyond their eight-year bond and have done well in their respective roles.

Mr Quek Poh Huat
Managing Director, Singapore Aircraft Industries (1981 to 1983) and President, Singapore Aerospace (1983 to 1995)

Quek Poh Huat in 1990 as President, Singapore Aerospace

GROWING UP WITH ST AEROSPACE

Mr Ku Kay Choon graduated from the Stanford University with a Bachelor of Science degree in Electrical Engineering in 1994 and worked as an Avionics System Engineer on aircraft upgrade programmes. He subsequently took on a broad spectrum of roles and appointments before becoming the General Manager of STA Engines in 2015. He is currently the General Manager of STA Systems. "The ST Aerospace scholarship has given me a world-class education, allowing me to be part of a rapidly growing industry steeped in engineering content. All of us must be well prepared for the new technologies and innovations that are coming into aviation. With every project, we get to learn about new technologies and how to apply them within all kinds of constraints to meet operational requirements. Young engineers should be proud of their engineering training, as the same skillset can be applied to tackle business and organisational challenges, beyond technical issues."

THRIVING THROUGH MENTORSHIP

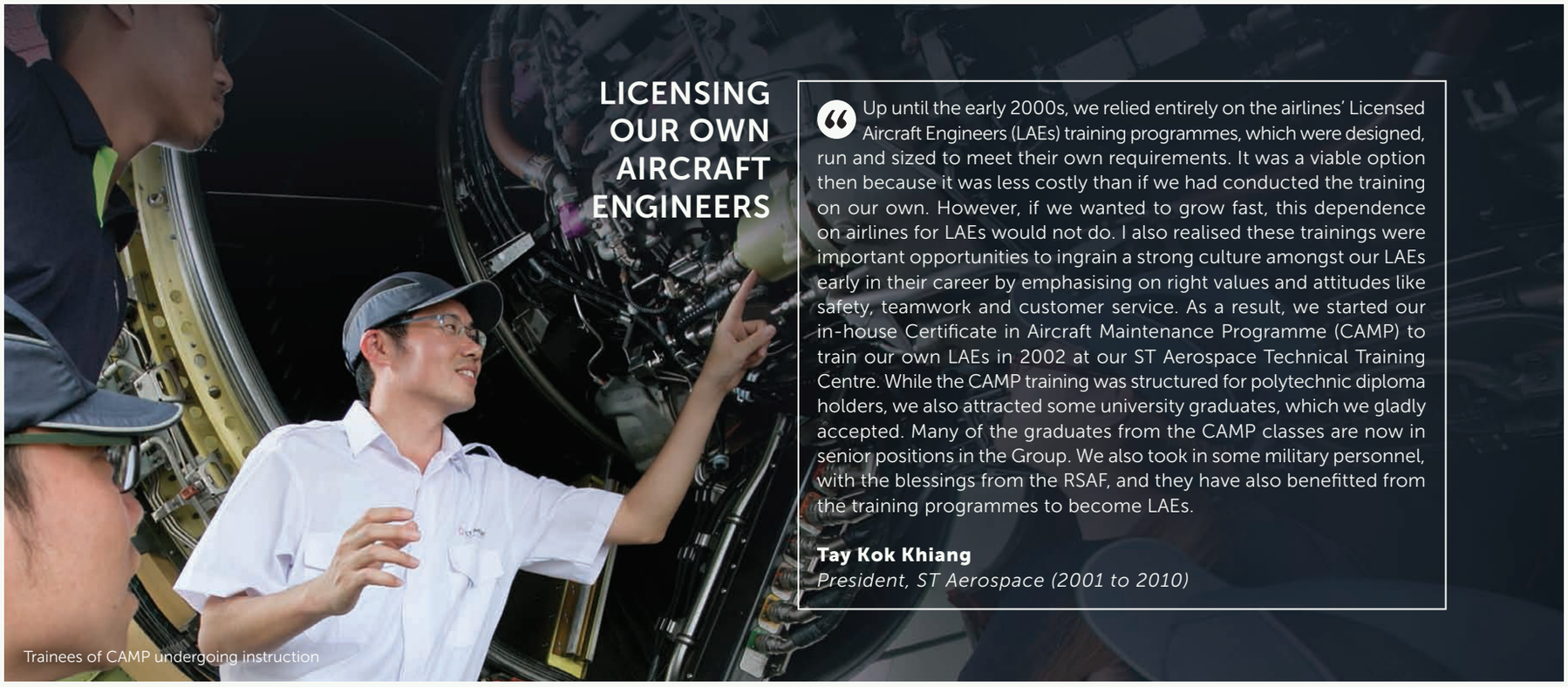
Mr Foo Ming Qing is a Senior Engineer at ST Electronics (InfoComm Systems) and a recipient of ST Engineering overseas scholarship. He graduated with a Bachelor's degree in Electrical and Information Sciences from the Cambridge University, and a Master's degree in Computation for Design and Optimisation from the Massachusetts Institute of Technology. Ming Qing has always dreamt about putting his training to projects that improve people's lives. "My job as a software developer for the Internet of Things management systems involved in Singapore's Smart Nation initiative has provided the perfect avenue for this. I've also benefitted from ST Engineering's mentorship programme that allows me to tap into the wisdom of my seniors. Being able to seek help from colleagues, regardless of seniority or rank, has enabled me to come up with new ideas and make many good friends at work. By organising events such as robotics competitions and staff carnivals, I've found yet another way to give back to the community and to keep innovation alive."

THE LKY MODEL STUDENT

Mr Muhammad Shiddiq Bin Abdul Rasid is a Senior Technician at ST Kinetics. He started as an apprentice in a tie-up with the Institute of Technical Education, where he was conferred the Lee Kuan Yew Model Student/Trainee Award in 2012. As an outstanding performer after completion of his NITEC certification, he was sponsored by the company for a Diploma in Engineering (Mechanical Engineering) from Singapore Polytechnic in 2016. "I'm truly grateful for the opportunity to be offered these training programmes while working at ST Kinetics. The courses have equipped me with a better understanding of my job. The new skills that I have acquired have improved the quality of my work and helped me in my career advancement. I'm looking forward to leading the Dyno-Testing section after completing my current stint with the engine section and transmission MRO operations."

DEVELOPING SPECIALISED SKILLS

Mr Alex Ting Choon Boon is a Principal Engineer in charge of naval weapons and equipment at ST Marine, where he started out as an Assistant Engineer in 2001. Through an ST Marine Overseas Training Award in 2006, Alex was given the chance to pursue a Bachelor of Electronic Engineering degree at the University of Hull, completing the course with an upper second-class honours. In 2011, he was sponsored to attend the Master of Defence Technology and Systems (MDTS) programme, jointly offered by the National University of Singapore and the Naval Postgraduate School in the US. "The MDTS course was an experience in multi-disciplinary learning with a world-class faculty. It has provided me with the global exposure required to better understand the complex issues underlying some of my projects. This will go a long way, now that I've been assigned the enlarged responsibility of leading different teams of engineers to run the naval projects."



LICENSING OUR OWN AIRCRAFT ENGINEERS

"Up until the early 2000s, we relied entirely on the airlines' Licensed Aircraft Engineers (LAEs) training programmes, which were designed, run and sized to meet their own requirements. It was a viable option then because it was less costly than if we had conducted the training on our own. However, if we wanted to grow fast, this dependence on airlines for LAEs would not do. I also realised these trainings were important opportunities to ingrain a strong culture amongst our LAEs early in their career by emphasising on right values and attitudes like safety, teamwork and customer service. As a result, we started our in-house Certificate in Aircraft Maintenance Programme (CAMP) to train our own LAEs in 2002 at our ST Aerospace Technical Training Centre. While the CAMP training was structured for polytechnic diploma holders, we also attracted some university graduates, which we gladly accepted. Many of the graduates from the CAMP classes are now in senior positions in the Group. We also took in some military personnel, with the blessings from the RSAF, and they have also benefitted from the training programmes to become LAEs.

Tay Kok Khiang
President, ST Aerospace (2001 to 2010)

Trainees of CAMP undergoing instruction

LEARNING TO LEAD

Mr Ed Onwe is the Chief Operating Officer of VT San Antonio Aerospace (VT SAA). He was a Manager of Compliance and Continuous Improvement when he was sponsored by the company for the Master of Business Administration and Master of Science in Industrial Engineering programmes at St. Mary's University. He graduated from both programmes with distinction. "These educational programmes have helped me to chisel my path to senior leadership within VT SAA. The knowledge, experience and development gained through this training opportunity have prepared me to be effective in driving innovation and growth within the company. The programmes also have equipped me for effective leadership."

PUSHING PERSONAL BOUNDARIES

Mr Low Jin Yi is a Senior Engineer in charge of shipbuilding projects, and an ST Engineering overseas scholar who has returned with a Master's degree in Mechanical Engineering from the Imperial College, London. At ST Marine, Jin Yi is living his ambition to develop cutting-edge naval platforms. "ST Engineering has provided me with many opportunities, be it my main job scope or additional work commitments. Even though there are always challenges, these obstacles have allowed me to push my personal boundaries, as well as develop my tenacity and determination in coming up with new solutions. Engineering is never a one-man effort – there are multi-faceted challenges requiring tremendous teamwork from many stakeholders. My aspiration is to make a difference by contributing new engineering ideas and approaches, and to collectively bring about success by delivering the right solutions to our customers."

GROOMING FUTURE RESEARCHERS

> To ensure we have a constant pool of talents to pursue research, ST Kinetics adopts a holistic approach by engaging good interns to work on advanced materials. We then select the more promising ones to join the R&D team after they graduate. To sustain their interest, we put those who are keen on the Industrial Postgraduate Programme (IPP) introduced by the Economic Development Board to pursue their doctorate degree in relevant areas of research. The first batch of IPP candidates would be awarded their PhDs in 2017.
>
> **Dr Richard Kwok**
> *Chief Technology Officer, ST Kinetics*

From left: Tan XingHe (with focus in Advanced Magnesium Alloy), Jeremy Koh Siang Hui (Advanced Ceramics), Tan Sheng Cai (Graphene Composites), Dr Richard Kwok (IPP PhD supervisor) and Ang Yinn Leng (Acoustic Meta-materials)

THE REWARDS OF BEING METICULOUS

Ms Ang Lay Peng is an Assistant Principal Engineer at ST Kinetics, attached to the Quality Assurance (QA) Department under Advanced Material Engineering. Her work entails product quality planning to ensure product safety and reliability. "In QA, we operate under the mantra that 'one incident is too many'. To deliver highly reliable products, our production processes must comply with the most stringent standards. ST Engineering has given me many opportunities and new experiences within and outside my job scope. Other than honing my knowledge and skills, I've gained confidence in taking calculated risks and have learned to be more open to feedback. What drives me is the chance to work in an organisation with diversified businesses, to be able to support a product through its entire life-cycle, and the satisfaction of overcoming challenges."

THE ACCIDENTAL ACCOUNTANT

CIS started awarding undergraduate scholarships in 1980 and among the first batch of recipients are ST Kinetics' current management like Mr Tung Yui Kee, Deputy Chief Engineering Officer, ST Kinetics (1980); Mr Allan Ong, Vice President of Business Development (1983); and **Ms Daisy Kok**, Vice President of Finance (1983).

Daisy's career is particularly interesting. A diploma holder from Singapore Polytechnic, Daisy was working as a Planner when she applied for a CIS scholarship in 1983 and graduated with a first-class degree from the University of Birmingham, UK in Engineering Production. "The course opened up my horizon. I learned to question the logic behind things and once I figured that out, it's so much easier to apply the knowledge to my work," said Daisy. Over the years, Daisy took on many roles and unexpectedly, her involvement in a costing project kicked off her second career in Finance. "Feeling somewhat inadequate dealing with debit and credit transactions, I applied for company sponsorship for a part-time Master's course in Accounting from the Monash University, Australia. Armed with my working experience as a planner and an engineer, and a Master's degree in Accounting, I began to integrate finance processes with operations output and vice versa. I'm glad that successive generations of senior management in ST Kinetics appreciate my versatility as a strong Finance person with practical engineering and operations background," Daisy grinned.

ENJOYING EVERY MOMENT

Mr Dennis Teo Wee Boon is a Manager at ST Electronics' Satcom & Sensor Systems Group, where he is responsible for programmes involving the integration of satellite communications as well as defence sales. Dennis was looking to broaden his horizons and experiences when he decided to chart his career with ST Engineering in 2011. "I discovered my interest in the industry while working on small-scale defence projects in my previous company. I joined ST Engineering as I figured that it would allow me to hone a wider variety of skills and develop myself professionally. Today, I'm tackling multiple challenges and working with people from diverse backgrounds. I'm also exposed to different domains, technological competencies as well as complex and large-scale engineering projects. It is always exciting to be at the forefront, to exploit the latest technologies available in the market – there's never a boring moment at work!"

"THE NEXT 50 YEARS WILL BE EVEN MORE EXCITING FOR ST ENGINEERING. WE MUST BE PREPARED TO THINK DIFFERENTLY, AND TO TAKE GREATER LEAPS OF FAITH IN TECHNOLOGY AND INNOVATION. WE HAVE COMPETENT PEOPLE WHO HAVE PROVEN THEIR TENACITY AND COMMITMENT TO THIS CAUSE, AND A CAPABLE LEADERSHIP THAT IS READY TO RUN THE NEXT LAP."

Kwa Chong Seng
Chairman
ST Engineering


POSTFACE

ST Engineering at 50

It has been five decades since CIS, the first pioneer company, was set up to support Singapore's national defence. It has also been 20 years since companies in the Aerospace, Electronics, Land Systems and Marine sectors came together to form ST Engineering. The Group has grown alongside Singapore and is proud of its illustrious history.

ST Engineering's achievements can be attributed to the legacies of its pioneers. Their passion for engineering solutions that make a difference to society has remained intrinsic to the Group's DNA. The Group's accomplishments have also come from the unwavering support of its customers, business partners and suppliers.

Above all, ST Engineering owes its continued success to its employees around the world. "Our deep appreciation for your energy, resilience, loyalty and passion that have contributed to our growth and expansion globally. You have helped us to surmount the unrelenting wave of unprecedented changes, challenges and disruptions to the business landscape and intensifying market competition," said Mr Vincent Chong, President & CEO of ST Engineering, in his tribute to staff on the 50th anniversary of ST Engineering.

At 50, ST Engineering is focused firmly on the future. It will remain resolute to accomplish more and create greater value for all its stakeholders.

HONOURING OUR PIONEERS

"The Corporate Communications team was tasked with condensing the Group's 50 years of history into an eight-panel poster walk-through and five-minute video for the commemorative event. We had painstakingly pored through entire libraries of media galleries, photos and other archival materials, and when it was completed, we thought we had a good grasp of our legacy - but how wrong we were. When our guest-of-honour Ms Ho Ching spontaneously invited a long list of pioneers on stage, it jolted me then - that was the one moment which captured the essence of the enduring ST Engineering spirit through all these years. No poster or video could top the experience of meeting the pioneers in person; hearing them recount the stories of yesteryear brought our history alive. I was truly humbled, yet at the same time, motivated to contribute meaningfully to the ST Engineering story someday.

Sylvia Lee
Assistant Manager, Corporate Communications, ST Engineering

ENCAPSULATING OUR ACHIEVEMENTS

"I had the privilege of putting together our 50th Anniversary Time Capsules, which were symbolically sealed on 26 January 2017 by Ms Ho Ching, Mr Kwa Chong Seng and Mr Vincent Chong. Within them, we preserved memorabilia from our present-day achievements such as the AIR+ Smart Mask, images taken by the TeLEOS-1 satellite, and a model of the Terrex Infantry Fighting Vehicle. These 'trophies' will serve as proud pedestals in the future, and we will always be able to reflect on how far we have come together as a Group.

Yuen Jia Feng Justin
Assistant Manager, ST Engineering
(2nd from left)

SHOWCASING OUR INNOVATIONS

Planning and putting together the exhibits for our 50th Anniversary Open House from 25 to 26 January 2017 was mostly a labour of love for the Group-wide team involved. What impressed me most was Mr Henry Cheong, CIS' pioneer engineering chief who despite having difficulty walking, spent over an hour and a half asking highly thought-provoking and technical questions about the products we displayed. He and his generation of engineers and technologists have truly made us who we are today!

Lam Siew Cheong Daniel
Vice President, Marketing, ST Engineering
(2nd from right with Henry Cheong to the immediate left and Lai Chun Loong to the right.)

GOLFING FOR A GOOD CAUSE

Not even the heavy downpour could quell the enthusiasm for a good deed at our 50th Anniversary Charity Golf on 26 May 2017. Defence Minister Dr Ng Eng Hen, who was the guest-of-honour, took to the course with 180 golfers in a shotgun tee-off to raise S$1 million for children and youths with special needs and people with disabilities. The event ended on a high note with dinner and memorable performances put up by several charities supported by ST Engineering through the Community Chest. I'm thankful for the opportunity to be part of the organising committee.

Lau Jie Xian Jacinth
Assistant Programme Manager, ST Aerospace
(6th from left)

CELEBRATING AS A FAMILY

I'm very honoured to have helped with the organisation of ST Engineering's 50th Anniversary Family Day Carnival at Sentosa. We spared no detail in our planning to ensure a meaningful and engaging experience for the 14,000 participants. I got to work with counterparts across the sectors and to experience the heartwarming effort put in by everyone. A highlight was the S$1 million donation to 'President's Challenge 2017'. This came from the total amount raised from business partners, staff and management across the Group through a Charity Golf in May and an internal Charity Draw in July, with proceeds beyond the million-dollar mark used to support charities directly identified by ST Engineering.

Lee Hwee Siong
Assistant Vice President, Human Resource, ST Marine

DEBUTING ON SILVER SCREEN

ST Engineering's products and solutions will be featured in the fourth and fifth instalments of 'Ah Boys To Men', a highly successful Singapore movie franchise about National Service. It is an excellent way to commemorate our 50th year as a strategic partner to the SAF in air, land and sea operations. Both National Service and ST Engineering were borne out of necessity five decades ago, so it is with great pride that we can showcase products like the SAR21 and Bionix used by our National Servicemen, and the futuristic NGAFV, to mark our continued support for the peace and stability of Singapore. Some of our staff will have cameo roles in the movies, and I'm especially pleased that I can draw on my years in the SAF to contribute ideas for a realistic storyline.

Winston Toh
Executive Vice President and Chief Marketing Officer, ST Kinetics, and Chief Coordinator for ST Engineering's role in the movie production.

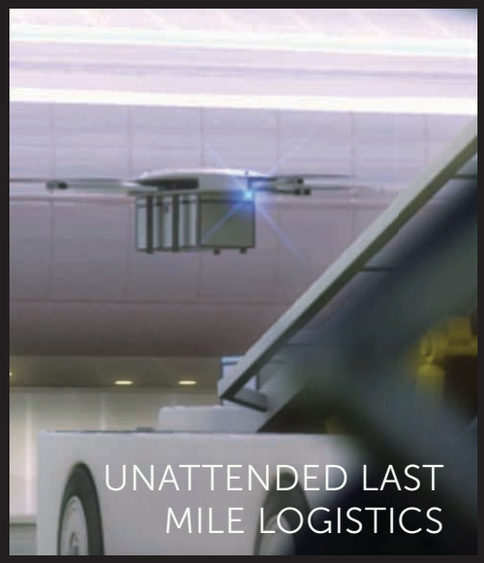
Our Future ST Engineering

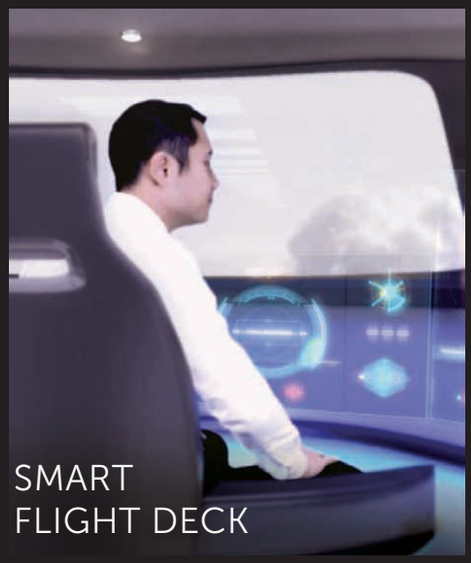
About 100 young employees from across ST Engineering came together to share their visions on the types of innovative solutions that would shape the future development of ST Engineering's defence and commercial businesses. Bold ideas were ventured into, such as a holographic instructor, a solar-powered vessel, an electro-magnetic pulse weapon and an Artificial Intelligence-assist co-pilot. The young talents also gave a shot at envisaging how the future workspace could be more productive and creative. Their ideas were made into a video as part of the year-long activities to commemorate ST Engineering's 50th Anniversary.


RENEWABLE ENERGY VESSELS


ADVANCED SATELLITE CONNECTIVITY


HOLOGRAPHIC INSTRUCTOR


UNATTENDED LAST MILE LOGISTICS


SMART FLIGHT DECK

ADDITIVE MANUFACTURING AND PREDICTIVE MAINTENANCE


ADVANCED AIRFRAME DEFECT DETECTION SYSTEM

The Engineering Passion Lives on

What does the future hold for ST Engineering, already a well established, global technology, defence and engineering group? Will the Group be able to maintain its leadership position in the areas it operates? How would emerging technologies transform the next generation of ST Engineering solutions? How do our people envision their future workplace and what are their dreams and aspirations for the next 50 years? We asked our staff around the world for their aspirations and here are what some of them said:

"I'd like ST Engineering to be the leader of cutting-edge technological advancement and innovation, inspiring minds and enhancing lives on the global stage!"

Chee Hong Ern
ST Electronics

"That ST Engineering will be the company of choice for customers and partners seeking solutions for their operational or business requirements, and employer of choice for those seeking career fulfilment.

Steve Teng
ST Aerospace

"The world's best engineering company recognised for its strong heritage, professionalism, technical knowledge and sense of social responsibility in addressing the world's complex and changing challenges.

Pravin Premnavas
ST Kinetics

"I wish ST Engineering would become the industry leader in engineering excellence and innovation, providing breakthrough solutions to meet customers' needs.

Noel Casiño
VT SAA

"My ideal ST Engineering is a workplace where all employees can find fulfilling and long-term careers; an organisation that believes in providing people with a growth environment to achieve their dreams and goals.

Charlton Ng
ST Electronics

"May we become a leading global engineering company known for our innovation, passion and ability to engineer cutting-edge solutions and technologies for everyday problems. May we carry on to make life better for everyone. May we continue to ENGINEER WITH PASSION!

Danny Low
ST Electronics

"To be a leading smart environmental engineering company in the world, helping to build and maintain sustainable cities, and make a difference to the management of climate change.

Chew Men Leong
ST Marine

"We can create a stronger culture where individual success can be pursued and achieved for the betterment of the Group, and a place for continuous improvement and creativity to thrive.

Michael Perkins
VT DRB Aviation

"Indisputably, one of the top engineering groups in the world and a preferred company to work for.

Goh Aik Hoong
ST Aerospace

A Singaporean company with a truly global focus, and more internationally competitive products and services in more overseas markets!

Aw Kah Wai
ST Marine

To be a responsible and socially conscious Group for the betterment of all humanity and all our customers!

Edwin Tan
VT Systems

My wish is for ST Engineering to be one of the world's most sought-after employer; the global brand reputed for its creative and self-driven high performers.

Chong Liang Ming
ST Engineering Corporate

For ST Engineering to always be at the forefronts of innovation and technology for the Aerospace, Electronics, Land Systems and Marine sectors. May we continue to serve Singapore proudly with excellent products of the highest quality and safety, and to bring out the best in every ST Engineering employee.

Ng Siew Ling
ST Kinetics

May we grow stronger as One ST Engineering, unified with one heart, one soul, one mission and one goal!

Sheila Chin
ST Kinetics

That ST Engineering will continue to deliver innovative solutions that bring lasting value to people, organisations and societies.

Jerome Lee
ST Engineering Corporate

I hope to continue working for a world-class defence and engineering group with innovative technologies and products that attract the world's best talents.

Hong Shufen
ST Electronics

A multi-national corporation with an undisputed market-leading position in selected key industries; a strong and widely recognised brand known for its dependable, reliable and quality services; and a warm, fun, exhilarating and challenging workplace where compassion and passion co-exist in harmony.

Tang Kum Chuen
ST Electronics

I envision ST Engineering as a shining beacon of light that attracts customers with its brilliant technological solutions. I also see us as the number one choice for aspiring engineers seeking to develop their full potential.

Ben Lim
ST Electronics

Looking into the next 50 years, I envision ST Engineering's continued leadership with innovative products and services, made possible through a combination of creative thinking and relentless effort, to improve the world that we share.

Rolando Peña
VT SAA

I hope ST Engineering can continue to be one of the best employers in Singapore – a company where there is growth, opportunity and work-life balance; where top talents and committed people are drawn to contribute good ideas; and where ideas are eventually transformed into useful products and solutions. I also hope we can contribute more smart city solutions!

Lim Kwee Yen
ST Electronics

GLOSSARY

ABBS	Aviation Behaviour Based Safety
ACMS	Advanced Combat Man System
AES	Aerospace Engineering Services (Australia)
AGL	Automatic Grenade Launcher
AHTS	Anchor Handling Tug Supply
AI	Artificial Intelligence
AMC	Army Materiel Command (US)
AMM	Aircraft Maintenance and Modification
AOG	Aircraft-On-Ground
AOS	Allied Ordnance Company of Singapore
ARL	Airline Rotables Limited (UK)
ASEAN	Association of South-East Asian Nations
ATTC	All Terrain Tracked Carrier
AUV	Autonomous Underwater Vehicle
AV	Autonomous Vehicle
BCM	Business Continuity Management
BMCR	Bullpup Multirole Combat Rifle
BF	Business Foresight
BEC	Business Excellence Council
BX	Bionix Infantry Fighting Vehicle
C2	Command and Control
C3	Command, Control and Communications
C4	Command, Control, Communications and Computers
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CAI	Chartered Ammunition Industries
CAV	Commercial Articulated Vehicle
CE	Customer Excellence
CETS	Component and Engine Total Support
CIC	Combat Information Centre
CIS	Chartered Industries of Singapore
CLS	Contractor Logistics Support
CRISP	Crisis Response Intelligence Support Programme
CRO	Component Repair and Overhaul
CSR	Corporate Social Responsibility
CTO	Chief Technology Officer
DBG	Defence Business Group
DARPA	Defense Advanced Research Projects Agency (US)
DHC	Dee Howard Company (US)
DOA	Design Organisation Approval
DSO	DSO National Laboratories (Singapore)
DSTA	Defence Science and Technology Agency (Singapore)
DTP	Defence Technology Prize (Singapore)
EAMS	Enterprise Asset Management System
EASA	European Aviation Safety Agency
ECP	Entity-centric Code Platform
EDC	Engineering & Development Centre
EFW	Elbe Flugzeugwerke GmbH (Germany)
EHS	Environment, Health & Safety
ERM	Enterprise Risk Management
FAA	Federal Aviation Authority (US)
FedEx	Federal Express Corporation
FOD	Foreign Object Debris
GCV	Globally Competitive Venture
HK FSD	Hong Kong Fire Services Department
HMX	Hydro-Mechanical Transmission
IAV	Interim Armoured Vehicle (US)
ICT	Information and Communication Technologies
ICV	Infantry Carrier Vehicle
IED	Improvised Explosive Devices
IFSS	Infrared Fever Screening System
IFV	Infantry Fighting Vehicle
IMU	Inertia Measuring Unit
IoT	Internet-of-Things
IP	Intellectual Property
LMV	Littoral Mission Vessel
LPD	Landing Platform Dock
LRT	Light Rail Transit
LTA	Land Transport Authority (Singapore)
LST	Landing Ship Tank
M2M	Machine-to-Machine
MBH	Maintenance-By-the-Hour

MINDEF	Ministry of Defence (Singapore)
MRO	Maintenance, Repair and Overhaul
MRT	Mass Rapid Transit
NGAFV	Next Generation Armoured Fighting Vehicle
NTUC	National Trade Union Congress (Singapore)
ODA	Organisation Designation Authorisation
ODE	Ordnance Development and Engineering
OEM	Original Equipment Manufacturer
OHSAS	Occupational Health and Safety Assessment Series
PELO	People Excellence and Learning Organisation
PTF Conversion	Passenger-to-Freighter Conversion
PV	Patrol Vessel
RNO	Royal Navy of Oman
RoRo	Roll-on/Roll-off
RSAF	Republic of Singapore Air Force
RSN	Republic of Singapore Navy
RTN	Royal Thai Navy
SACO	Singapore Aero-Components Overhaul
SADC	Singapore Air Defence Command
SAE	Singapore Automotive Engineering
SAEOL	Singapore Aero-Engine Overhaul
SAF	Singapore Armed Forces
SAI	Singapore Aircraft Industries
SAMCO	Singapore Aerospace Maintenance Company
SASCO	Singapore Aviation Services Company / ST Aerospace Services Company
SAWS	Singapore Aero-Warehousing and Supplies
SBEMS	Smart Building Energy Management System
SEEL	Singapore Electronic & Engineering
SES	Singapore Engineering Software
SFI	Singapore Food Industries
SI	Systems Integrator
SIA	Singapore Airlines
SISEU	Singapore Industrial and Services Employees' Union
SMCC	Smart Metro Control Centre
SMEEU	Shipbuilding and Marine Engineering Employees' Union
SMMWU	Singapore Manual and Mercantile Workers' Union
SQA	Singapore Quality Award
SRAMS	Super Rapid Advanced Mortar System
SSE	Singapore Shipbuilding and Engineering
SSRV	Submarine Support Rescue Vessel
ST	Singapore Technologies
ST Aerospace	Singapore Technologies Aerospace
ST Automotive	Singapore Technologies Automotive
ST Electronics	Singapore Technologies Electronics
ST Kinetics	Singapore Technologies Kinetics
ST Marine	Singapore Technologies Marine
STA Engineering	Singapore Technologies Aerospace Engineering
STA Engines	Singapore Technologies Aerospace Engines
STA Supplies	Singapore Technologies Aerospace Supplies
STA Systems	Singapore Technologies Aerospace Systems
STC	Singapore Technologies Corporation
STC	Supplemental Type Certificate
STPL	Singapore Technologies Pte Ltd
STSE Engineering	STSE Engineering Services
SUTD	Singapore University of Technology and Design
TAS	Total Aviation Support
TDMA	Time Division Multiple Access
TGMS	Third Generation Mobilising System
TII	Technology, Intellectual Property and Innovation
UAV	Unmanned Aerial Vehicle
UHV	Unmanned Hybrid Vehicle
UI	Unicorn International
USTAR	Urban-Surveillance & Tracking Autonomous Rotorcraft
USV	Unmanned Surface Vehicle
VR	Virtual Reality
VSAT	Very Small Aperture Terminal
VT MAE	VT Mobile Aerospace Engineering (US)
VT SAA	VT San Antonio Aerospace (US)
VT Systems	Vision Technologies Systems (US)
VTHM	VT Halter Marine (US)
VTS	Vision Technologies Systems (US)
WSH	Workplace Safety and Health

ACKNOWLEDGEMENTS

ST Engineering

To produce a book of such detailed facts, supported by a large number of illustrations is not a task that can be accomplished without the help of numerous people who have contributed information and photographs.

We thank all those who have helped us in the compilation of materials for this book - our pioneers; our directors and employees past and present; our business partners and customers, including the Singapore Ministry of Defence; all who have shared their stories, quotes and personal photographs; and all organisations who have granted the use of proprietary images and infographics.

While the Book Committee aimed to be comprehensive in featuring the contributions of our pioneers, employees and all stakeholders, there will be areas that would have been left out due to limitations in time and resource.

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Title : Engineering With Passion
ISBN : 978-981-11-3894-2

Publisher:
Singapore Technologies Engineering Ltd
ST Engineering Hub
1 Ang Mo Kio Electronics Park Road, #07-01
Singapore 567710
www.stengg.com

Production Team: Meta Fusion, Cactus Communications & Dominie Press

GREETINGS FROM
ST ENGINEERING
EMPLOYEES ACROSS
THE WORLD

E N G I N E E R I N G








WITH PASSION










ST Engineering