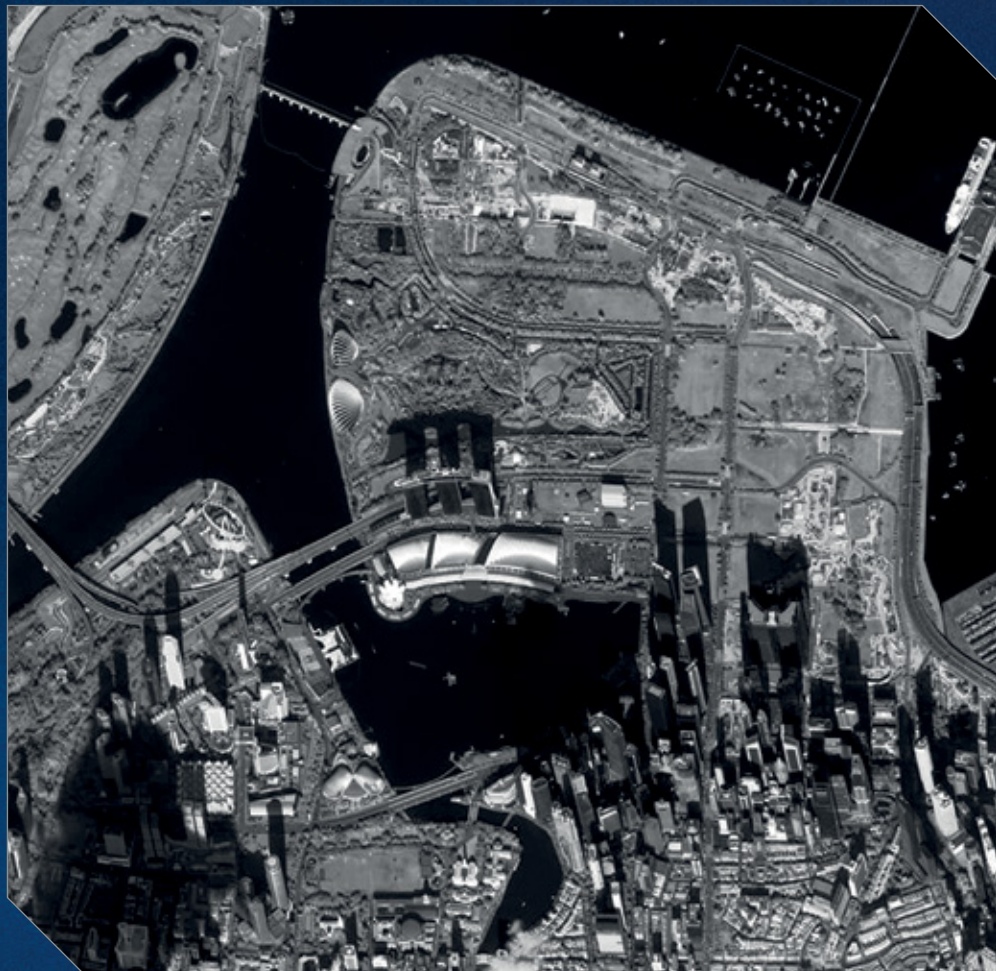


SINGAPORE'S SPACE ECOSYSTEM

AUGUST 2022



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Payload qualification activities for DSO National Laboratories' NeuSAR satellite at ST Engineering Satellite Systems' thermal vacuum facility.

Cover photo: Image of Marina Bay in Singapore taken by TeLEOS-1, Singapore's first commercial earth observation satellite developed by ST Engineering Satellite Systems.

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Launch of the SpooQy-1 satellite from the International Space Station.

“ ” ▶ THE SPACE SECTOR HAS UNTOLD POTENTIAL AND POSSIBILITIES. MANY SPACE TECHNOLOGIES HAVE FOUND APPLICATIONS HERE ON EARTH, LIKE THE GPS IN OUR SMARTPHONES AND CARS.

SINGAPORE MAY NOT BE A SPACE-FARING NATION, BUT WE ARE DOING R&D IN SPACE-RELATED CAPABILITIES TO SUPPORT KEY PILLARS OF OUR ECONOMY SUCH AS AVIATION AND MARITIME. I HOPE FUTURE BREAKTHROUGHS WILL ONE DAY HELP US SOLVE PRESSING CHALLENGES LIKE CLIMATE CHANGE, AND IMPROVE LIVES.

Mr Lee Hsien Loong
Prime Minister

“ ” ▶ HERE IN SINGAPORE, THE SPACE SECTOR CONTINUES TO STAY VIBRANT, WITH MORE THAN 50 COMPANIES EMPLOYING MORE THAN 1,800 PROFESSIONALS. THESE COMPANIES ARE CRITICAL ENABLERS FOR OTHER SECTORS – FROM AVIATION TO MARITIME... CENTRAL TO THIS ECOSYSTEM ARE SINGAPORE'S STRONG CAPABILITIES IN RESEARCH AND TECHNOLOGY, AS WELL AS OUR POSITION AS A TRUSTED BUSINESS HUB FOR CAPITAL, TALENT, AND INTELLECTUAL PROPERTY.

Mr Gan Kim Yong
Minister for Trade and Industry

INTRODUCTION TO OSTIN: SINGAPORE'S NATIONAL SPACE OFFICE



Office for Space Technology & Industry, Singapore

OSTIn

To capture economic opportunities in the space sector, the Singapore Economic Development Board (EDB) established the Office for Space Technology & Industry (OSTIn) in 2013.

In its early years, OSTIn focused on growing a globally competitive space industry in Singapore, collaborating closely with local and international space industry players to realise their business and innovation initiatives as well as with partners within and beyond Singapore's space ecosystem to build up local research capabilities.

In April 2020, OSTIn took on the mandate of Singapore's national space office. While still hosted within the EDB, it is now an autonomous office under the purview of the Ministry of Trade and Industry, reporting to its own governing board. Today, OSTIn focuses on five workstreams to build up Singapore's space ecosystem and advance the country's space interests:

- Nurturing the development of local space technology capabilities through investments in R&D;
- Growing a globally competitive local space industry;
- Developing policies and regulations to support Singapore's space activities;
- Expanding bilateral and multilateral partnerships, and contributing to strengthening the global governance regime for space activities; and
- Supporting the development of talent for Singapore's space sector and future workforce.

OSTIn's SPACE TECHNOLOGY DEVELOPMENT PROGRAMME

OSTIn's S\$150M flagship Space Technology Development Programme (STDP) seeks to develop space capabilities to support domains such as aviation, maritime and sustainability, which are critical to Singapore and many other countries, as well as disruptive space technologies that can improve the country's space industry's competitiveness.

Projects supported by the STDP include:

- Very low Earth orbit (VLEO) satellite technologies that would allow satellites to operate in orbits closer to Earth and deliver differentiated capabilities.
- Quantum key distribution (QKD) satellite solutions that would enable quantum-safe transmission of secure information.
- Use of satellite data for applications such as carbon measurement, reporting and verification (MRV), agriculture, pollution monitoring.

In addition, OSTIn is exploring new opportunities emerging in the space economy, such as on-orbit servicing, in-space manufacturing and space life sciences, including whether Singapore's strengths in domains like AI, robotics, materials science and life sciences can be pivoted to support space applications.

OSTIn's PARTNERSHIPS ACROSS THE WORLD

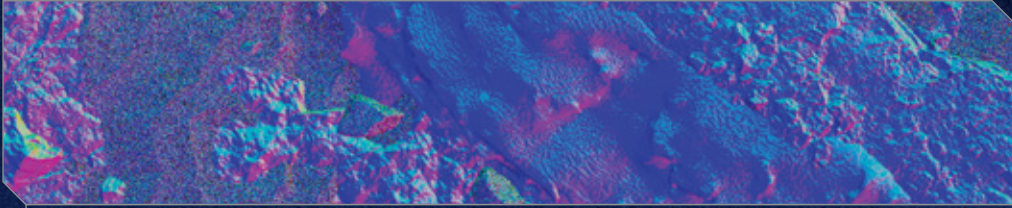
Central to OSTIn's work are its partnerships with other space agencies as well as its efforts to contribute to global space governance.

OSTIn has partnership agreements with counterparts such as the Centre National d'Etudes Spatiales (France's space agency), European Space Agency and United Arab Emirates Space Agency, to grow collaboration in space R&D, human capital development, and space policy and law.

OSTIn represents Singapore at forums such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) and Asia-Pacific Regional Space Agency Forum (APRSAP), and is a member of the Space for Climate Observatory (SCO) and International Astronautical Federation (IAF). Singapore is also a signatory of the Artemis Accords.



THE SINGAPORE SPACE ECOSYSTEM



The undulating terrain of a synthetic Martian environment developed by Bifrost.

Singapore has a nascent but fast-growing space ecosystem that builds on the country's strengths in areas like microelectronics and advanced manufacturing.

Today, there are more than 50 companies in the local space industry engaged in a wide range of activities across the value chain, from designing and manufacturing space components to providing satellite-based services. These companies comprise both local startups and SMEs, as well as international leaders such as Inmarsat, Planet and Thales.

Singapore's space research ecosystem is also growing. There are satellite engineering research centres as well as centres for remote sensing research at both the National University of Singapore and Nanyang Technological University. The Agency for Science, Technology and Research also has a satellite cluster within its Institute for Infocomm Research, which focuses on research in satellite communications, tracking and data analytics, while DSO National Laboratories works closely with institutes of higher learning and other entities within the ecosystem, contributing their strong engineering expertise to develop space technologies for commercial and whole-of-government applications.

The country's space scene is now buzzing, with the Global Space and Technology Convention typically held in February each year and a number of other space-related events, such as Asia Satellite Business Week and SatelliteAsia, held annually. There are also space-focused accelerator and venture building programmes, such as the Singapore Space & Technology Ltd's Space Accelerator Programme.

More information on local space players can be found in the Annex.

KEY FIGURES



MORE THAN 15 SATELLITES BUILT AND LAUNCHED SINCE 2011



FIRST COMMERCIAL SATELLITE LAUNCHED IN 2015



OVER 2,000 PROFESSIONALS ACROSS ENGINEERING, RESEARCH AND BUSINESS ROLES WITHIN THE SECTOR



OVER 50 LOCAL AND INTERNATIONAL COMPANIES

SINGAPORE'S SPACE JOURNEY

2011 – Now

Ongoing Programmes



AOBA VELOX-III
Demonstrator satellite with electric propulsion technology



AOBA VELOX-IV
Demonstrator satellite for propulsion and low-light camera



ATHENOXAT-1
Satellite with low-light vision imaging payload



DS-EO
Commercial / Government EO imaging satellite



ARCADE
Space environment measurement satellite



DS-SAR
Commercial / Government SAR satellite



ELITE
VLEO remote sensing satellite demonstrator




GALASSIA-2
EO imaging satellite



GALASSIA
Photon correlation verification demonstrator



KACIFIC 1
Commercial Ka-band HTS



KENT-RIDGE 1
Hyperspectral imaging microsatellite



NEUSAR
Singapore's first locally-developed SAR satellite



KACIFIC 2
Commercial Software-defined Ka-band HTS



LUMELITE-1/2/3
Formation flying satellites



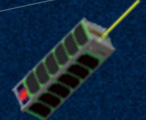
LUMELITE-4
VDES for maritime communications



LUMELITE-5
Small satellite demonstrator



POPSAT-HIP 1
Micropropulsion system nanosatellite



SCOOB-I
3U student cubesat with solar spectral sensor



SPATIUM
Space-precision atomic-clock timing utility mission



NULION
Nanosatellite demonstrator to enable IoT applications in rural areas



ORB-12 STRIDER
Hall-effect thruster demonstrator satellite



SCOOB-II
Cubesat to test commercial processor



SPEQTRAL-1
QKD satellite demonstrator



NUX-1
IoT satellite



TELEOS-1
Commercial / Government EO imaging satellite



VELOX-1
Nanosatellite with tele-optics imaging



VELOX-II
LEO-GEO intersatellite communications demonstrator satellite



TELEOS-2
Commercial / Government SAR satellite



VELOX-AM
Additive Manufacturing demonstrator satellite



ZEUS
Platform for science and commercial applications



ZEUSX
Space system for Moon infrastructure deployment



SPOOQY-1
Photon entangled source demonstrator satellite




VELOX P-II
Technology demonstrator picosatellite



VELOX-PIII
iPhone-sized picosatellite



XSAT
Singapore's first indigenously developed microsatellite



VELOX-CI
Tropical climate satellite demonstrating radio occultation

>15 Satellites built and launched since 2011

>15 Satellite projects in the pipeline



WHY SINGAPORE?

This is what Singapore has to offer to top tech firms to power their work.



TECHNOLOGY

- Top tech innovation hub after Silicon Valley.⁰¹
- 2nd in digital competitiveness in Asia, ahead of South Korea, Japan, and China.⁰²
- 1st in Global Smart City Index, ahead of London and New York.⁰³



CONNECTIVITY

Geographical

- In 2018, Changi Airport served >100 airlines flying to 400 cities in 100 countries and was named Asia's most connected international airport.¹²
- >1,000 flights daily connect more than 65 million passengers annually.¹³

Digital

- 2nd in digital connectivity globally.¹⁴
- 3rd most desirable location for data centres globally, with more than 60 per cent of Asia Pacific's data centre supply.¹⁵
- Top global submarine cable hub,¹⁶ with 24 submarine internet cables linking to key locations worldwide.¹⁷
- Established progressive Digital Economy Agreements (DEAs) with key trade partners, such as Australia and Chile, to ensure digital connectivity and data protection regime interoperability.¹⁸



BUSINESS

- 2nd for ease of doing business in Asia, the only Southeast Asian nation in the top 10 for Asia, and 18th globally.⁰⁴
- Most innovative economy in Asia.⁰⁵
- 1st for IP protection in Asia and 2nd globally.^{06, 07}



TALENT

- 1st in developing, attracting and enabling talent in Asia and 3rd globally.⁰⁸
- 2nd most attractive destination in Asia for global talent.⁰⁹
- More than five in 10 workers in high-skilled employment.¹⁰
- 74.3% of resident population literate in two or more languages.¹¹

Trade

- Access to 26 Free Trade Agreements (FTAs) that benefit Singapore-based exporters and investors.¹⁴

A*STAR

ADDVALUE

ALIENA

NUS SATELLITE
TECHNOLOGY AND
RESEARCH CENTRE
(STAR)

NUSPACE

QOSMOSYS

AMPLUS
COMMUNICATION

BIFROST

CHIPSAFER

SINGAPORE
SPACE &
TECHNOLOGY LTD

SINGTEL
SATELLITE

SKYMAP
GLOBAL

DSO
NATIONAL
LABORATORIES

EQUATORIAL
SPACE
SYSTEMS

INFINITE
ORBITS

SPACECHAIN

SPACE
FACULTY

SPECTRAL

KACIFIC
BROADBAND
SATELLITES

LIGHTHAUS

NEO
AERONAUTICS

ST ENGINEERING
iDIRECT

ST ENGINEERING
GEO-INSIGHTS

ST ENGINEERING
SATELLITE
SYSTEMS

NTU EARTH
OBSERVATORY OF
SINGAPORE REMOTE-
SENSING LAB (EOS)

NTU SATELLITE
RESEARCH CENTRE
(SARC)

NUS CENTRE FOR
REMOTE IMAGING,
SENSING AND
PROCESSING (CRISP)

TRANSCESTIAL

ZERO-ERROR
SYSTEMS

COMPANY OVERVIEW

The Agency for Science, Technology and Research (A*STAR) is Singapore's lead public sector research and development (R&D) agency. Through open innovation, it collaborates with its partners in both the public and private sectors to benefit the economy and society. As a science and technology organisation, A*STAR bridges the gap between academia and industry and plays a key role in nurturing scientific talent and leaders for the wider research community and industry. A*STAR's R&D activities span biomedical sciences to physical sciences and engineering, with research entities primarily located at Biopolis and Fusionopolis.

CAPABILITIES, PRODUCTS AND SERVICES

Robust and affordable communication for maritime applications

A Very High Frequency (VHF) Data Exchange System was developed to provide a robust communication system between ship-to-ship and ship-to-shore. A joint effort with ST Engineering Electronics, the project won the "Outstanding Maritime R&D and Technology Award" at the International Maritime Awards 2019.

Effective air navigation services for aviation

VHF voice is the primary form of communications in aviation to enable effective air navigation services. Space-based VHF communication enables the relay of voice and data signal via satellites to enable air navigation services in

oceanic airspace and remote areas. A joint collaboration involving A*STAR, OSTIn, the Civil Aviation Authority of Singapore (CAAS) and local industry partners is exploring key issues such as mitigation of ionospheric scintillation effects of VHF signals and novel antenna design.

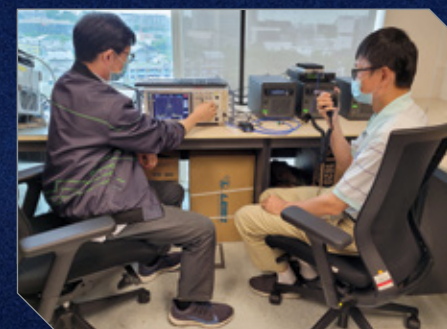
Small satellites with novel payloads

Leveraging current capabilities in millimetre wave technologies, A*STAR is developing a cost-effective inter-satellite relay for high bandwidth data communications at millimetre wave, meeting stringent requirements in size, weight and power. A key component is the lightweight phased array antenna technology for very high-resolution electronics beam steering and pointing.

Another effort is the development of flat optics hyperspectral imaging camera, leveraging A*STAR's expertise in flat optics technologies. This has the potential to substantially reduce the size of the satellite and lower the cost of manufacturing and launch. Spaceborne hyperspectral imaging allows for transboundary monitoring and tracking of greenhouse gas emissions and other environment pollutants. A*STAR is also developing key technologies, including the additive manufacturing of complex satellite parts, advanced packaging of RF electronics and continual satellite imageries learning, analysis and reasoning, to enable high performance in small satellites.






I²R researchers performing tests on the Ka-band antenna array for inter-satellite link.



I²R researchers testing VHF voice communication.

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-  www.a-star.edu.sg
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-  contact@a-star.edu.sg



COMPANY OVERVIEW

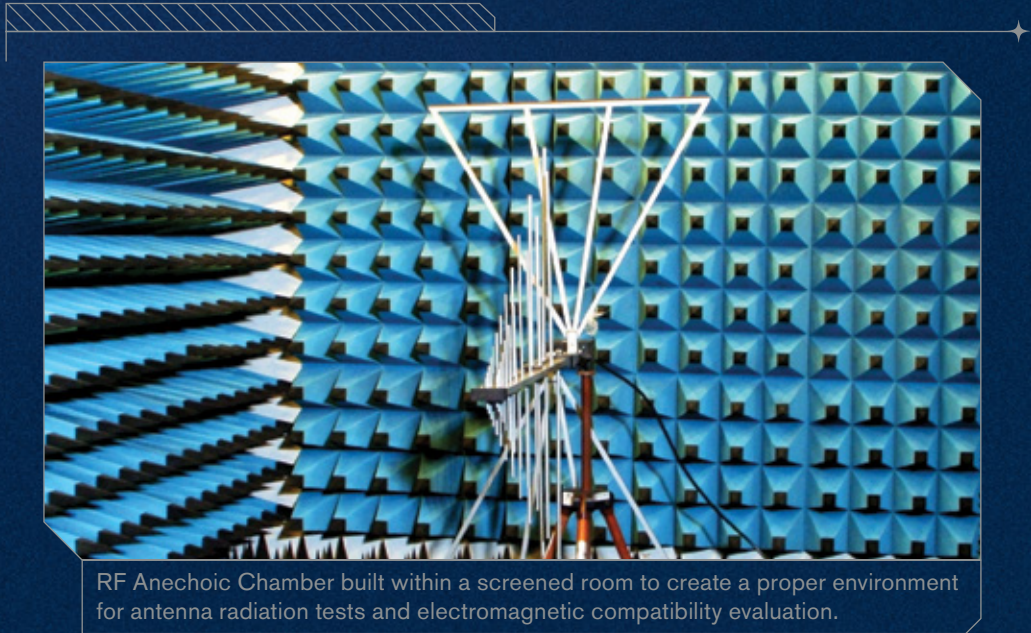
Addvalue Technologies Ltd, a Singapore Exchange Mainboard-listed firm, is a leading satellite-based communication company that provides state-of-the-art digital connectivity solutions to applications at sea, on land, in flight and even in space.

CAPABILITIES, PRODUCTS AND SERVICES

Addvalue has revolutionised the space communications used in the low Earth orbit (LEO) satellite industry. Through its collaboration with Inmarsat, the company has developed and commercialised the Inter-Satellite Data Relay System (IDRS) – the world’s first commercial “always-on”, full duplex IP based data communications for LEO satellite operators to monitor, control and conduct satellite missions in real-time and on-demand, without the rigid reliance on a ground station network.

Besides providing connectivity solutions to the space industry, the company also offers connectivity solutions tailored to support sustainability management and various industrial Internet of Things (IoT) applications across industries spanning fisheries to environmental surveillance, agriculture, energy, mining and any industrial digital transformation programme that requires both satellite communication and terrestrial communication.

The company has deep technical competencies in radio frequency (RF) and embedded re-configurable system design for software-defined radio and edge-computing applications. It also has a proven track record of developing complete communication terminals and takes a holistic approach to ensure customers can achieve their full business potential. Its comprehensive and proven capabilities in high-quality product development and depth of technical know how in sophisticated engineering projects are highly regarded by leading organisations in the commercial, defence and space industries.



RF Anechoic Chamber built within a screened room to create a proper environment for antenna radiation tests and electromagnetic compatibility evaluation.



A vacuum chamber is used to simulate the space environment to stress-test the electronics design of the IDRS terminal.

LET'S CONNECT

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COMPANY OVERVIEW

Aliena is a Singapore-based space-tech company on a mission to sharpen the edge of small satellite capabilities for sustainability from Earth to space. The company's suite of robust plasma propulsion systems facilitates low-cost access to any orbit of interest, enhancing the value of customers' missions. Aliena aims to unleash new in-space capabilities for small satellites with its unique plasma propulsion systems, from flying closer to the Earth on very low Earth orbit (VLEO) to increase the quality of collected data sets, to empowering frontier space operations such as debris removal and in-space manufacturing. Aliena was named the most promising space propulsion start-up at the Space Propulsion Conference 2022.

CAPABILITIES, PRODUCTS AND SERVICES

Aliena's oversubscribed S\$1.5 million seed funding round in late 2019 allowed for rapid business growth with the commissioning of a jet propulsion test facility, extensive R&D of its plasma propulsion systems and in-orbit deployment of an instant-ignition thruster.

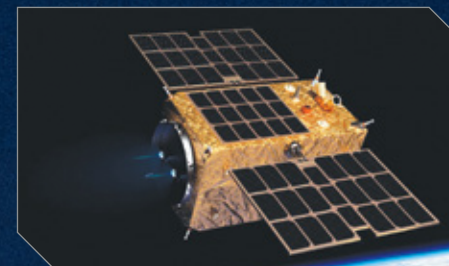
The company has spent the past three years perfecting its low-power Hall thruster technology at its jet propulsion test facility. Today, Aliena develops turnkey plasma propulsion solutions in the range of tens to hundreds of watts, providing thrust capabilities from micro to milli-Newtons for small satellites.

Its main product line includes the MUSIC (Multi-Stage Ignition Compact) thruster, which relies on a novel and innovative design based on the mature Hall effect thruster technology. Aliena's instant-ignition miniaturised Hall thruster was deployed in space on a 3U nanosatellite in January 2022. Operating at below 10 watts, the engine was the first Hall thruster to ever be used on such a small spacecraft.

Aliena aims to be a reliable global provider of propulsion systems to constellation operators and satellite manufacturers. The company has plans to grow into a prominent earth observation data business by flying its own fleet of microsatellites in VLEO to provide affordable and powerful datasets to terrestrial businesses and governments for a more sustainable future. Aliena's next mission in 2023 will see in-space deployment of the MUSIC thruster operating with a highly efficient hollow cathode.



Co-founders CTO Dr George-Cristian Potrivitu (left) and CEO Dr Lim Jian Wei Mark (right) at Aliena's Jet Propulsion Test Facility with a MUSIC engine firing in one of their space environment simulators.



Aliena's MUSIC system, shown onboard a microsatellite, is modular and scalable, making it suitable for all small satellite platforms.

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AMPLUS COMMUNICATION



COMPANY OVERVIEW

Amplus Communication is a Singapore-based global radio frequency, microwave and millimetre-wave service company that offers leading-edge technologies to the wireless communication, optical communication, medical instruments and electronics industries. Founded in 1999 by a group of engineers from the satellite communication industry, the company employs about 140 staff with 21 design engineers, including some of the most experienced practising microwave product designers in Singapore.

Amplus Communication products and services are exported to more than 55 countries in the Americas, Europe, Middle East and Asia. The company's main product design and manufacturing is carried out in Singapore, while its sales and support offices are located in Bangalore, Bangkok, Beijing, Jakarta and New Delhi.

CAPABILITIES, PRODUCTS AND SERVICES

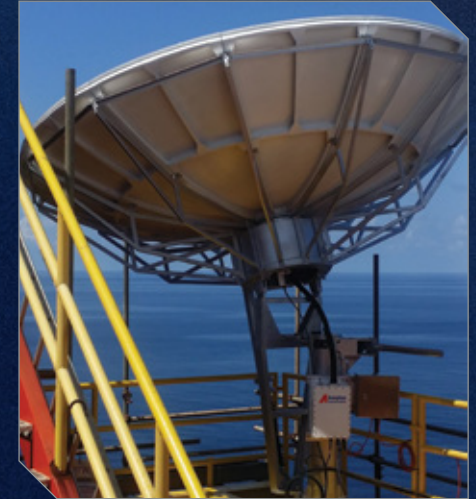
Amplus Communication has five patents under its belt, with advanced manufacturing capabilities in areas from wire bonding and chip blazing, to chip packaging, final product assembly, performance testing and product environmental qualification testing. Amplus Communication offers full OEM/ODM product design and manufacturing services, system integration of communication systems, and has developed a complete family of satellite transceiver products.

The company is also a leading designing and manufacturing house for phased-locked dielectric resonator oscillators and optical component testers of up to 400GBS.

Amplus' family of patented satellite transceiver products are some of the most sophisticated in the industry, including a complete family of C-band block upconverters (BUC) and transceivers of up to 800 watts, Ku-band BUCs and transceivers of up to 400 watts, and Ka-band BUCs and transceivers of up to 40 watts. All are equipped for digital and remote control, and are redundancy-ready. The company supplies its products to satellite communication providers, system integrators and end users, and they are widely used in private data networks, rural telecommunication networks, emergency services, broadcasting and oil and gas industries. Amplus Communication satellite BUCs and transceivers are designed to operate in some of the harshest environments on Earth, and are currently operating in diverse places such as near the North Pole, in the punishing heat of the sub-Saharan African desert, and in the salty and humid environment of the Indonesian and Indian coasts.



100W Ku-Band BUC.



150W C-Band BUC.

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COMPANY OVERVIEW

Bifrost generates high-fidelity 3D worlds at scale and robust synthetic datasets for artificial intelligence (AI) development.

Bifrost was founded in 2019 by CEO Charles Wong, who previously worked on self-driving cars at Nuro, and CTO Aravind Kandiah, an AI hacker and computer vision expert whose algorithms at Medios outperformed Google in clinical trials. Freshman-year friends turned founders, the pair, who are laser focused on building a world-class team and revolutionising 3D worlds for AI, have steered Bifrost through the Techstars Starburst Space Accelerator, won Slingshot Singapore 2019, Techblazer 2019 and were winners and finalists at numerous competitions and hackathons globally.

The company is backed by Sequoia Capital, Lux Capital, Wavemaker Partners, Cap Vista, Hustle Fund, Champion Hill Ventures and other prominent investors. Its seven-figure revenue and headcount are doubling year-on-year, through strong market pull and efficient unit economics.

CAPABILITIES, PRODUCTS AND SERVICES

In applications like defence, space, gaming, metaverse, mobility and robotics, AI teams must train models to detect and recognise other objects, thereby requiring millions of images and datasets. Traditionally, such images and datasets are labour-intensive,

take years and cost millions of dollars. About 80% of development time is spent on tedious data collection, curation and labelling. Bifrost's software-as-a-service (SaaS) platform enables AI teams to generate diverse, customisable and rare datasets in virtual worlds that real data cannot provide. Bifrost provides higher accuracy model training in minutes, instead of months or years, thereby disrupting the incumbent workflow and economics of AI development.

Bifrost's platform is designed intuitively and doesn't require 3D expertise, enabling its high school intern to beat state-of-the-art synthetic data in five days, and users to increase model accuracy from 50% to 98%.

Bifrost's technology is prized by the private and public sectors for landing spacecrafts on Mars and multiple other use cases. For example, Bifrost's research collaboration with the National Aeronautics and Space Administration's Jet Propulsion Laboratory (NASA-JPL) showcased the use of synthetic Martian terrain to train NASA's next-generation Mars Science Helicopter Mission Concept on how to land safely on the harsh landscapes of Mars. Bifrost has also unlocked new performance levels for object detection and image recognition for class-leading geospatial analytics companies, who use Bifrost's synthetic data to augment their state-of-the-art computer vision models.




Aerial view of a synthetic city port developed by Bifrost.



Founders of Bifrost, CTO Aravind Kandiah (left) and CEO Charles Wong (right).

LET'S CONNECT

 www.bifrost.ai
 www.linkedin.com/company/bifrost-ai

COMPANY OVERVIEW

Chipsafer was founded in 2012 in Uruguay, a small country in South America with over 3 million heads of cattle, after founder and CEO Victoria Alonsoperez witnessed the devastating effects Foot and Mouth Disease had on the agricultural sector a decade earlier.

Chipsafer expanded to Brazil in 2016, and in 2020 moved its headquarters to Singapore to pursue market access opportunities through a deep-tech space accelerator programme. Through Singapore's connections, Chipsafer was introduced to partners that helped accelerate the innovation process of its Smart Tracker collar from prototype to final product.

CAPABILITIES, PRODUCTS AND SERVICES

Chipsafer strives to improve the safety and security of livestock herds and to enable sustainable farming globally by ensuring traceability across an animal's lifecycle. Chipsafer's platform offers real-time animal tracking and captures current and historic health, behaviour and transaction information. Chipsafer empowers farmers by using space technology to increase the efficiency and sustainability of operations, improve animal health monitoring, reduce operational costs and make better use of natural resources. Beyond livestock, Chipsafer is also looking to diversify into tracking wildlife interaction for environmental research and anti-poaching causes.

Chipsafer's data also generates value for other stakeholders in the meat supply chain. Whilst farmers benefit directly from knowing the location of their herd and tracking health outcomes in real time, this traceability data can also be correlated with other data such as satellite imagery, to achieve transformative transparency across the supply chain – verifiable and transparent data from farm to fork. This approach builds confidence and integrity, and reinforces value and customer loyalty across the supply chain.



Livestock wearing the Chipsafer Smart Tracker at a farm in Uruguay.



Chipsafer Smart Tracker provides real time geolocation and behaviour data of livestock.

LET'S CONNECT

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DSO NATIONAL LABORATORIES



COMPANY OVERVIEW

DSO National Laboratories (DSO) is Singapore's largest defence research and development organisation. It aims to develop technological solutions to sharpen the cutting edge of Singapore's national security. Established in 1972, DSO has grown from a three-man team to more than 1,600 research scientists and engineers working across land, sea, air, space and cyberspace domains.

DSO is proud to be able to contribute to the growth of Singapore's space ecosystem, drawing technologists and aspiring engineers to further push the boundaries in this game-changing field.

CAPABILITIES, PRODUCTS AND SERVICES

Harnessing its advanced systems engineering expertise from the successful development of X-SAT, Singapore's first experimental microsatellite in 2011; and TeLEOS-1, the nation's first near-equatorial commercial electro-optical mini-satellite in 2015, DSO has continued to push the boundaries in space engineering by developing high-performance small satellites with superior remote sensing and geospatial solutions.

With the recent successful development of NeuSAR by DSO, Singapore is one of the first few countries in the world with the capability to develop such small and capable SAR satellites. NeuSAR is able to perform imaging through clouds and smoke, making it a 24-hour, all-weather remote sensing technology. The success of NeuSAR opens up the possibility of a small satellite constellation to enable high revisit imaging for commercial purposes.



DSO researchers working on the integration of NeuSAR sub-systems.



NeuSAR satellite assembly carried out by DSO researchers.

LET'S CONNECT

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EQUATORIAL SPACE SYSTEMS



COMPANY OVERVIEW

Equatorial Space Systems is a propulsion and launcher company that builds non-explosive, low-cost and eco-friendly rocket systems. Outside its headquarters in Singapore, the company has a presence in the United States, Australia and Thailand as well as an engineering team in Argentina.

The company was incubated at The Hangar by the National University of Singapore Enterprise (NUS Enterprise) and is a member of the Singapore Space & Technology Ltd Space Accelerator and the Q Station Accelerator in Albuquerque, New Mexico. It was also selected for the prestigious Techstars accelerator in Los Angeles in 2022.

CAPABILITIES, PRODUCTS AND SERVICES

Equatorial Space differentiates itself with its high-performance solid fuel composition that eliminates the historic limitations of hybrid rocket propulsion – a safe and simple combination of liquid oxidiser and solid fuel that has been long proposed as a transformative architecture for space launch applications.

Equatorial Space plans to use this technology to provide suborbital and orbital launch services, as well as custom rocket propulsion products for third-party buyers, with its longer-term aspiration being affordable and green human spaceflight.

The company's core technology has been demonstrated in flight conditions at a test launch of its Low Altitude Demonstrator rocket, which became the first commercially built prototype rocket test flight in Southeast Asia in December 2020.






An Equatorial Space launch vehicle, which can provide access to space at low cost, while eliminating key risks of rocket propulsion.



Equatorial Space's proprietary technology was previously proven in the region's first commercial rocket launch.

LET'S CONNECT

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COMPANY OVERVIEW

Infinite Orbits (IO) is a NewSpace company with a vision to provide reliable, turnkey in-orbit services to global satellite operators, including satellite life extension. IO designs, develops, owns, and operates in-orbit servicing vehicles known as Servicers to offer autonomous, flexible, and commercially viable services to satellite operators worldwide.

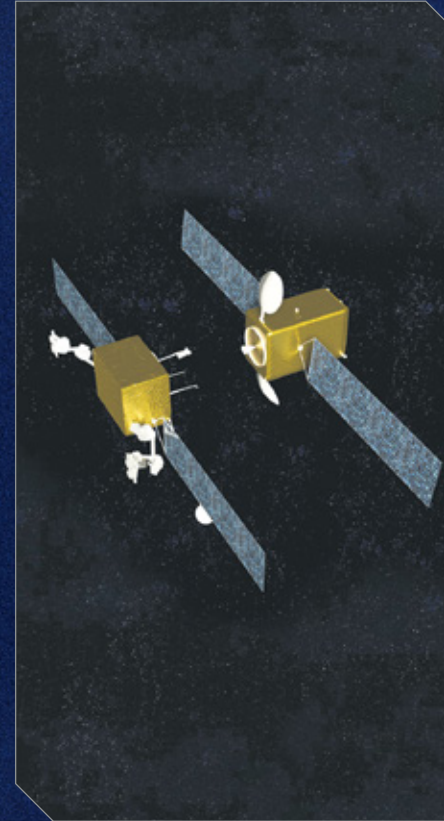
Founded in 2017 by telecommunication entrepreneurs and aerospace engineers following a National Aeronautics and Space Administration (NASA) challenge at Columbia University, Infinite Orbits currently has offices in Singapore and France. The company is prepared to offer next-generation NewSpace technologies to address all satellite maintenance requirements.

CAPABILITIES, PRODUCTS AND SERVICES

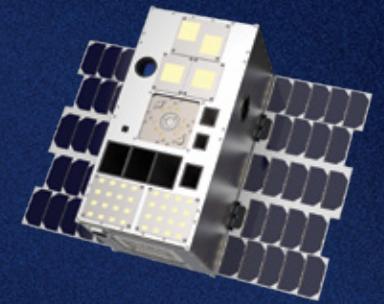
OrbitGuard, IO's first-generation servicer, is a small-sat with the capacity to autonomously perform both far-range and near-range rendezvous, offering space situational awareness and inspection services.

OrbitGuard is powered by IO's proprietary state-of-the-art machine learning algorithms, making it capable of detecting targets up to several hundred kilometres away, and performing pose estimation with robustness against extreme lighting conditions. OrbitGuard 1&2 are scheduled to be launched by Q4 2022 and will provide services from 2023.

IO's life extension servicer, Endurance, performs autonomous rendezvous and docks to the end-of-life client satellite, taking over the AOCS (Attitude and Orbit Control System) control for the next five years. Life extension services will be available from 2025.



Advanced artificial intelligence and machine learning algorithms help the IO servicer perform autonomous rendezvous, pose estimation, and docking to the client satellite for life-extension services.



IO's patented Autonomous Vision-based Navigation system aids IO in developing a simplified hardware suite offering sustainable and commercially viable in-orbit servicing solutions.

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KACIFIC BROADBAND SATELLITES



COMPANY OVERVIEW

Kacific Broadband Satellites (Kacific) is a next-generation broadband satellite operator. We are committed to providing universal, fast, high-quality broadband access at an affordable cost using robust technologies and an agile business model. Founded by Christian Patouraux, and developed in 2013 by a core team of senior satellite professionals, Kacific is backed by a group of investors with experience in global telecommunications and infrastructure.

Kacific's services foster greater internet adoption, fuel economic growth and drive positive social outcomes across covered regions. Kacific partners with local telecommunications operators, internet service providers and governments to distribute its range of satellite-based services for economic and social development.

Kacific aims to make a rapid and lasting impact across Southeast Asia and the Pacific by providing high-quality, low-cost satellite broadband accessible from a small, easy-to-install and affordable antenna. The company believes that with reliable broadband connectivity, critical government services can reach the heart of otherwise vulnerable rural communities, allowing them to thrive both economically and socially.

Kacific has been recognised with multiple industry accolades, including Outstanding Satellite Company (PTC Awards, 2022), Project of the Year – Satellite (Global Carrier

Awards 2021), Best Digital Inclusion (Pacific ICT Awards, 2019), CEO of the Year for Wholesale & Capacity (Operator): Christian Patouraux (Telecom Review, 2021), Satellite Executive of the Year: Christian Patouraux (APSCC, 2019) and Better World Satellite Award (SSPI, 2018).

CAPABILITIES, PRODUCTS AND SERVICES

Kacific's first Ka-band high throughput satellite, Kacific1, was launched in 2019 to stream high-speed, low-cost, ultra-reliable broadband, using the latest multi-beam space communications and ground technology, to rural and suburban areas of the Pacific and Southeast Asia.

Covered nations include:

- | | |
|---------|--|
| Pacific | American Samoa, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, Micronesia, New Zealand, Niue, Northern Mariana, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu. |
| Asia | Bangladesh, Bhutan, Brunei, Indonesia, Malaysia, Myanmar, Nepal, Philippines, Timor-Leste. |



Twenty-five regions in the Asia-Pacific are covered by the Kacific1 satellite.



The launch of Kacific1 from Cape Canaveral, Florida.

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COMPANY OVERVIEW

LightHaus Photonics is a high-tech company founded in 2011. Its core business is transforming technologies through research and development (R&D) by engineering specialists in optics/photonics, imaging, electronics, and system integration. Optical inventions from LightHaus are state-of-the-art, rugged, and highly cost-effective.

The company is excited to contribute to Singapore's efforts in discovering the next frontier in space. In 2022, LightHaus crossed another milestone when it participated in a Singapore consortium to create a remote-sensing satellite. LightHaus will be the first local technology small-medium enterprise to design and build a space camera with advanced imaging capabilities, enhancing local capabilities in developing next-generation optical imaging payloads for commercial satellites.

CAPABILITIES, PRODUCTS AND SERVICES

True to its original passion, the company has successfully transited its proprietary US-patented inventions into cutting-edge products. One such invention is frinGOe, an optical add-on attachment that transforms a camera into a spectrometer that measures the spectral power distribution of light. This invention captured the attention of those in the photonics technology field and was profiled by Laser Focus World, a global resource for coverage of photonics technologies, applications, and markets. The frinGOe spectrometer is extremely rugged and well-suited for space environments with applications such as monitoring of a satellite's on-board optical calibration system.

LightHaus also has capabilities in the design and production of optical payloads for satellites such as high-resolution cameras, deployable optical telescopes and push broom mid-wave infrared hyperspectral cameras. It provides bespoke optical systems for clients, which include government agencies, institutions, statutory boards as well as multinational corporations.



Electro-optical infra red imaging capabilities from a LightHaus optical imaging payload.



One of many spectral imaging payloads developed in-house by LightHaus.

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COMPANY OVERVIEW

Founded by Dr Neo Kok Beng in 2018, NEO Aeronautics focuses on designing and producing a manned personal aerial vehicle (PAV) that is safe, reliable, and affordable, and to build urban aerial mobility communities globally.

CAPABILITIES, PRODUCTS AND SERVICES

NEO Aeronautics has developed two Crimson S8 (a PAV) prototypes as proof-of-concepts. At present, the company is developing a certified version for flight trials.

Besides its aerospace industry involvement, NEO Aeronautics also engages and inspires students in STEM (Science, Technology, Engineering and Mathematics) fields, and incubates commercialisation ideas. ASPIRE Incubation Labs is a collaboration with Science Centre Singapore and Singapore Institute of Technology. It engages youth in STEM seminars, workshops and hackathons. The company has a multi-year partnership centred around the aeronautical and astronautical sciences, along with developing curricula, workshops, competitions and hackathons to ignite the youth's interest in space science. The company also partners with astronauts to work with researchers and start-ups to incubate their technologies for space applications such as 3D medicine printing in space.



Dr. Neo Kok Beng (left) and NASA Astronaut Jeff Williams (right) with the Crimson S8.



Crimson S8 Version 2.

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NTU EARTH OBSERVATORY OF SINGAPORE – REMOTE SENSING LAB (EOS)



COMPANY OVERVIEW

The Earth Observatory of Singapore – Remote Sensing Lab (EOS-RS) was created in 2021 by Nanyang Technological University (NTU), with Dr. Sang-Ho Yun as the founding director of the lab.

Assoc Prof Yun is responsible for leading a diverse team of research staff and students, who work to achieve two primary goals: first, to support decision-makers across Southeast Asia (and beyond) by monitoring and mapping regional hazards, natural disasters, environmental crises, sea-level rise and climate change using cutting-edge technology; second, to drive scientific innovation and improved understanding of hazards through development of new algorithms and systems for mapping hazards and disasters, and through symbiotic collaboration with NTU, Singapore government agencies, and industry.

The EOS-RS team works closely with Singapore government ministries and agencies, international space agencies, regional disaster-response agencies, and international NGOs and IGOs. EOS-RS is a member of the Sentinel Asia consortium, working with space agencies and governmental disaster response agencies across Asia to assist in regional disaster response. EOS-RS also has extensive academic collaborations internationally.

CAPABILITIES, PRODUCTS AND SERVICES

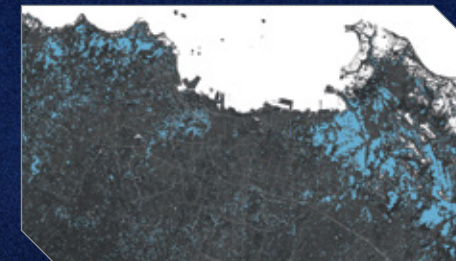
EOS-RS currently focuses on the use of Synthetic Aperture Radar (SAR) satellite data for hazards monitoring and disaster response. SAR data are considerably more complicated to process than optical satellite data but have the strong benefit of being able to image both through clouds and day-and-night.

Over the past few years, EOS-RS has provided critical information for response and recovery efforts following 50 major disasters. This information has been in the form of maps that show flood extent and damage caused by earthquakes, tropical cyclones, wildfires, volcanic eruptions, landslides, and anthropogenic events.

EOS-RS is continuing to produce impacts in Southeast Asia and globally. Collaboration with EOS-RS can have a very wide scope from automated rapid disaster response, observation-based risk assessment for disaster events, as well as calculation of the global impacts of climate change. EOS-RS is currently creating a robust framework to translate satellite radar observations into human observables in the field and participate in a team-based multi-disciplinary programme with realistic engineering challenges.



Disaster events for which EOS-RS has provided decision-support information.



Urban flood extent map of Jan 2020 flash floods in Jakarta, Indonesia, used by the ASEAN Humanitarian Assistance Centre, among others.

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- @EOS_RS
- Sang Ho Yun

NTU SATELLITE RESEARCH CENTRE (SARC)

COMPANY OVERVIEW

Nanyang Technological University's (NTU) first foray into space began more than 20 years ago, in 1999. The university's Satellite Research Centre (SaRC) has since developed, built, tested, and operated 10 satellites successfully. Ranging from nanosatellites to microsatellites (<150 kg), these satellites are operated with SaRC's 24/7 automated mission room via the UHF/VHF and 6.1m S & X band ground dish system.

CAPABILITIES, PRODUCTS AND SERVICES

SaRC is the birthplace of the first Singapore-designed satellite, XSAT (April 2011). The centre works with local and international industry players and academics on various R&D collaboration programmes, pushing for new science and technology breakthroughs. SaRC also runs undergraduate and postgraduate training programmes in parallel, which provide students with relevant exposure to the practical aspects of satellite design and space-related requirements. Its R&D areas encompass weather/climate, satellite technology, materials, integrated chips, deployers, synthetic aperture radar, artificial intelligence, 3D printing and more.

The SaRC team is currently working on building a very low Earth orbit (VLEO) remote sensing platform with its partners, with an expected launch in 2025 to demonstrate a series of technologies at VLEO.






Students preparing the nanosatellite for a final check of its Attitude Determination & Control System in a Helmholtz cage.



6.1m S & X band ground antenna dish operating 24/7 in full automation, controlled from the SaRC Mission Room.

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NUS CENTRE FOR REMOTE IMAGING, SENSING AND PROCESSING (CRISP)

CRISP
National University of Singapore

COMPANY OVERVIEW

The Centre for Remote Imaging, Sensing and Processing (CRISP) is a research centre of the National University of Singapore (NUS). Established in 1992, CRISP's mission is to develop an advanced capability in remote sensing to meet the scientific, operational and business requirements of Singapore and the region. CRISP has been at the forefront of all of Singapore's flagship satellites, contributing in areas such as in-house development of satellite payload processing systems, calibration and validation campaigns, launch and early operations support and satellite ground station operations. CRISP has diverse and ongoing collaborations with international space agencies such as NASA, ESA, JAXA, GISTDA, BRIN and MYSA.

CAPABILITIES, PRODUCTS AND SERVICES

CRISP operates a world-class high-tech satellite ground station which tracks, receives and processes data from remote sensing satellites for research and distribution to users. The CRISP ground station currently has four high-performance tracking antennas. CRISP has deep experience in all aspects of the operation and maintenance of high-quality tracking antennas. This knowledge serves as a springboard for the development of an integrated antenna farm to connect and control all the antennas as an integrated system, providing all satellite missions in their charge with the highest

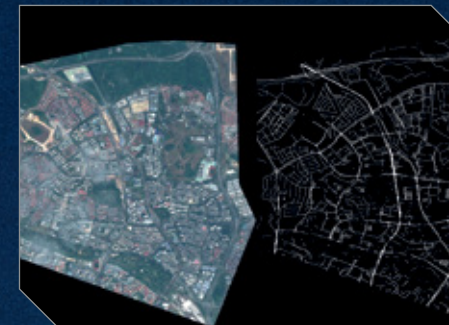
possible number of contact windows and the best chance of mission success.

CRISP's research focuses on the processing and applications of very high spatial resolution imagery, hyperspectral data and synthetic aperture radar. CRISP's scientists have expertise in developing customised solutions, utilising both science-based modelling and machine learning, to meet specific client requirements. Application areas include various aspects of terrestrial, aquatic and atmospheric remote sensing.

CRISP has built up its niche in environmental monitoring, from satellite-based collection of evidence for the illegal discharge of marine fuel, to monitoring land clearing activities that generate smoke haze pollution. CRISP has many years of in-depth and widespread practical experience in providing authorities and interested parties with products that can be used in courts of law, and in pursuing international environmental agendas.



13m diameter tracking antenna with X- and S-band downlink and S-band uplink.



U-Net++ with EfficientNetB2 over Ang Mo Kio, Singapore.

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NUS SATELLITE TECHNOLOGY AND RESEARCH CENTRE (STAR)

COMPANY OVERVIEW

Established in 2018, STAR at NUS (National University of Singapore) is a world-class satellite centre that aims to be a leader in advanced distributed small satellite systems, with a focus on flying multiple small satellites in formation or constellation. The centre aims to contribute to the development of new applications such as collaborative sensing for the environment and more timely and scalable communication services.

The founding director of STAR, Professor Low Kay Soon, is a pioneer in satellite development. He has been the principal investigator of several successful small satellite programmes in Singapore since 2003. STAR employs more than 20 full-time research engineers from different engineering disciplines and a majority of them have postgraduate degrees.

CAPABILITIES, PRODUCTS AND SERVICES

STAR has a state-of-the-art clean room facility for satellite testing and assembly works, electrostatic discharge controlled laboratories for research and student projects, as well as environmental testing facilities such as thermal chamber, thermal vacuum chamber and shock test machine. The centre has also developed several hardware-in-the-loop testing facilities for GPS experiments, electrical power system validation, and ADCS calibration for satellites.

Through its satellite programme, STAR has developed small satellites of various scales (e.g. 12U-125U) for different applications and which are suitable for mass production. STAR is presently completing the flight models of several satellites that will be ready for launch in 2023. The small satellites are designed such that they can be equipped with other instruments for remote sensing, Internet of Things, aviation applications and more. Three of these satellites – Lumelite-1, 2 and 3 – will be flying with a separation distance of 50–200 km. These satellites have inter-satellite communication capability, precise clock synchronisation, and accurate relative ranging technology. Lumelite-4 is another programme demonstrating VHF Data Exchange System application for maritime safety and communication. Lumelite-1 to 4 are 12U, while Lumelite-5 is a 50-kg satellite with a dimension of approximately 50 x 50 x 50 cm. It is designed to demonstrate small satellites' capabilities in supporting advanced payloads.

In addition to the satellite programme, STAR has an undergraduate programme on CubeSat with a focus on student-centric satellite development. This programme allows NUS Engineering students to take up coursework in the field and participate in a team-based multi-disciplinary programme with realistic engineering challenges.




Full scale satellite model built by STAR@NUS.




Testing of Lumelite-1 satellite in the clean room of STAR@NUS.

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COMPANY OVERVIEW

NuSpace was founded in 2018, when its co-founders realised that there were few companies in Asia that knew how to design satellite missions. NuSpace specialises in building small satellites. Its vision is to be the go-to small satellite service provider in the Asia-Pacific region. NuSpace provides two main services: Satellite-as-a-Service (SatAAS) and satellite-based Internet of Things (IoT) connectivity.

CAPABILITIES, PRODUCTS AND SERVICES

Satellite-as-a-Service (SatAAS)

NuSpace's SatAAS product allows customers wanting to access space to do so. Services provided by NuSpace include satellite mission design and analysis, building satellites and payload ridesharing. NuSpace focuses on integrating commercially available subsystems instead of developing its own. This gives customers the flexibility to mix and match services and allows NuSpace to deliver to customers highly optimised satellites. If needed, NuSpace also has the ability to develop customised satellite subsystems.

NuSpace has also worked with contract manufacturers to explore how satellites can be mass-manufactured, to leverage on cost efficiencies and supply chain capabilities of contract manufacturers. This is especially beneficial for building satellite constellations and achieving high reliability in a cost-effective manner.

Satellite IoT connectivity

NuSpace is developing a constellation of IoT nanosatellites based on LoRaWAN connectivity. The network provides coverage to areas along the equatorial belt, addressing markets that have high potential for benefits. Industries of interest include carbon sequestration where the growth of trees is monitored to estimate the amount of carbon captured, agriculture, and personal safety. These industries require IoT connectivity in areas where conventional communication infrastructure is lacking and the application is delay-tolerant.

Any sensor device can be connected to NuSpace's satellite IoT network as it follows the LoRa standard. If the sensor device has a LoRa modem and follows LoRa modulation, NuSpace's satellite IoT network would be able to receive and relay the data packets. This lowers the adoption barrier for IoT solution developers as no modifications need to be made to their devices.



Assembly of small satellites in a controlled, clean environment.



The Space LoRa Gateway, which was developed in-house and enables affordable IoT connectivity in remote areas.

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COMPANY OVERVIEW

Qosmosys is a private company with its main office in Singapore. With its own designed spacecraft, Qosmosys aims at contributing to space exploration by human kind.

Qosmosys was founded in 2020 with the ambition to manufacture families of space vehicles with robotic extensions that will serve the development of infrastructures in space, on the Moon and beyond.

Moreover, Qosmosys is the only company that endeavors to organise properly gigantic amount of data produced collectively by World citizens who want to take part into the biggest challenge of our times.

CAPABILITIES, PRODUCTS AND SERVICES

Qosmosys offers on-demand services to public or private organisations that desire to operate in outer space (OSAM), on the Moon and beyond in three sectors: science & tech, transportation and robotic, representing a cumulated market of \$200bn+ over the next fifteen years.

Our strategy is to set the relevant organisation to design each client's mission relying on our Zeus or ZeusX, and leveraging their business growth with our space vehicles.

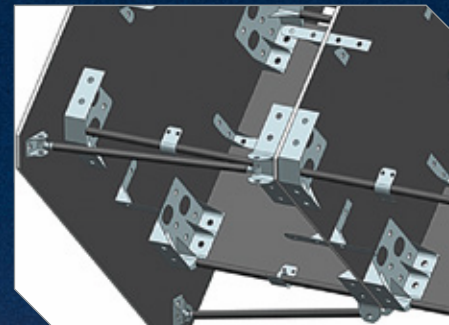
- Zeus family is a nano/micro-satellite platform design dedicated to various scientific or commercial missions mostly for LEO applications, ideal for testing technologies or various business models,
- ZeusX family is a large/heavy spacecraft design, today composed of the assembly of a service module (QSM), a Moon lander (QML) and a versatile extension of robotic solutions dedicated to unmanned missions onto our natural satellite

Zeus spacecraft constitutes the best pathway for customers expecting a fast-track programme, demonstrator, or a lean, high-reliability constellation. Zeus offers reentry capabilities on specific demand, with safety area return to Earth. All kind of orbits can be offered, from 400km to 1,200km altitude with various inclinations. Pointing accuracies are exceptional and adapted to the mission.

ZeusX has that incredible ambition to offer on-demand services for multiple civilian applications on the Moon or other celestial bodies, including robotic mining solutions, scientific experiment deployments or organizing remote supply chains or telecom networks. ZeusX does not rely on human intervention in space to successfully complete its missions.



Equipped Primary Structure Central Tube of the Qosmosys Moon Lander (QML).



Qosmosys Moon Lander (QML) rib concept structure.

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SINGAPORE SPACE & TECHNOLOGY LTD



COMPANY OVERVIEW

Founded in 2007, Singapore Space & Technology Ltd (SSTL) is Asia's leading space organisation that connects players in the region's growing space industry to government agencies, deep-tech companies and non-government agencies so that space-related technologies and innovations can be applied in other areas that have an impact to the man-on-the-street.

CAPABILITIES, PRODUCTS AND SERVICES

Connecting and commercialising the space sector for enterprises, NGOs and government partners

SSTL works with government organisations, enterprises, startups and NGOs, developing proofs of concept to market research and business development. Its international partners include Hungary's Ministry of Foreign Affairs and Trade, Indonesia's Space and Aeronautics Association, the Federation of Indian Chambers of Commerce & Industry, Singapore Land Authority, JTC (Jurong Town Corporation) and tech venture capital HAX.

In recent collaborations, SSTL inked a memorandum of understanding with the UK Science and Technology Facilities Council in 2022 on a two-way deal flow of investment and trade between Singapore and UK-based space tech startups, encompassing market access, test-bedding, market validation of opportunities, potential investment, research and capability-building.

SSTL also works with the World Bank and Changi Regional HADR Coordination Centre to leverage space technologies to find new innovations for disaster management and relief.

Industry champion and connector

SSTL launched the annual Global Space and Technology Convention (GSTC) in 2008, the region's go-to marketplace for insights, commercial opportunities, public-private partnerships and funding. GSTC is one of the fastest-growing deep tech conventions in Asia, drawing close to 1,000 delegates from 350 companies across over 50 countries each year, underscoring its global impact.

Accelerator programmes critical for growth in Asia

SSTL's Space Accelerator Programme, started in 2020 and supported by Enterprise Singapore (ESG), has a strong portfolio of 40 companies from 18 countries including Japan, India, Singapore, the US and Europe, across 5G connectivity, remote sensing technologies, cybersecurity for critical infrastructure and semi-autonomous space robots. The combined valuation of the companies is close to US\$850million, with a CAGR of over 60 per cent. A testament to the quality of the startups, over 40 per cent of the portfolio already receives institutional investment.



Mr Teo Chee Hean, Singapore's Senior Minister and Coordinating Minister for National Security with international participants at GSTC 2020.



SSTL signed a Memorandum of Understanding with the Ministry of Foreign Affairs and Trade of Hungary to promote commercial partnerships and space activities.

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SINGTEL SATELLITE



COMPANY OVERVIEW

Singtel Satellite is Asia's leading provider of managed satellite solutions. The company delivers award-winning innovations to meet voice and digital challenges in fixed and mobile satellite segments on both land and at sea. With more than 35 years of collective experience in fixed and mobile satellite services, it offers customised solutions to meet the varied business needs of industries such as oil and gas, broadcast, energy, maritime, telecommunications, banking and finance, transportation and logistics, government agencies and non-governmental organisations. Singtel Satellite's success in the satellite industry is evidenced by its global coverage stretching from Asia, Middle East and Africa, and versatility across platforms from satellite to fiber to IP.

CAPABILITIES, PRODUCTS AND SERVICES

Backed by three teleports with more than 30 antennas pointing at the satellites from 36°E to 180°E, Singtel Satellite's teleports allow enterprises to access high-performance, reliable and secure global connectivity through its state-of-the-art teleport infrastructure to meet the specialised needs of market niches in remote areas.

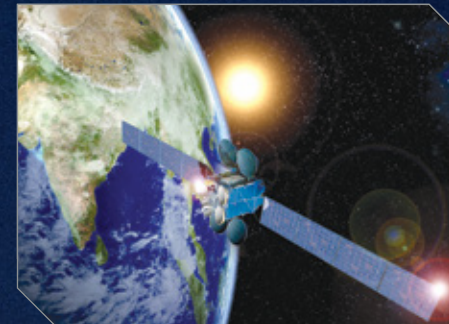
To ensure the availability of power at all times, the teleports are equipped with onsite generators and an Uninterruptible Power Supply system, and are connected to an extensive terrestrial network and international

submarine cables in the event of connectivity disruptions. As security remains an utmost concern for enterprises, the teleports provide the maximum level of security as they are designed with double-fenced compound, fence intrusion detection system and 24x7 manned CCTV. In addition, the teleports are secured with armed security guards and the restricted area is safeguarded by a security card key access system, with access only for authorised personnel.

As part of Singtel Satellite's commitment to deliver the highest service availability to customers, its Earth stations are the only teleports in Southeast Asia to have attained the World Teleport Association's highest Tier 4 certification, providing customers with the highest quality of security, infrastructure and operational standards to meet their communications needs.



Singtel Satellite's teleports are the only ones in Southeast Asia with the World Teleport Association's highest Tier 4 certification.



Singtel Satellite's footprint covers Asia, the Middle East and Africa.

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COMPANY OVERVIEW

SkyMap Global (SkyMap) is an earth observation (EO) based data analytics company providing operational solutions to both commercial and government organisations worldwide. Headquartered in Singapore, it partners with global data partners to provide artificial intelligence (AI) based monitoring applications on its EOfactory.ai platform to a diverse range of markets including infrastructure, forestry, agriculture, insurance and environment with an emphasis on climate change, relayed on daily or weekly based monitoring applications.

CAPABILITIES, PRODUCTS AND SERVICES

Everyday satellites and drones capture terabytes of EO data of our changing planet. However, despite technological advancements in data collection, over 90 per cent of the data is neither visualised nor analysed, primarily due to lack of access to the data and outdated mapping and image analysis techniques.

SkyMap transforms the user experience for the 21st century EO user. Its EOfactory.ai platform leverages imagery data, cutting-edge AI and the power of cloud to provide analytics and intelligence that help organisations make better revenue and operational decisions, delivering data and analytics solutions as Data as a Service (DaaS) and Analytics as a Service (AaaS).

EOfactory.ai's features include inbuilt pre-processing toolkits, download and/or upload of data from various sources, reinforcement learning by linking and aggregating various data flows across networks, a library of AI-based models (building footprint extraction, ship and car detection, tree detection, etc.), user-upload/creation of custom algorithms on platform Software as a Service (SaaS) architecture, API-based subscription for seamless integration into clients' existing applications, and custom world class dashboards with Insight Studio.

EOfactory.ai can be adopted under different business models depending on the client's needs, such as cloud-based pay-as-you-go for data and analytics, on-premise enterprise products, subscription-based monthly dashboards, and original equipment manufacturer (OEM) partnerships. It also allows revenue-sharing with data producers and community builders of dashboards and AI models. SkyMap has also launched various products powered by the backend of the EOfactory platform. For example, the company uses the EOFstudio platform to deliver projects on change detection for green cover, mining, carbon stock and other use cases. EOFmonitor and EOFsurvey also allow for easy and efficient crop monitoring for the agriculture sector. Together with the farm boundaries of almost the entire world, the company delivers an all-in-one solution for agriculture companies.



Building footprint change detection for rapid decision making during disaster or insurance related applications.



Processing high-resolution imagery for vegetation management.

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COMPANY OVERVIEW

As the leading integrator of space technology and blockchain, SpaceChain helps enterprises harness the ultra-security and immutability of space-grade infrastructure to protect their digital assets from hackers and cybercriminals. The company's vision is to build a collaborative, accessible, and blockchain-integrated satellite infrastructure for the global community.

Founded in late 2017, SpaceChain has launched six blockchain-enabled satellite payloads into orbit. The company executed the first bitcoin multisignature blockchain transaction in space in 2019 and the first Ethereum multisignature blockchain transaction in space in 2021. Both payloads were launched into orbit via the SpaceX Falcon 9 rocket and installed at the International Space Station, in collaboration with Nanoracks and its Space Act agreement with the National Aeronautics and Space Administration (NASA).

CAPABILITIES, PRODUCTS AND SERVICES

Space-based multisignature wallet technology

SpaceChain has developed the world's first space-based multisignature authentication service that allows users to validate their transactions through the satellite. Its flagship application uses a space node as one of the parties to approve a multisignature transaction.

One of the private keys is generated after the space node is launched into orbit.

In addition, the measurement, control and data transmission of the space node use the aerospace-specific code encryption protocol and communication band, making the data hard to decrypt.

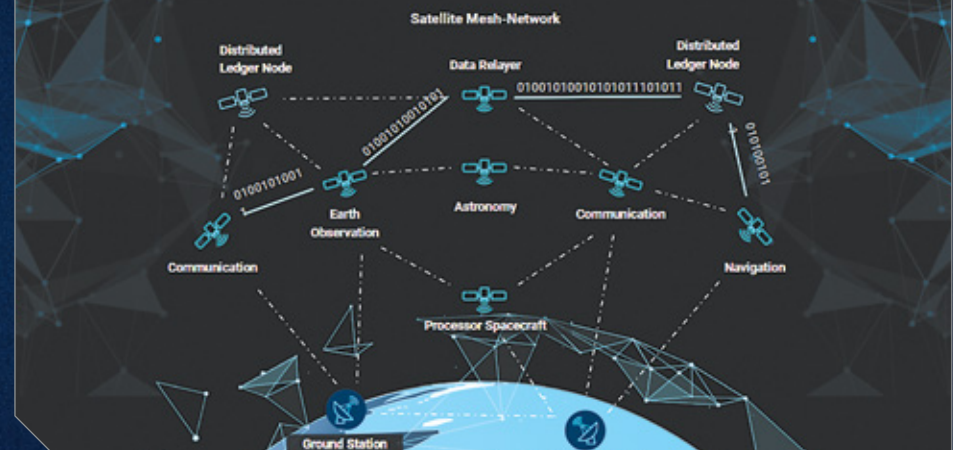
Decentralised Satellite Infrastructure (DSI)

SpaceChain is building the world's first open-source DSI – a mesh node constellation of low Earth orbit micro-satellites that will serve as a decentralised infrastructure for the blockchain industry. The open-source blockchain-based satellite platform provides a private network in space to carry out transactions using virtually any cryptocurrency. Once completed, the result is then broadcast back to Earth. This process eliminates 99% of hacking opportunities.

Decentralised Satellite Applications (DSA)

The DSA is a digital interface for users to directly acquire satellite data or images and apply analysis tools with zero knowledge requirement. The platform is supported by blockchain infrastructure, where distributed and transparent ledgers take record of system operations. Transactions and communications of information are encapsulated in an envelope where the cryptographic algorithm is applied. Through the platform, users can establish direct connections with aerospace companies.

DECENTRALIZED SATELLITE INFRASTRUCTURE



The DSI enables a shared and collaborative environment for space.



SpaceChain co-founder Zee Zheng says blockchain nodes are transforming the way satellites are used in space.

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COMPANY OVERVIEW

Space Faculty is Asia's pioneer in creating opportunities for experimentation, learning and leadership through space.

A spin-off of Singapore Space & Technology Pte Ltd, Space Faculty creates a learning pathway for companies and individuals in space and STEM-related industries for young learners, youths and professionals.

Backed by SSTL's connections, the global faculty from renowned space agencies, deep-tech organisations and NGOs gives students unrivalled access to the best minds and latest thinking across STEM, artificial intelligence, machine learning, sustainable development and data security, among other disciplines.

CAPABILITIES, PRODUCTS AND SERVICES

Strategic Cross-Border Partnerships

Space Faculty is Singapore's exclusive distributor of the J-SSOD (JEM Small Satellite Orbit Deployer) service on board the Japanese Kibo Module in the ISS (International Space Station), and a Singapore facilitator for other commercial services provided on the Kibo module. It also provides opportunities for partners in the region to conduct experiments on board the Kibo module to fast-track research and development in space.

Under this banner, Space Faculty partnered with the Japan Aerospace Exploration Agency (JAXA) to launch SpooQy-1 in 2019,

an advanced nanosatellite by the Centre of Quantum Technologies at the National University of Singapore. This was a world's-first to use nanosatellite technology to study quantum entanglement, for practical applications in coding and cryptography.

Bespoke programmes

Space Faculty's long-term programme for the Singapore Land Authority (SLA) advances innovation in GNSS (Global Navigation Satellite System), leveraging on SLA's SiReNT technology to accelerate innovation and build the talent pipeline for the space and deep tech sector.

Space Faculty partners government agencies and private enterprises to develop professional learning programmes and bring space innovations into satellite communications, defence and disaster relief sectors.

Bridging the international community

The International Space Challenge, an SSTL signature programme led by Space Faculty, connects young minds internationally with industry experts to develop creative solutions for space and leveraging space tech for broader applications. Since 2007, the Challenge has become a global platform bringing together over 2,000 youths from over 20 countries.



Students making an antenna out of PVC pipes and measuring tape at the Youth Space Camp.



Young space cadets with their solar-powered rovers at the Junior Space Camp.

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COMPANY OVERVIEW

SpeQtral was established in 2018 with a mission to secure the world's networks for the fast-approaching quantum revolution. Comprising world-class, multidisciplinary quantum scientists, cryptographers and engineers from around the world, the rapidly growing startup is a spin-off from the Centre for Quantum Technologies at the National University of Singapore (NUS). This group is known for being the first and only team in the world that has demonstrated a miniaturised source of entangled photons in space. The quantum entangled signals made by the nanosatellite, dubbed SpooQy-1, form the foundation to enable future secure quantum communication.

SpeQtral places a strong emphasis on collaboration and cross-disciplinary work practices. The company is accelerating its business and technology strategies globally through forging strategic alliances with leaders and innovators in the industry. In 2021, SpeQtral partnered with Toshiba Digital Solutions Corporation (Toshiba) to bring fibre-based quantum key distribution (QKD) solutions to Singapore and markets in Southeast Asia. It has also established collaborations with the European Space Agency through Singapore's Office for Space Technology & Industry (OSTIn), US-based space startup Antaris, and NUS' Quantum Engineering Programme (QEP) to develop, validate and advance quantum-secure communication technologies from Singapore to the world.

CAPABILITIES, PRODUCTS AND SERVICES

Leveraging its deep roots in quantum technologies, SpeQtral kicked off a new quantum satellite mission in 2022. The SpeQtral-1 satellite, to be launched in 2024, is primed to be one of the first few QKD satellite missions to be launched by a commercial entity. During the mission, SpeQtral-1 is also expected to perform commercial demonstrations that provide QKD services to users across different continents. SpeQtral-1 is also expected to serve as the backbone for a global quantum network, providing interconnection between various metropolitan quantum networks, which are currently being set up.

SpeQtral provides two types of QKD solutions that can be customised across a variety of client requirements for quantum-secure communications. Its fibre-based QKD solution, in collaboration with Toshiba, covers local distances of about 10-100 kilometres, and is ideal for dense metropolitan areas. Its satellite-based, or space-based, QKD solution connects these metropolitan areas to create an integrated global quantum secure communications network. SpeQtral also provides bespoke satellite QKD missions to customers, primarily in the government and defence sectors, and telecommunications services providers.



SpeQtral co-founder and CEO Chune Yang Lum holding the CubeSat SpooQy-1, which was the first to demonstrate a miniaturised source of entangled photons in space.



SpeQtral partnered QEP to trial quantum-safe communication technologies in Singapore via the country's new National Quantum-Safe Network.

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COMPANY OVERVIEW

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

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

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

CAPABILITIES, PRODUCTS AND SERVICES

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

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

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




The world's leading service providers and operators rely on ST Engineering iDirect's technology to power their satcom services.



ST Engineering iDirect is a global organisation with centres of excellence in the U.S., Europe and Asia.

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ST ENGINEERING GEO-INSIGHTS



COMPANY OVERVIEW

ST Engineering Geo-Insights (GI) is a joint venture company formed between DSO National Laboratories (DSO) and ST Engineering. GI develops geospatial analytics solutions to transform data into insights to support informed decision making for customers in the maritime, agriculture, energy and infrastructure sectors. GI also taps on emerging new space technologies to pursue growth opportunities in small satellite constellation design, development, manufacturing & operations.

CAPABILITIES, PRODUCTS AND SERVICES

High Re-visit and High Resolution Satellite Constellation

World's first commercial constellation operating in Near Equatorial orbit that is capable of producing 50 centimetres resolution multispectral satellite imagery and quad-polarization Synthetic Aperture Radar imagery up to 1 metre resolution.

Maritime Domain Awareness

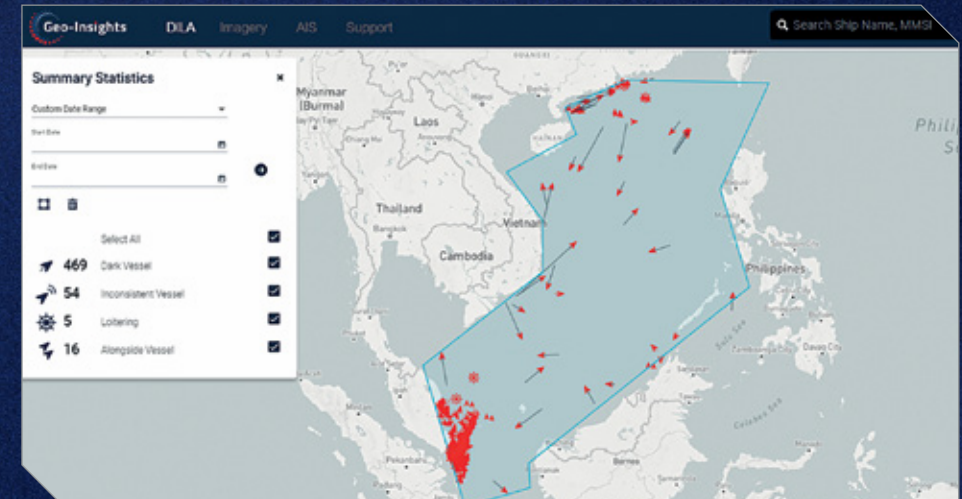
The KnOcean platform monitors suspicious vessel activities in near real time – Dark vessels, vessels broadcasting inconsistent AIS information, vessels anchored alongside and loitering vessels.

Fire Hotspot Monitoring

The Fire Hotspot Monitoring dashboard provides daily detection and tracking of forest fire incidents including automated reporting of location, duration of fire incident as well as the burned area extent and type of vegetation cover burned.

NPK Health Monitoring

GI's NPK (Nitrogen, Phosphorus, Potassium) Health Monitoring solution enables targeted and optimised crop fertilisation regime, thereby increasing yield, reducing over fertilisation and GHG emissions.



GI's satellite imagery and geospatial analytics business continues to grow its solution portfolio, while maintaining its focus on R&D to deepen domain capabilities.



GI's macronutrient analysis is a proven solution that empowers farmers to implement sustainable operational practices to combat climate change and its impacts.

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ST ENGINEERING SATELLITE SYSTEMS

 **ST Engineering**



COMPANY OVERVIEW

ST Engineering Satellite Systems (SatSys) is a joint venture company formed between ST Engineering, DSO National Laboratories and Nanyang Technological University (NTU). SatSys pioneered the design, development, build, test and operation of Singapore's first commercial earth observation satellite TeLEOS-1. SatSys has also obtained AS9100 Certification since 2016, which is a standard that is often required for effective participation in the aviation, space and defense businesses.

Today, SatSys continues to offer high performance, high assurance small/medium satellite systems with unique solutions for its customers.

CAPABILITIES, PRODUCTS AND SERVICES

Creating space solutions

SatSys provides its customers with innovative solutions that meet their stringent requirements. The company's technical team works closely with partners and customers to deliver complete space solutions through system engineering, design, development and manufacturing of space avionics, system integration and testing. Its space solutions also encompass flight, mission control, and payload mission planning software suite, making the company a one-stop space solutions provider.

Providing Space Avionics

SatSys develops different types of space components to meet its development needs, as well as design needs of other space solution providers. This is made possible with its in-house designed, manufactured, and tested space avionics, which are cost-effective and flight proven solutions. Its space avionics include:

- On-board computers
- On-board recorders
- On-board network node
- Electrical power system
- Payload data transmitter

Engineering services

SatSys also provides customers with Space Solution operation and maintenance services, as well as concept and feasibility study as a service for those who are looking for possible space solutions that give them an edge over their competitors.



TeLEOS-2, a Synthetic Aperture Radar (SAR) earth observation satellite, is set to launch in 2023.



TeLEOS-1 has successfully passed its 5-year mark in 2020 and is still capturing imagery.

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COMPANY OVERVIEW

Transcelestial is a technology company that leverages its proprietary wireless laser communication technology to deliver superfast internet and alleviate last-mile connectivity challenges around the world. Founded in December 2016, the Transcelestial team is located in Singapore and is backed by major investors such as Wavemaker Partners, EDBI, Airbus Ventures, Kickstart Ventures and Cap Vista, among others.

With about 3 billion of today's global population still without internet connectivity, despite many living within 10 km of the nearest fiber optic cable, Transcelestial is committed to improving the connectivity experience for 1 billion users globally.

CAPABILITIES, PRODUCTS AND SERVICES

The continued use of physical fibre cable networks is not only costly and slow to implement, but remains the main hindrance to ubiquitous internet across cities, otherwise known as last-mile connectivity.

Transcelestial's proprietary wireless laser communication technology beams fibre-grade internet between any two dedicated points without the need for wires. The dedicated units, known as CENTAURIs, can be easily installed on buildings, cell towers, street-level poles and other physical infrastructure with a much quicker set-up time, lower set up and operating cost and minimal upgrading downtime compared to traditional fibre cables.

Benefits of Transcelestial's laser communications technology:

- Quick half-day to deploy
- Cost-effective
- No right of way required
- Not impacted by spectrum congestion
- No regulatory approvals
- Highly secure
- Extensive future capacity
- Line rate throughput

In the longer term, Transcelestial aims to develop a constellation of small satellites positioned in low Earth orbit, allowing their laser network to not only beam across cities but to eventually connect continents as well.



Preparing Transcelestial laser communication terminals for spaceflight.



CENTAURI mounted on a standard telecom pole to connect the last-mile quickly and easily, as it requires no spectrum licensing.

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COMPANY OVERVIEW

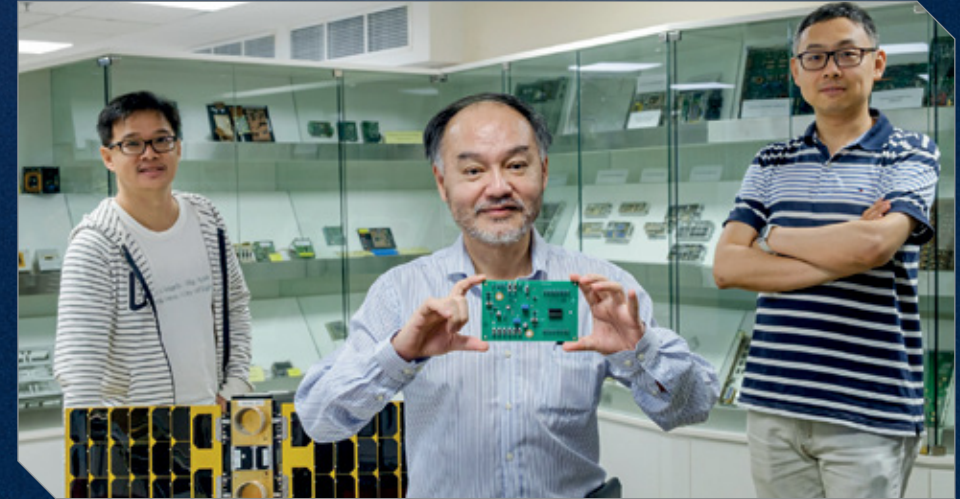
Zero-Error Systems (ZES) is a spin-off from Singapore's Nanyang Technological University. It was founded in 2019 by a group of researchers and semiconductor industry veterans with more than 30 years of industry experience. The team caters to growing demands for larger constellation and smarter low Earth orbit satellites to provide communication, data access, earth observation, surveillance, and reconnaissance. Cost, reliability, and performance remain a constant challenge for satellite subsystem and space electronics manufacturers that are under constant pressure by their end customers (e.g. service providers) to keep the system delivery price down despite the increased sophistication in functionality and processing capability.

CAPABILITIES, PRODUCTS AND SERVICES

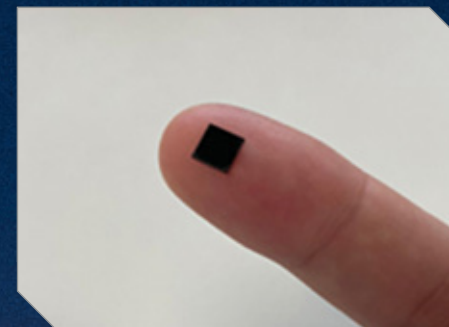
ZES addresses the power reliability and data integrity issues of space electronics by protecting commercial off-the-shelf (COTS) semiconductor devices from malfunctioning with its patented Radiation Hardened by Design (RHBD) technology.

ZES offers RHBD semiconductor devices that protect COTS-integrated circuits against radiation-induced Single Event Latchup and Single Event Upset occurrences. Intellectual property licensing options are available for companies that intend to build radiation hardened integrated circuits with ZES-patented technologies. ZES also invented a high power efficient (>90%) direct current-direct current converter with built-in redundancy that applies to both satellites and any battery-powered device. ZES provides laser test characterisation and integrated circuit design advisory services to satellite manufacturers to identify the radiation vulnerability of their components and systems so that they can take the right steps to mitigate the issue and strengthen their systems.

The company's RHBD workshops impart radiation knowledge to customers that are new to space so that they are aware of the impact of radiation on their electronics systems, key power reliability and data integrity issues, as well as reliability tests to qualify their systems for space missions.



NTU Prof Joseph Chang (centre) holding the new ZES smart chip, with CTO Dr Shu Wei (right) and co-founder Dr Chong Kwen Siong (left).



ZES' RHBD integrated circuit solution.

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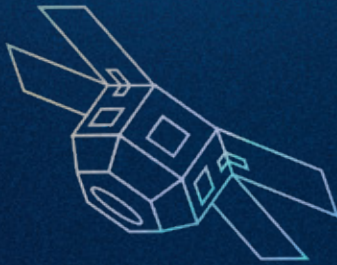
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Photo on page 4: National Aeronautics and Space Administration

Photo on page 8: Bifrost





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