

TeLEOS-1 IN MULTI-SOURCE MARITIME SECURITY AND SAFETY APPLICATIONS

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ABSTRACT: Riding upon the success of X-SAT launched since 20 Apr 2011, ST Electronics (STEE) has embarked on small satellite manufacturing through its ST Electronics – Satellite Systems, a joint venture company. STEE is currently developing TeLEOS-1, Singapore’s first commercial Earth observation satellite to be launched in Near Equatorial Orbit (NEqO) in Q4 2015. TeLEOS-1 differentiates itself from the world players of Earth Observation satellites in Sun Synchronous Orbits by providing high responsiveness and high availability data by nature of its low inclination orbit at 15 degrees. However, this is achieved at the expense of foregoing global coverage for equatorial belt coverage. The equatorial belt covers many major shipping routes. TeLEOS-1 imagery is especially applicable for maritime security and safety, a business application which many service providers are offering in conjunction with AIS correlation for vessels. STEE – Satcom & Sensor Systems aims to be a commercial service provider in value-added geospatial services using multiple satellite imagery sources together with TeLEOS-1 in the mix for effective surveillance, classification and identification of vessels over global coverage through fusion with Automatic Identification System (AIS) as well as information from vessel traffic management system and port information system for a near real time recognised maritime situation picture. Besides the TeLEOS-1 S-400 bus, STEE also has the SS-150 bus in partnership with ATK of USA for microsatellites of less than 200 kg mass. One or more electro-optical microsatellites in NEqO constellation can supplement the user’s capability for enhanced maritime security and safety. The specifications of SS-150 and S-400 buses will be introduced.

ST ELECTRONICS’ EMERGING SPACE BUSINESS

ST Electronics (STEE) started out in the satellite communications (satcom) business in 1991 selling RF modules in the Asia Pacific region. In 2005, the company acquired iDirect Inc., a leading manufacturer of Internet Protocol-based broadband satellite networking solutions. Today, STEE is a leading global satcom ground infrastructure solutions provider offering the integration of iDirect’s satcom network equipment and our satcom front-end transceivers marketed under the Agilis™ brand. Leveraging on these capabilities in design and production of satcom and sensor modules, STEE advanced into the space business as a next growth area.

On 20 Apr 11, Nanyang Technological University (NTU) and DSO National Laboratories (DSO) successfully launched their eXperimental SATellite (X-SAT) into a Sun Synchronous Orbit (SSO) in space. X-SAT celebrated its happy third year anniversary on 21 Apr 14. Riding upon the success of X-SAT microsatellite with a mass of 100 kg based on the SS-100 bus, STEE has since embarked on small satellite manufacturing through its STEE - Satellite Systems (SatSys), a joint venture company comprising STEE - Satcom & Sensor Systems (SatComS), NTU and DSO, formed on 31 May 11 to design, develop and deploy Earth observation satellite systems, and to exploit and commercialise indigenous satellite engineering capabilities.

STEE is currently developing its indigenous TeLEOS-1, Singapore’s first commercial satellite planned to be launched in a Near Equatorial Orbit (NEqO) in Q4 2015 on the Indian Polar Satellite Launch Vehicle (PSLV). TeLEOS-1 differentiates itself from the world players of Earth Observation satellites in Sun Synchronous Orbits (SSOs) and yet complements them by providing high responsiveness and high availability data with a short mean revisit time of 12 to 16 hours by nature of its low inclined orbit at 15°. This is achieved by foregoing global coverage for equatorial

belt coverage. The inclination angle is selected based on optimal coverage in the equatorial belt and mean revisit rate. The equatorial belt covers many major shipping routes and natural disaster prone regions. With a satellite mass of about 400 kg, TeLEOS-1 with its electro-optical payload provides a panchromatic resolution of 1m (at nadir) is based on STEE's own S-400 bus (See Table 1 and Figure 1).

We have successfully completed the environmental qualification test on the Qualification Model in May 2014. This is a very significant milestone achievement whereby the satellite was subjected to the vacuum environment, extreme temperature cycles, and vibration test and acoustic blast to be encountered during rocket launch. Currently we are building the Flight Model and the ground segment system for satellite operations and maintenance.

Recognising the growing global demand for remote sensing satellites and GeoServices, STEE has built up its space business operations through a team of experienced professionals to proficiently undertake the venture into Earth observation products and solutions. As a result of the venture, brand AgilSpace™ was launched. It encompasses GeoServices (i.e. geo-spatial image analysis and exploitation), satellite and subsystem solutions that global customers can tap on for their specific needs.

Table 1. Performance Specifications of TeLEOS-1

Spacecraft Bus Attributes	TeLEOS-1 Specs
Launch Date	Q4 2015
Mission Life	Fully redundant 5-year design life
Orbit	Type/Period - Near Equatorial Orbit / 96min Inclination – 15 degrees Altitude - 550 km
Satellite Mass	Approx. 400 kg
Satellite Data Storage	8 GBytes solid state recorder
Communications (CCSDS Compliant)	150 Mbps (X-Band)
Attitude Determination and Control	3-axis stabilised
Mission Control	Multiple ground station support
Mean Revisit Time	12 to 16 hours
Availability	Up to 6 daylight imaging opportunities per day
Image Resolution	1m pan (nominal at nadir)
Dynamic Range	10 bits per pixel
Swath Width	12 km @ nadir
Slew Rate	2.5 degree/sec
Max Viewing Angle	± 45 degrees off-nadir nominal

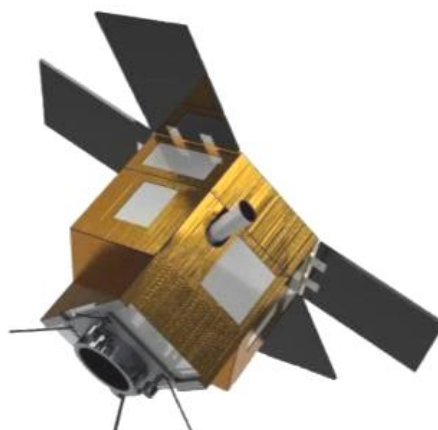


Figure 1. Model of TeLEOS-1 Minisatellite

MARITIME SECURITY AND SAFETY APPLICATIONS

TeLEOS-1 imagery is especially applicable for maritime security and safety, a business application which many service providers are offering in conjunction with AIS correlation for vessels. STEE-SatComS aims to be a commercial service provider in value-added geospatial services using multiple satellite imagery sources together with TeLEOS-1 in the mix for effective surveillance, classification and identification of vessels over global coverage through fusion with Automatic Identification System (AIS) as well as information from vessel traffic management system and port information system for a near real time recognised maritime situation picture.

The list of maritime security and safety applications for coastal nations includes the following areas:

- Shipping routes / Sea Lines of Communication
- Pollution (oil slicks, dumping)
- Anchorage monitoring
- Navigation aids & hazards
- Collision avoidance
- Search & Rescue
- Natural disasters (earthquake, tsunami)
- Illegal fishing
- Piracy
- Trafficking
- Terrorist threats
- Harbour / Offshore islands protection

Satellite Synthetic Aperture Radar (SAR) has proven to be a useful means of vessel detection in the ocean outside the coverage of coastal radars. There are not many objects in the ocean to reflect energy emitted by radar. Hence vessels with their metal structures can reflect a large amount of backscattered radar energy for detection. These vessels appear as bright objects and spots against a dark background of the ocean in a SAR image. Furthermore, the wake from each vessel also facilitates vessel detection. The vessel speed and heading can be estimated from the displacement between the positions of vessel and its wake due to Doppler shift of returned signal produced by vessel movement in range direction against returns from wake which are not Doppler-shifted.

As such, SAR image lends itself to automatic vessel detection through image processing and object extraction. The detected size of the vessel can also provide a first cut target classification. Such a vessel detection algorithm has already been developed by STEE's partner, CRISP (Centre for Remote Imaging, Sensing and Processing) of NUS in Singapore. While TeLEOS-1 is an optical satellite, it can be used to supplement SAR when so cued for target identification.

Under its sensors business, STEE-SatComS has developed and implemented AgilTrack™, a robust track-before-detect single radar tracker with low probability of false alarms in high clutter environments. It also has developed AgilFusion™ (see Figure 2) which performs multi-radar tracking with provisions for multi-source fusion from satellite SAR, AIS, Electro-Optical sensors and radio direction finders.

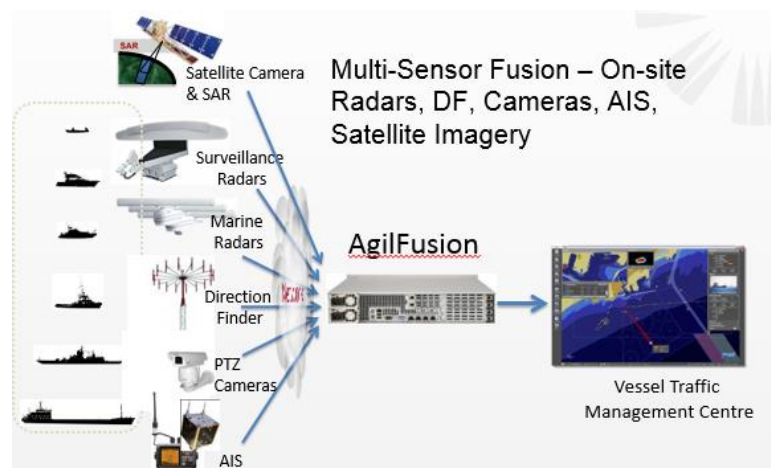


Figure 2. SatComS' AgilFusion Multi-Source Fusion Engine

STEE-SatComS has co-developed a Maritime Information System which can be integrated over Internet to local port authority for vessel traffic management information and notices and to public maritime community such as FleetMon for detailed information on vessels from static voyage databases. The application also processes and displays live feed of AIS data into its multi-source database (See Figure 3). The Web-based system runs on open source operating system and open source object relational database management system.

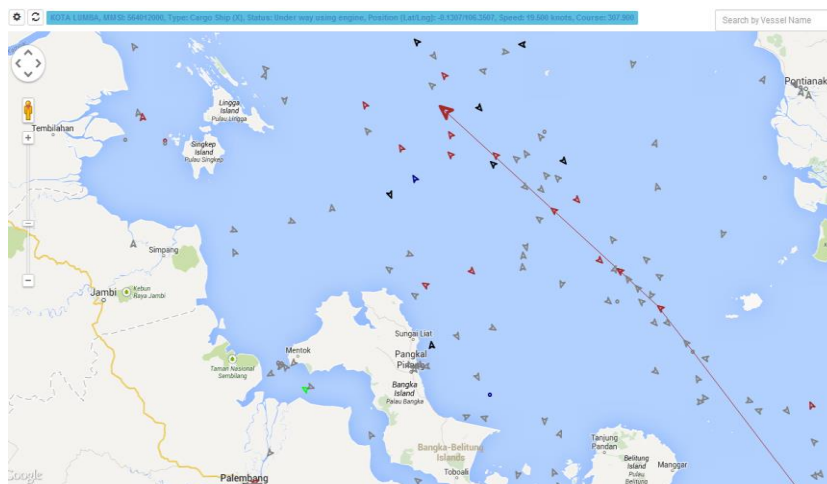


Figure 3. Maritime Information System Displaying AIS Symbols on Google Map

With its various software subsystems in place, SatComS is ready to offer the integrated suite of maritime domain awareness applications ranging for multi coastal radar tracking to fusion with satellite imageries and AIS sources in anomaly detections for enhanced maritime security and safety. The system can automatically detect events based on event definition, source, location and time where applicable. For example, alerts can be created for two ships which are alongside for a definable number of hours in a particular region of the ocean for suspected illegal cargo transfers. STEE also provides value-added geospatial image exploitation and analysis services for maritime security and safety alongside a host of other remote sensing business solutions.

MULTI-SOURCE SATELLITE IMAGERY

While TeLEOS-1 has yet to be launched into service in 2016, STEE-SatComS is presently a reseller of KOMPSAT-2 (optical), KOMPSAT-3 (optical) and KOMPSAT-5 (SAR) imagery. SatComS is planning to be reseller of more satellite imagery sources such as RADARSAT-2, Cosmo-SkyMed, TerraSAR-X, SPOT, etc. to provide one-stop value-added geo-services in the region. Based on customers’ imaging requirement for maritime surveillance, SatComS will compute and select the appropriate satellite pass over the area of interest from its portfolio of multi sources to deliver high temporal resolution services. SatComS hopes to have a constellation of NEqO satellites joining TeLEOS-1 in its emerging space business model, complemented by satellites in SSOs and vice versa.

STRTEGIC COLLABORATIONS WITH PARTNERS

STEE continually seeks collaborations with international and local partners for its new venture into the space business. Building on partnerships for business success in market strength and presence, STEE & ATK have collaborated to bring innovation in microsatellites of less than 200 kg mass. At the Global Space and Technology Convention 2014, STEE-SatComS and ATK’s Space Systems Division announced their strategic marketing and manufacturing agreement to jointly develop, manufacture and supply the A150S/SS-150 microsatellites and integration services to the world market. The partnership leverages on the respective and unique strengths of both companies in satellite design and production for cost competitiveness. The A150S will be produced at ATK’s Space Systems Division facility in Beltsville, MD. Future versions of the SS-150 will be produced at STEE in its fully equipped state-of-the-art satellite production and Assembly, Integration and Testing (AIT) facility in Singapore. This STEE Satellite Systems Centre was officially opened by the Second Minister for Trade and Industry, Mr S Iswaran on 19 Aug 14. Table 2 shows the A150S/SS150 target performance metrics and Figure 4 shows a model of A150S/SS-150.

Table 2. Performance Specifications of A150S/SS150

Spacecraft Attributes	A150S/SS-150 Specs
Mission Class/Design Life (Years)	Class B/C/D; 3-year (Design); 5-year (Goal)
Redundancy	Single String to Selective
Bus Volume (Nominal, cm)	61 x 71 x 91
Attitude Knowledge (°)	0.008
Attitude Control (°)	0.05
T&C Uplink (Band; kbps)	S; 2 to 32
T&C Downlink (Band; kbps)	S; 16 to 2000
Data Downlink (Band; Mbps)	X; 300
Battery Chemistry; Size (Ah)	Li Ion; 22.5
Propulsion (ΔV , m/sec)	150
Payload Mass (Nominal, kg)	Up to 60
Payload Volume (Nominal, cm)	51 x 46 x 20
Payload Power (W, Orbit Average)	75
Payload Peak Power (W)	125
Voltage (V)	28 \pm 6
Aperture Size (\varnothing cm)	46
Payload Data Storage (GBytes)	16
Launch Vehicle Compatibility	ESPA, Athena IIc, Dnepr, Falcon 9, Vega, LauncherOne, and others



Figure 4. Artist's rendering of the A150S/SS150 Bus

BUSINESS OF NEqO CONSTELLATION CLUBS

In the current global financial situation of tight budgets, emerging space nations can collaborate in higher temporal resolution access to constellations brokered by satellite manufacturers or operators. One business model is for customer to procure and contribute a satellite to an evolving constellation becoming a member of that 'club'. Another model is for the operator to build a constellation and provide shared capacity contracts to anchor customer(s). Variations on these themes, e.g., access to constellation without satellite contribution or partial ownership agreements with monthly access time quota, are similarly possible.

STEE and ATK envision the potential of delivering TeLEOS-1 class mini-satellites and A150S/SS-150 class micro-satellites to form a NEqO constellation with shared access and increased temporal resolutions for customers in the equatorial belt. These satellites could accommodate separate payloads of mixed imaging modalities to meet the range of application interests by emerging space nations. The synergy also extends to launch services as NEqO satellites could ride on the same launch vehicle instead of being piggy-back payloads waiting on the schedule of a compatible prime spacecraft.

It should be pointed out that not every application requires sub-meter resolution, especially in commercial applications. Budget conscious, customers will find the A150S/SS150 microsattellites well positioned for the niche 80/20 rule applications; $\approx 80\%$ performance of a high end satellite at $\approx 20\%$ of their price. Furthermore microsatellite delivery time can be shorter, within 18 to 24 months with a choice of electro-optical, weather, scientific and or navigation payloads, e.g. Automatic Identification System. Satellite SAR in NEqO requiring a larger bus can also be considered for the constellation club.

CONCLUSION

The development of TeLEOS-1, STEE's Near Equatorial Orbit (NEqO) satellite will provide high responsiveness and high availability in remote sensing services which are especially suited for maritime safety and security applications. In collaboration with strategic partners, STEE has engineered a comprehensive suite of products and services especially suited for maritime domain awareness applications. Covering the entire value chain, STEE supports data acquisition and processing, data management, value-added geospatial services and integrated turnkey solutions. STEE's satellite remote sensing solutions and services will benefit customers in high responsiveness for their maritime security and safety business needs and operations.