TeLEOS-1: First Commercial Earth Observation Satellite in Near Equatorial Orbit

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ABSTRACT: TeLEOS-1, Singapore's first commercial Earth observation satellite was launched into a 15° inclination Near Equatorial Orbit (NEqO) on 16 December 2015 by ST Electronics (STEE). By end June 2016, it has successfully undergone six months of in-orbit test for camera calibration of its high resolution panchromatic imagery. TeLEOS-1 with an orbital period of 96 minutes with up to six daylight passes per day over its ground station, can deliver high responsiveness coverage to the equatorial belt. TeLEOS-1 is geared for applications such as maritime security and safety, environmental monitoring, humanitarian assistance and disaster relief and infrastructure development planning and monitoring. A near equatorial orbit also allows coverage of the gaps in STEE's partner sun synchronous satellites for a well-rounded portfolio of Electro-Optical (EO) and Synthetic Aperture Radar (SAR) imagery. Commercialisation of TeLEOS-1 imagery services under the "AgilSpace" brand has commenced through the new "AgilSpace GeoPortal", an imagery hub for e-commerce over Internet with embedded simulation of satellite passes over customer's area of interest.

1 INTRODUCTION

In May 2011, ST Electronics (STEE) envisioned and set out to indigenously develop its TeLEOS-1, Singapore's first commercial Earth observation satellite. TeLEOS-1 was launched into Near Equatorial Orbit (NEqO) on 16 December 2015 at Satish Dhawan Space Centre in Sriharikota, India by the Indian PSLV-C29 along with five other piggy-back satellites from local universities: Nanyang Technological Institute (NTU) and National University of Singapore (NUS). It culminated Singapore's year-long "SG50" celebration of fifty years of independence on a high note. Following the launch, some two weeks of Launch and Early Operations (LEOP) was successfully completed whereby all satellite bus subsystems were checked and calibrated. Several test imagery taken soon after were already of very good quality. TeLEOS-1 underwent six months of In-Orbit Test for camera calibration and validation and in July 2016, STEE officially launched its commercial imagery services under the AgilSpace brand name.

2 TELEOS-1 SATELLITE MISSION OVERVIEW

2.1 Imaging Opportunities

TeLEOS-1 has an orbital inclination of 15 degrees and an orbital period of about 96 minutes at altitude of 550 km. The satellite mission profile enables increased imaging opportunities in comparison to the traditional Sun Synchronous Orbit (SSO). TeLEOS-1 has about 6 imaging passes every 24 hours over a single Communication Zone (COMZONE) compared to only two for SSO satellites. Although TeLEOS-1 is equipped with a day only Electro-Optical (EO) payload, TeLEOS-1 will be tasked for imaging on every orbit to perform imaging missions on the other side of Earth during the night hours in the Singapore Main Ground Station (MGS). Table 1 provides an overview of the TeLEOS-1 technical and imaging specifications.

Table 1: TeLEOS-1 Specifications

TeLEOS-1 Satellite Technical Specifications	
Design Life:	Fully redundant 5 years design life
Orbit Type/ Period:	Near Equatorial Orbit (NEqO)/ 96min
Orbital Inclination:	15 degrees
Orbital Altitude:	550 km
Satellite Mass:	400 kg
Imagery & Ancillary Data Downlink (CCSDS Compliant):	300 Mbps (X-Band)
Attitude Determination and Control:	3-axis Stabilised
TeLEOS-1 Imaging and Collection Specifications	
Mean Revisit Time:	~ 12 to 16 hours
Image Resolution:	1 m Panchromatic (nominal at nadir)
Swath Width:	12 km @ nadir
Geolocation Accuracy:	100 m CE90 without GCPs
Slew Rate:	2.5 degree/ sec
Max Viewing Angle:	± 45 degrees off-nadir nominal

2.2 Satellite Mean Revisit Time

Equipped with an EO payload, TeLEOS-1 is able to attain about 15 passes daily (including maintenance passes) worldwide, and provide user a Mean Revisit Time (MRT) of about 12 to 16 hours. Figure 1 provides a graphical simulation result of the TeLEOS-1 MRT.

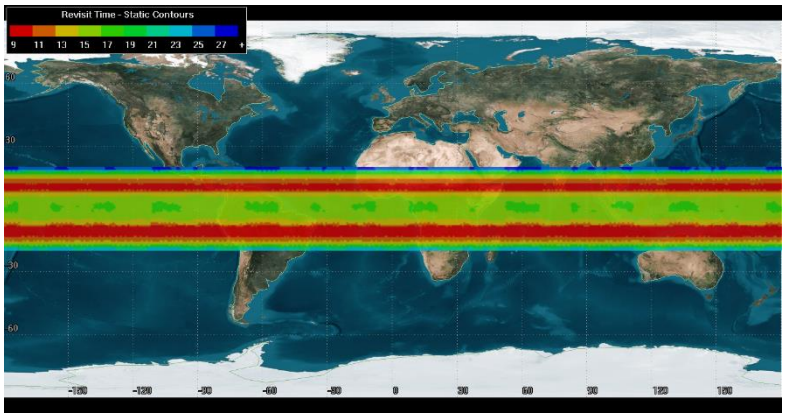

Figure 1: TeLEOS-1 Mean Revisit Time

2.3 Imaging Modes for Varying Applications

TeLEOS-1 will provide users with various imaging modes to support varying applications and requirements. The imaging modes allow optimisation of the satellite resources to fulfil the different application requirements. Figure 2 illustrates the various imaging of TeLEOS-1.

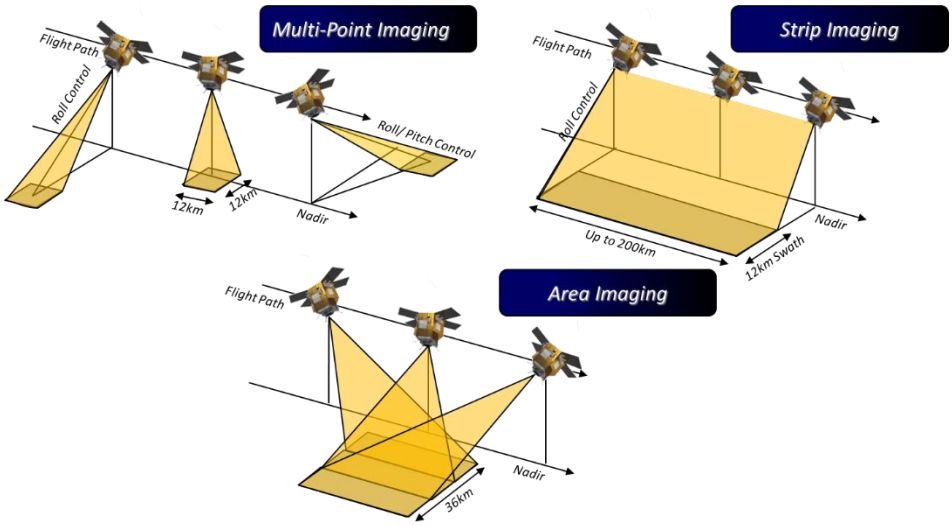

Figure 2: TeLEOS-1 Imaging Modes

3 TELEOS-1 MISSION CONCEPT OF OPERATIONS (CONOPS)

The TeLEOS-1 satellite mission CONOPS adopts a centralised satellite approach to support the highly diverse customer types worldwide so as to ensure optimised payload utilisation per orbit and to provide assured operational continuality and enhanced customer service experience. Figure 3 shows the TeLEOS-1 satellite mission CONOPS.

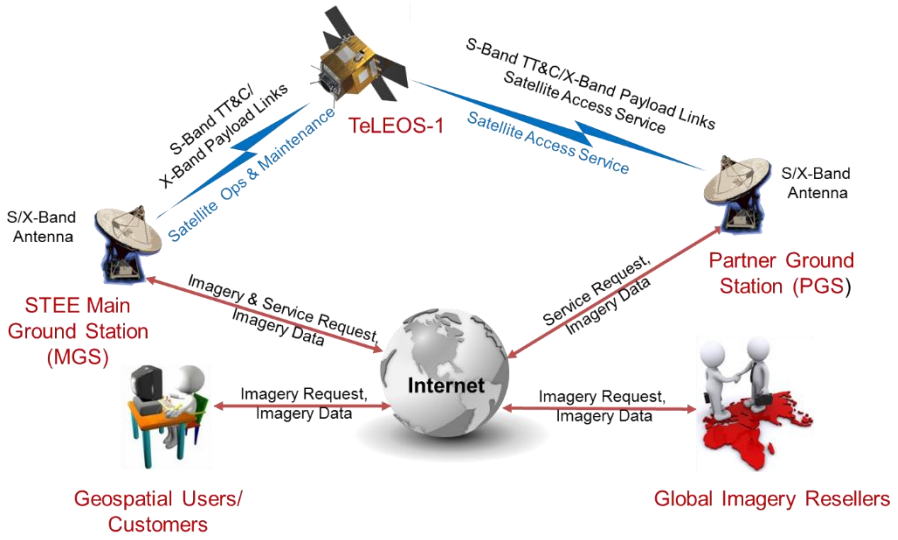

Figure 3: TeLEOS-1 Concept of Operations

4 APPLICATIONS

Satellite imaging at the equatorial regions can be difficult due to the high humidity and frequent cloud cover. Thus acquiring an image with relatively low cloud cover may typically only be possible every quarter. The orbit that TeLEOS-1 is launched into offers a high revisit rate thus allowing more opportunities for image acquisition. This means that with TeLEOS-1, the probability of acquiring cloud free imagery in the equatorial region is higher as compared to sun synchronous orbit satellites.

4.1 Maritime Security and Safety

The South East Asia region has faced challenges in piracy and concerns in protection of EEZs from illegal fishing. Pirates typically switched off all shipboard communications equipment and its Automatic Identification System (AIS) transponder once they strike. TeLEOS-1, with its high responsiveness and imaging opportunities can be tasked to locate a vessel reportedly hijacked by pirates in the South China Sea. Figure 4 shows a marked-up TeLEOS-1 imagery of bulk carriers in Eastern Anchorage of the Singapore port. Distinction can be made of bulk carriers with and without cranes on-board. Also small service crafts can be clearly seen alongside the large vessels.

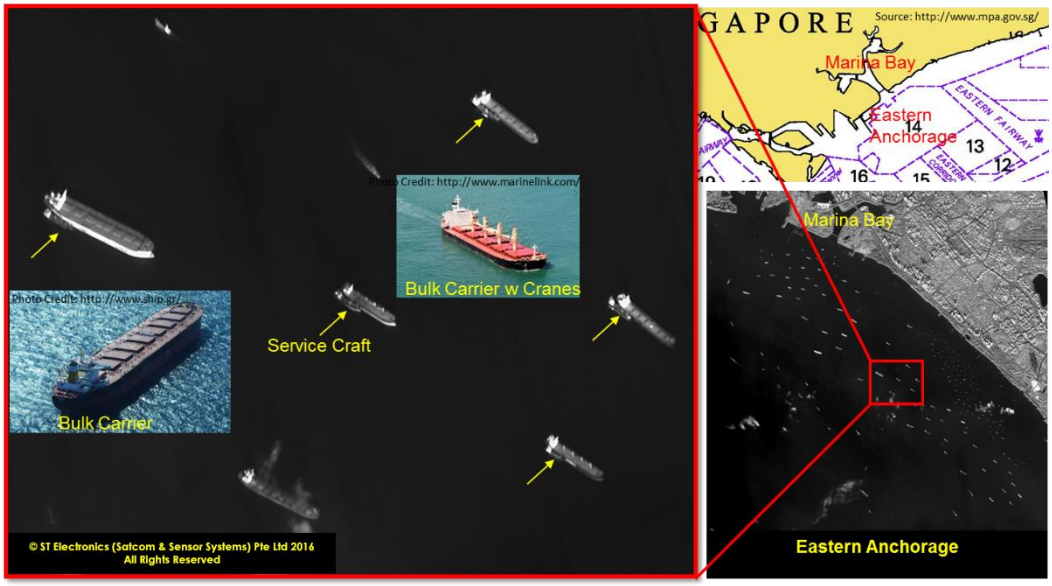

Figure 4: TeLEOS-1 for Maritime Surveillance Applications

4.2 Environmental Monitoring

Trans-boundary haze has been a perennial problem in the ASEAN region. In 2015, the region suffered one of the worst haze episodes along with the prolonged El Nino weather phenomenon. The haze began in August 2015 and by early September, the Pollutant Standards Index (PSI) fell into the unhealthy range of 101- 200 (Singapore National Environment Agency, 2015). On the 14th of September 2015, there were almost a thousand hot spots in Sumatra that Indonesia had to declare a state of emergency (Jakarta Globe, 2015). On the 25th of September, the PSI in Singapore had exceeded 300 which indicated that the air quality level in Singapore had deteriorated and became hazardous; Singaporeans were advised by the authorities to minimise outdoor activities (Channel NewAsia, 2015).

TeLEOS-1 can contribute towards fire-fighting efforts by verifying locations of hot spots for timely intervention. Once hotspots are detected by sources such as NASA's Fire Information for Resource Management System (FIRMS), TeLEOS-1 can be tasked to image the suspected area. With an orbital period of 96 minutes and six daylight passes, TeLEOS-1 can easily track the status of any major fire.

Figure 5 shows the smoke plume of a plantation fire captured by TeLEOS-1. The edges of the area that was burnt by the fire were clearly delineated; there were also enough details present to provide an estimate of the size of the fire as well as to identify the land-use type surrounding the area of the fire, which turned out to be an oil palm plantation.

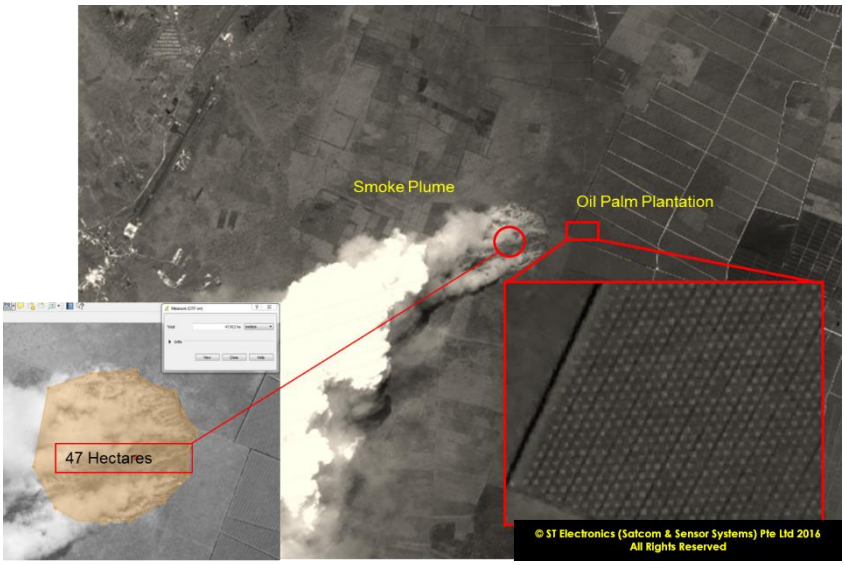

Figure 5: TeLEOS-1 Imagery of Plantation Fire

4.3 Humanitarian Assistance & Disaster Relief (HADR)

On the 16 April 2016, a 7.8 magnitude earthquake hit the coastal area of Ecuador, which is about 170 km from its capital, Quito. Widespread damage was reported across the country with hundreds dead and thousands more wounded (CNN, 2016) and a state of emergency was declared by its President (RT, 2016).

Three days after the earthquake, TeLEOS-1 acquired an image of an affected region as shown in Figure 6. After analysing the image, it was observed that the control tower at Eloy Alfaro International Airport had collapsed. This was corroborated by a photo taken by the news agency, Reuters (Reuters, 2016). Despite the collapse of the control tower, the airport appeared to be still in operation, as an aircraft could be seen taking off from the runway.

The multiple daily revisits of TeLEOS-1 can provide frequent satellite imagery updates of a disaster area. This is useful for HADR efforts, where search and rescue personnel require up-to-date maps in order to plan for their rescue operations and perform damage assessment. Similarly, the supply convoys also need up-to-date maps in order to avoid roads that have been rendered inaccessible. TeLEOS-1 imagery can also be used to track and monitor the size and location of camps established for people rendered homeless by natural disaster, thus allowing local authorities to better manage these camps.

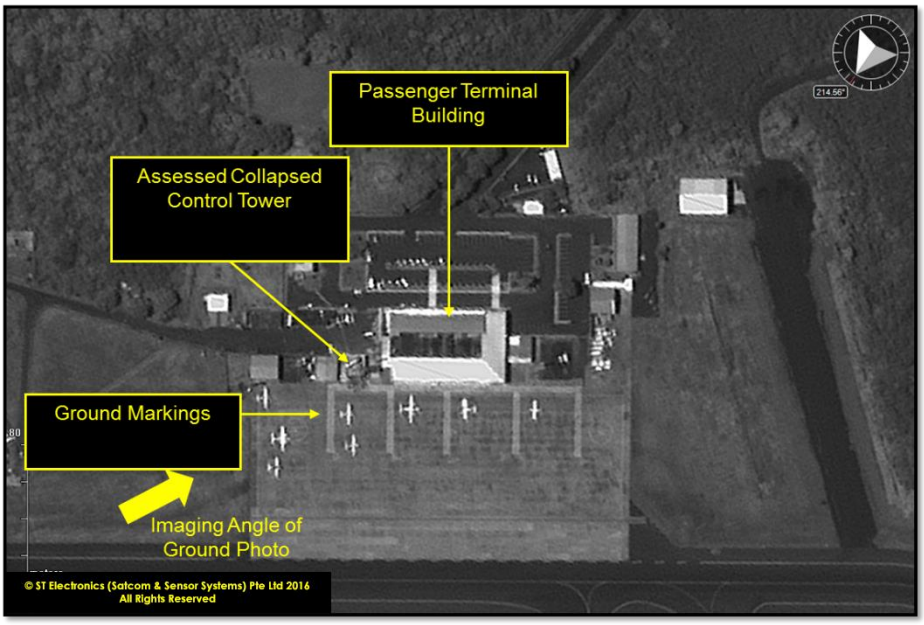

Figure 6: TeLEOS-1 Imagery of Earthquake Damage

4.4 Infrastructure Development Monitoring

TeLEOS-1 can be applied to large infrastructure development and construction projects like the construction of the new Terminals 4 and 5 for Singapore's Changi Airport. See Figure 7. The large area taken up by the site (approximately 7.6 square kilometres) means that satellite imagery is well suited for progress monitoring. TeLEOS-1's high revisit rates increases the chance for a relatively cloud free image as well as a potentially higher frequency of imagery updates on the construction site.

Figure 7: TeLEOS-1 Imagery of Changi Airport Construction Site

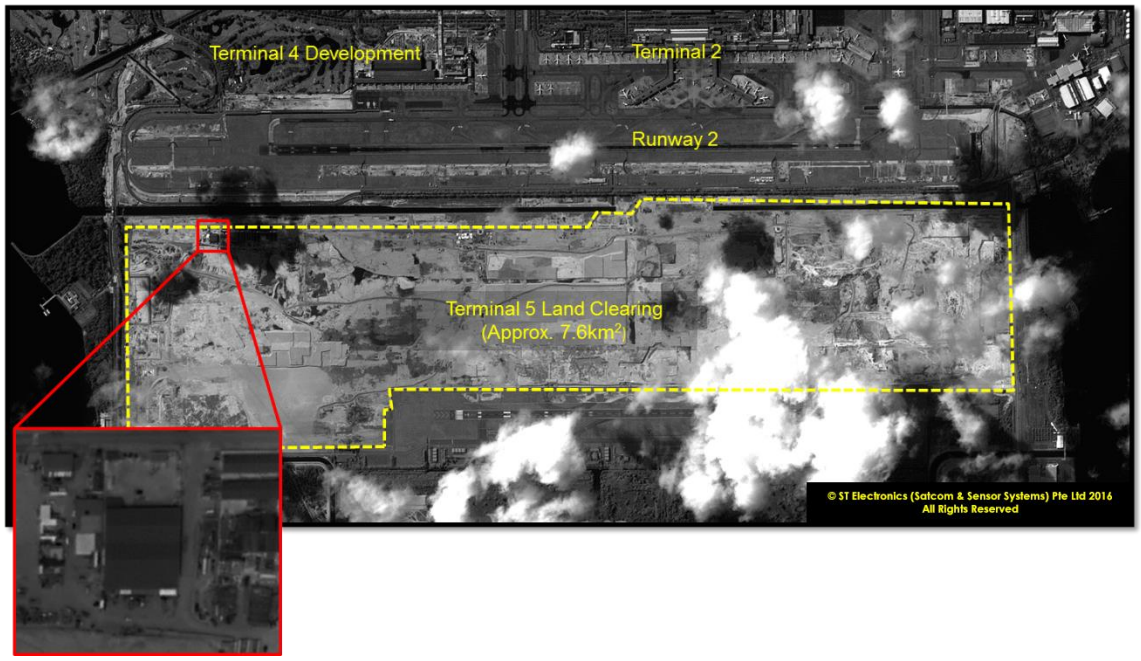

Figure 7: TeLEOS-1 Imagery of Changi Airport Construction Site

4.5 Accessing TeLEOS-1 Imagery – The AgilSpace GeoPortal

AgilSpace GeoPortal was launched on 31 May 2016 at CommunicAsia 2016, an international communications and information technology exhibition and conference held yearly in Singapore. The AgilSpace GeoPortal was developed in-house by STEE as a one-stop e-commerce portal for customers' purchase of TeLEOS-1 and AgilSpace partners' satellites imagery over the Internet. This portal allows customers to purchase archived imagery or request for new tasking over their area of interest. Payment options can be by credit card telegraphic transfer or purchase orders. The AgilSpace Geoportal can be accessed directly at https://www.agilspace.com:8080/ or via the AgilSpace website at http://www/agilspace.com. The AgilSpace GeoPortal landing page is shown in Figure 8.

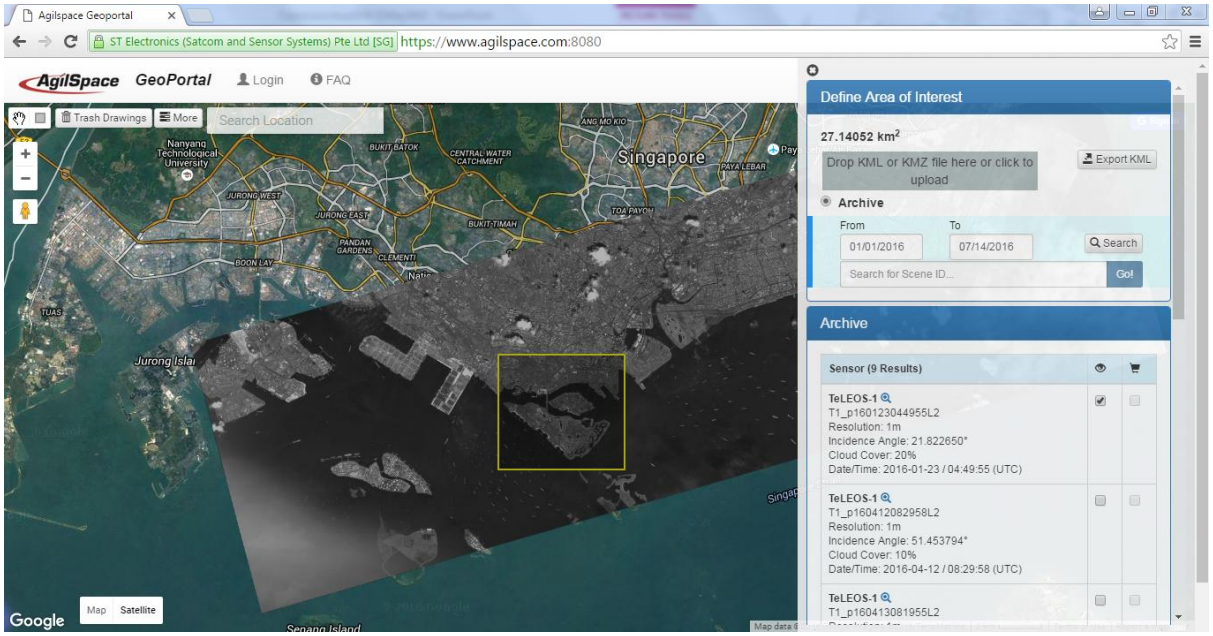

Figure 8: AgilSpace GeoPortal

5 CONCLUSION

Launched into Near Equatorial Orbit, TeLEOS-1 enables a high revisit rate and increased imaging opportunities over the equatorial regions. These two unique features allows TeLEOS-1 to complement other sun synchronous satellites in the supply of imagery over the equatorial region. As a high responsive and high resolution satellite, TeLEOS-1 can be used in applications such as maritime security and safety, environmental and forestry monitoring, disaster management and infrastructure development monitoring. TeLEOS-1 is the first commercial satellite launched by ST Electronics and plans are underway to build and launch a higher performance TeLEOS-2 satellite in the future.

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