Indonesian Non-GSO Satellites: Current Operations and Future Predictions

Satelit Non-GSO di Indonesia: Operasi Saat Ini dan Perkiraan Masa Depan

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ABSTRAK

Operasi satelit di Indonesia yang dikenal luas adalah tentang operasi satelit-satelit di orbit geostasioner (GSO) untuk misi telekomunikasi. Namun, dalam dekade terakhir ini, operasi satelit-satelit non-GSO di Indonesia meningkat dengan pesat. Sehingga, tujuan dari penelitian ini adalah mengetahui mengapa peningkatan tersebut terjadi dan mendapatkan gambaran tentang masa depan operasi satelit non-GSO di Indonesia. Untuk tujuan tersebut, dilakukan ulasan atas operasi satelit non-GSO yang lalu dan saat ini. Analisis dilakukan pada karakteristik misi, pemilik/operator, dan spesifikasi dari satelit-satelit tersebut. Selain itu, dilakukan kajian pustaka tentang tren global dan lingkungan strategis yang menentukannya. Hasil studi menyimpulkan bahwa penyebab pertumbuhan satelit non-GSO di Indonesia adalah bertambahnya penggunaan aplikasi penginderaan jauh, aplikasi M2M, dan pengembangan satelit oleh LAPAN. Di masa depan, diperkirakan naiknya penggunaan satelit non-GSO untuk penginderaan jauh akan disebabkan oleh faktor yang sama. Namun, untuk telekomunikasi, akan lebih didorong oleh beroperasinya konstelasi satelit global baru. Peningkatan penggunaan satelit non-GSO untuk penginderaan jauh tidak berakibat banyak pada kebutuhan frekuensi dan stasiun Bumi. Sementara, kenaikan penggunaan satelit non-GSO untuk telekomunikasi akan memerlukan tambahan alokasi frekuensi dan stasiun Bumi yang cukup banyak.

Keywords:
Satellite Operation
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ABSTRACT

Indonesian satellite operations are mainly known for the operation of geostationary orbit (GSO) satellites for telecommunication missions. In the last decade, however, the activities of non-GSO satellites in Indonesia are significantly increasing. Therefore, the objectives of this research are to find out the cause of the growth and to predict the future operation of non-GSO satellites in Indonesia. For such purpose, review on the operation of non-GSO satellites in the past and now was done. Analysis on the characteristics of their missions, owners/operators, and technical characteristics of the satellites were done. Literature studies on the global trends and their defining strategic environments were also done to complete the insight. The study shows that increase in the use of non-GSO satellites is caused by the growth in remote sensing application, M2M application, and development of LAPAN's satellites. In the future, the growth of non-GSO remote sensing satellite is predicted to be caused by the same reason. The increase in the use of non-GSO telecommunication satellites, however, will be affected more by the new global trend. The increase in non-GSO remote sensing satellites does not affect significantly on the needs of frequency and ground stations. The increase in the non-GSO telecommunication satellites, however, needs significant additional frequency allocations and ground stations.

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1. Introduction

1.1. Backgrounds and Objectives

The definition of satellite operated in Indonesia in this research is when it involves Indonesian ground station, therefore its frequency usages are registered by the Ministry of Communication and Information. The most known satellite operation activity in Indonesia is for telecommunication mission, including TV broadcast and automated teller machine (ATM) services, at geostationary orbit. Such mission, among others, has been discussed by Yuniarti (2013), Damanik (2014), and Damanik (2015). The 1st reference summarized the status of 19 Indonesian satellites launched between 1967 and 2012. Out of that, 18 were GSO telecommunication satellites, and 1 was a non-GSO Earth observation satellite. From the 18 satellites, 3 of them experienced failure in their launches. The 2nd reference mentioned that Indonesian telecommunication authorities noted 45 filings for Indonesian GSO satellites and 3 filings for non-GSO satellites. The 3rd reference mentioned that the Indonesian GSO satellites operating at the time supply 119 C-band and 5 Ku-band transponders. However, the telecommunication traffic that has to be served demands more capacity, so that there are 34 foreign GSO satellites providing services in Indonesia.

Other types of satellite, however, due to their specific user groups, are less known to the public. These are remote sensing satellites, navigation satellites, and scientific satellites. Most of these satellites flew at non-GSO. The 1st one provides support for mapping, weather information, and natural resources exploration, such as mining and fisheries. This type of satellite typically flew in low Earth orbit (altitude of 500–700 km). The 2nd type of satellite provides position information, such as GPS, which are mostly used by transportation industries. Such satellites flew in medium Earth orbit (altitude of 20,000 km). However, since its Earth stations do not require individual registration at the Ministry of Communication and Information (receive only, frequencies have been coordinated globally), it will not be discussed in this paper. The 3rd type of satellite is used by scientific communities.

Due to the lack of study on non-GSO satellites in Indonesia, the paper will focus on such satellites. The objective of the study is to predict the future of non-GSO satellite operation in Indonesia. For Indonesian government, such study results could be used for anticipating the necessary policies need to be formulated. For satellite business communities, such study results can be used for investment consideration.

2. Research Methods

In order to reach the research objective, the methods used in this research are descriptive-analytic, diagnostic analytics, and predictive analytics. According to Sugiyono (2013), the first method will answer ‘what happened?’ by organizing the data found. Such process commonly involves summarizing data and placing them in time or event-related order. The second method is meant to answer ‘why did it happen?’, and therefore, involves identifying patterns and visible relationships in the data or their aggregates. The third method is meant to answer ‘What could happen in the future?’, based on the extrapolation of the first method and the result from the second method.

The data mining is done in chapter 3 for remote sensing satellite and chapter 4 for telecommunication missions. Data on the missions, owners/operators, and technical specifications of the satellites ever operated are compiled in chapter 5 to explain the phenomena and the possible scenario of non-GSO satellites operation in Indonesia.

3. Earth Observation Missions

3.1. International Satellites Usage

The assessment for the use of satellite-based remote sensing data in Indonesia started in 1982, with the introduction of American remote sensing satellite, Landsat, and NOAA weather satellites for international users. The operation was started in 1992 with data receiving from Landsat-4 and Landsat-5 from LAPAN's Parepare ground station (Kushardono, 2016). The satellite provided medium resolution, i.e., 20 m resolution, multispectral imager for agriculture application, such as prediction of harvest, and forestry application, such as monitoring of deforestation. Landsat series orbit is at about 700 km altitude SSO (Sun Synchronous Orbit) or at inclination of about 97^o, and transmits its data using X-band. The early series have data rates of under 100 Mbps, but the later, i.e., Landsat-7 and Landsat-8, have more than 300 Mbps. As the Indonesian space agency, LAPAN operates the ground stations (see Figure 1) and provides added value services to the data for the Ministry of Agriculture and Ministry of Forestry. LAPAN ground stations also received non-GSO weather satellites, which are used for the application of weather and forest fire. The orbit of NOAA satellites is at 850 km SSO (inclination of 98^o), its data is transmitted using L-band and X-band frequencies.

Figure 1. LAPAN's Ground Station Built in Late 80s (Left) and Built in 2013 (Right), at Parepare, Sulawesi
(Source: Deputy of Remote Sensing, LAPAN)

With the availability of high-resolution satellite images (5 m or less) at the beginning of the millennium, the land applications have grown to, among others, infrastructure monitoring, calculating tax for plantations, and optimizing government-subsidized fertilizer distribution (from the observation of crop phase of growth). LAPAN's remote sensing data clients are now include Geospatial Information Agency, for yearly update of nation-wide high resolution map, Ministry of Finance, for property and natural resources tax, and private companies, mostly in mining and agroforestry business (Roswintiarti, 2010) (Tejasukmana, 2011). The satellites currently acquired from LAPAN ground station are French's SPOT-6, SPOT-7, and Pleiades. The satellites fly at SSO of 700 km altitude. Figure 2 shows LAPAN product of Indonesian Landsat images (20 m resolution), and Figure 3 shows the density of Indonesian forest data in 2016 obtained from the processing of satellite images.

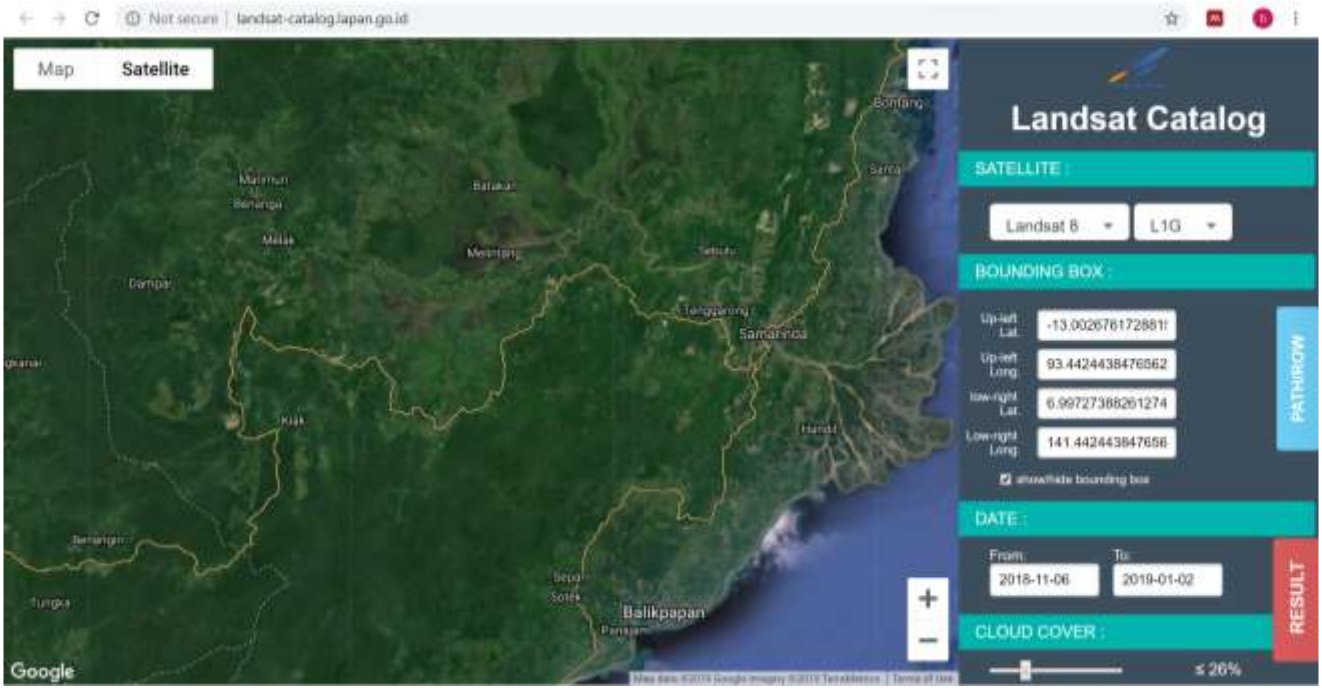

Figure 2. Web-based Catalog of Satellite Images at Remote Sensing Technology and Data Center, LAPAN

Figure 3. Web-based Catalog Information Extracted from Satellite Images
(Indonesian Forest Density at 2016) at Remote Sensing Utilization Center, LAPAN

Having oceans of 2/3 its territory, Indonesia is also increasingly aware of using remote sensing technology to manage its maritime economy better. The application that has been developed by LAPAN in 2000 is the fishing zone prediction using thermal imager data from NOAA satellites, as shown on the left side of Figure 4.

Since 2014, in the past few years, the Ministry of Maritime and Fisheries (MMF), has been using SAR (synthetic aperture radar) satellite to combat illegal fishing and pollution. The application has been proven to increase the detection of illegal fishing cases, as shown on the right side of Figure 4 (Hanggono, 2017). The satellite used is RADARSAT-2, until 2016, and COSMO-SKYMED, starting 2018, and its data receiving is done from MMF ground station at Perancak, Bali.

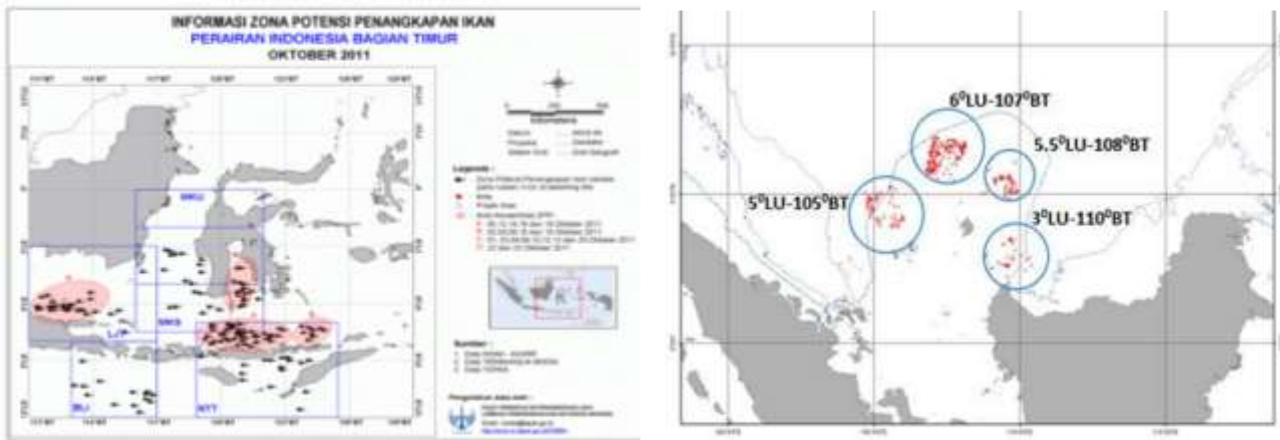

Figure 4. Fishing Zone Potency Map Developed by LAPAN (Left) and Detection of Illegal Fisheries Done by MMF (Right)

3.2. Indonesian-made Experimental Satellites

In addition to receiving international remote sensing satellites, LAPAN also developed micro-class (under 150 kg) Earth observation satellites (Judianto et al., 2018) (Triharjanto and Hakim, 2017) (Triharjanto, 2018). The references mentioned that the remote sensing micro-satellites approach was chosen so that the satellites can be built using the limited engineering resources in Indonesia, as shown in Figure 5. The goal of the program is to initiate self-sufficiency in satellite technology in the country. The operation of the satellites started in 2007 with the launch of LAPAN-A1/TUBSAT. The satellite was operated until 2013 and has served its purposes in satellite technology capacity building. The operation of Indonesian-made experimental satellites started with LAPAN-A2/ORARI and LAPAN-A3/IPB, which were launched in 2015 and 2016. Per June 2018, the two satellites have produced 2 millions km^2 of high resolution RGB images (among others shown in Figure 6) and 51 km^2 of medium resolution 4-band multi-spectral images.

Figure 5. Development of LAPAN-A2/ORARI (Left) and LAPAN-A3/IPB (Right) (Source: Satellite Technology Center, LAPAN)

Figure 6. Image of Semarang City Taken by LAPAN-A2/ORARI (Source: Satellite Technology Center, LAPAN)

Presidential Regulation No. 45/2017, which is about Indonesian space activities masterplan, has mandated the government satellite development program to continue, among others, the enhancement of Earth observation application in Indonesia. Therefore, more Indonesian micro-class satellite launches are expected in the future. LAPAN plans to launch LAPAN-A4, another optic-based Earth observation satellite, in 2020, and LAPAN-A5/ChibaSat, a SAR Earth observation satellite, in 2022. LAPAN-A4 will be able to produce twice the image coverage than LAPAN-A3 (Saifudin, 2018). LAPAN-A5 will be able to increase Indonesian Earth observation capacity, since images can be produced on cloudy days and even during the night (Triharjanto et al., 2018). Such capability is important in the case of disaster monitoring and other quick response mission.

Judianto (2018) mentioned that the micro-satellite programs had paved the way for satellite industry in Indonesia, as projects have created necessary infrastructure and manpower for such industry. With the involvement of private sectors, as the primary investor and marketing arm, the development of Indonesian micro-satellite industry can be realized in the near future. Such progress could drive more non-GSO satellites to be operated in Indonesia.

4. Telecommunication Mission

There are 3 types of non-GSO telecommunication satellite mission currently operating in Indonesia, i.e. mobile telephony, M2M (machine-to-machine), and amateur.

4.1. *Mobile Telephony and Broadband Internet*

The website of PT Amalgam shows that Iridium satellite telephones are used by the Ministry of Fisheries and Maritime Affair, National Search-And-Rescue Agency, state-owned oil company, and airlines that provide flight services to remote areas (http://www.amalgam.co.id/). The satellite constellation consists of 66 satellites in 6 orbital planes at an altitude of 780 km, as illustrated in Figure 7. The satellite communication can be done between 2 Iridium handsets or via ground station to interface with non-MSS (mobile satellite services) via L-band frequency (1.6 GHz), with data rate of 2.4 Kbps (Geoborders, 2012). The satellites also provide encrypted communication service for the US Department of Defense.

With the growing internet connectivity demand, while the competition to acquire GSO slot is getting tighter, non-GSO has become the future of communication satellite. At the moment, 2 proposals for non-GSO constellations for internet connectivity, i.e., Oneweb and Telesat. Oneweb constellation will consist of 900 satellites at orbit of 1,000 km (de Selding, 2014) and Telesat constellation will consist of 300 satellites at 1,000 km orbits (Henry, 2018). Most likely, the constellations will provide service in Indonesia when national regulation permits.

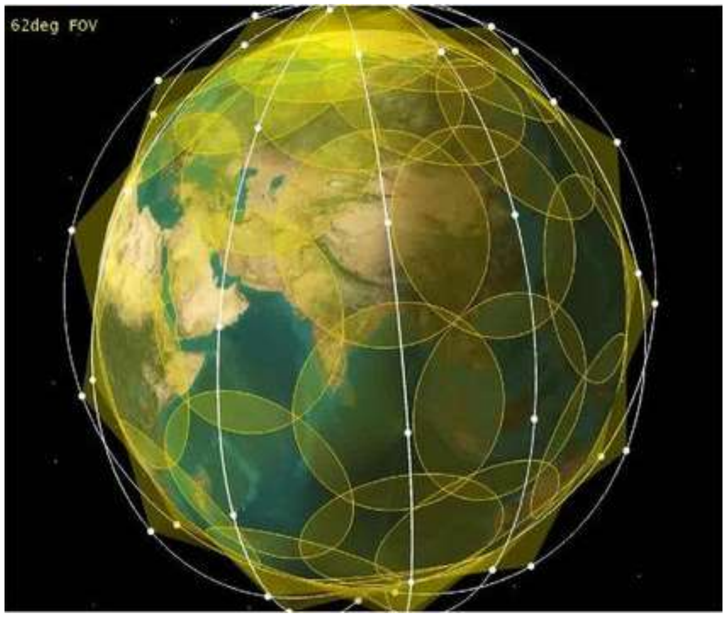

Figure 7. Iridium Satellite Constellation (Hooper, 2015)

Conceptual studies for Indonesian non-GSO telecommunication satellite was initially published by Nasser (2014). The concept of constellation consists of 14 micro-satellites at an equatorial orbit of 1,500 km to ensure dual satellite diversity during its service. A more recent study has been done by Pratama (2018), which constellation consists of 9 micro-satellites at 1,200 km. The study emphasizes on the model of communication handover as the satellite is coming and passing the user terminal coverage. Based on the LAPAN's experience in developing and operating micro-satellites, if the proposal is funded, the Indonesian telecommunication satellite constellation can be realized. Therefore, the constellation concept is also noted for future Indonesian non-GSO satellites.

4.2. *Machine-to-machine*

Orbcomm satellite constellation started its operation in Indonesia in 2006, via its Indonesian operator PT Imani Prima. The telecommunication service provided is VHF-based text message or known as M2M. The data can be transmitted manually or automatically via satellite as illustrated in Figure 8 (left). Among others, the use is for asset tracking, such as to monitor the operation of heavy machinery (Komatsu) at mining sites, as illustrated in Figure 8 (right), and shipping containers/vessel (Imani Prima, 2018).

The 1st generation of Orbcomm satellite constellation, called OG1, consists of 35 satellites with weight of about 45 kg. The satellite deployable configuration is shown in Figure 9 (left). The satellite orbited in 6 orbital planes with the altitude of 720 km and 45^{o} inclination, and operated until 2014, when the 2nd generation was deployed. The 2nd generation Orbcomm, named OG2, has twice times the data rate than its predecessor. The constellation consists of 12 micro-satellites (weight 172 kg) in several orbit planes at 52^{o} inclination and 750 km height (Spaceflight101, 2013), as shown in Figure 9 (right). In the 2nd generation, in addition to M2M service, the system also provides maritime traffic monitoring service via AIS (automatic identification system) (SpaceDaily, 2016).

Figure 8. Orbcomm M2M Operation Mode (Maclay, 2009) and Product

AIS is a VHF transponder installed on ships that reports their ship's identity and position via text messages, for the main purpose of safety (avoid collision). The equipment is mandatory by IMO (International Maritime Organization) for ships above 300 GT. The messages can also be picked up by satellite equipped with AIS receiver.

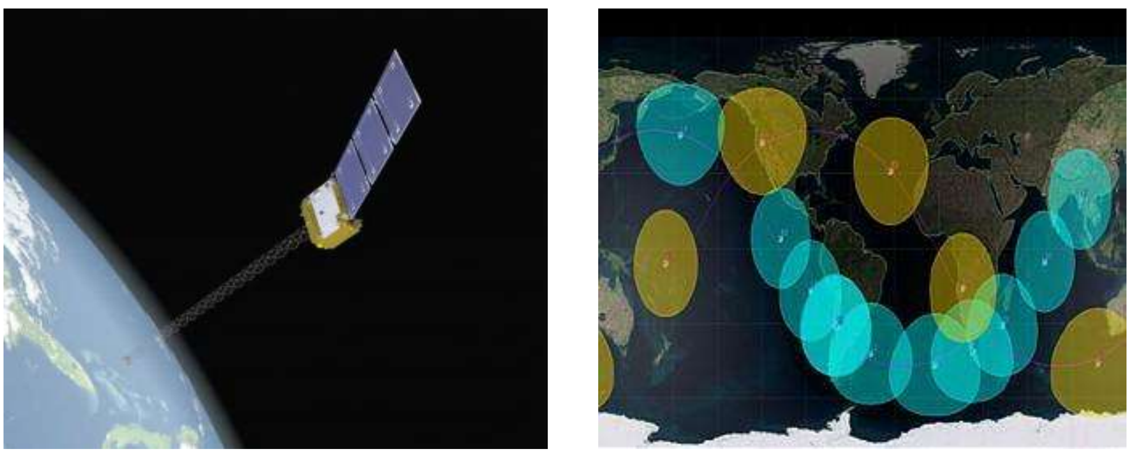

Figure 9. OG2 Satellite in-Orbit Configuration (Source: Spaceflight101) and Its Groundstrack in 2015 (Source: SpaceDaily)

M2M maritime (vessel traffic) surveillance using Indonesian satellite started with the operation of LAPAN-A2/ORARI in 2015. Since the satellite orbit is at a low inclination, it has high repeat pass over Indonesian territory and therefore, perfect for Indonesian maritime surveillance mission. The AIS receiver coverage, however, is limited from 20^o North and 20^o South latitude, as shown in Figure 10 (top). To increase the data needed for maritime surveillance, LAPAN-A3/IPB also carries an AIS receiver. Since the satellite is launched at polar orbit, its AIS receiver could receive data from the whole world, as shown in Figure 10 (bottom).

Among others, AIS data from LAPAN-A2 and LAPAN-A3 have been used to track the ship that damage precious coral reefs near Papua island, as shown in Figure 11 (left), and the ship hiding in the territory after allegedly related to a corruption case, as shown in Figure 11 (right). The track in the left shows that the ship escaping Indonesian territory after causing the damage, that resulted in a multi-million suit from the Indonesian government. The track on the left shows the voyage of the ship before detained by Indonesian police in Bali Island. Per June 2018, LAPAN-A2 and LAPAN-A3 have produced 310 million ship position/identification reports. The data were used among others by the Indonesian Ministry of Maritime and Fisheries.

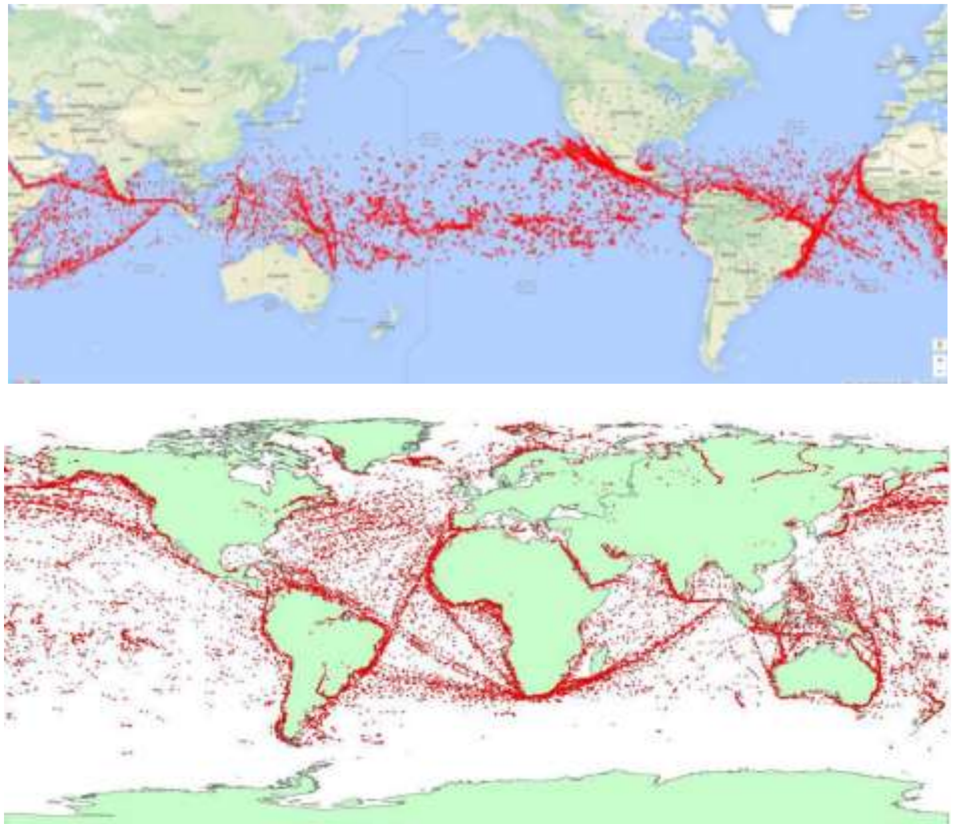

Figure 10. AIS Data from LAPAN-A2/ORARI (Top) and LAPAN-A3/IPB (Bottom)

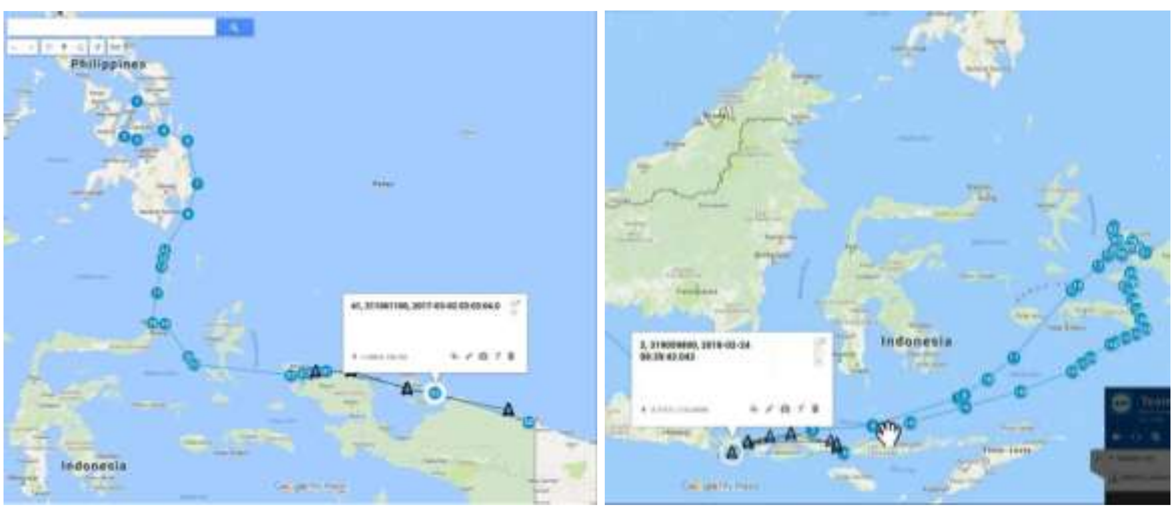

Figure 11. Tracking of Caledonia Sky Ship that Damage the Coral Reef at Raja Ampat, Papua, on March 2017 (Left) and Tracking of Equanimity Ship, that Hide from the FBI Surveillance, on February 2018. (Source : Satellite Technology Center, LAPAN)

4.3. Amateur Telecommunication

Indonesian amateur satellite community (ORARI) has been using satellite-based communication in early 2000, mainly from AMSAT (amateur satellite) launched by United States or other developed countries. For such activities, AMSAT-ID group was established under ORARI. The organization supported the development of LAPAN-A1/TUBSAT by performing frequency coordination to be used for its Telemetry, Tracking, and Command (TTC) in 2004. With the successful mission of the satellite, the group sponsored LAPAN to develop voice repeater and APRS (automatic position reporting system), and install them in LAPAN-A2/ORARI. APRS is an amateur radio text message repeater that has been extensively used by amateur satellite community in Indonesia.

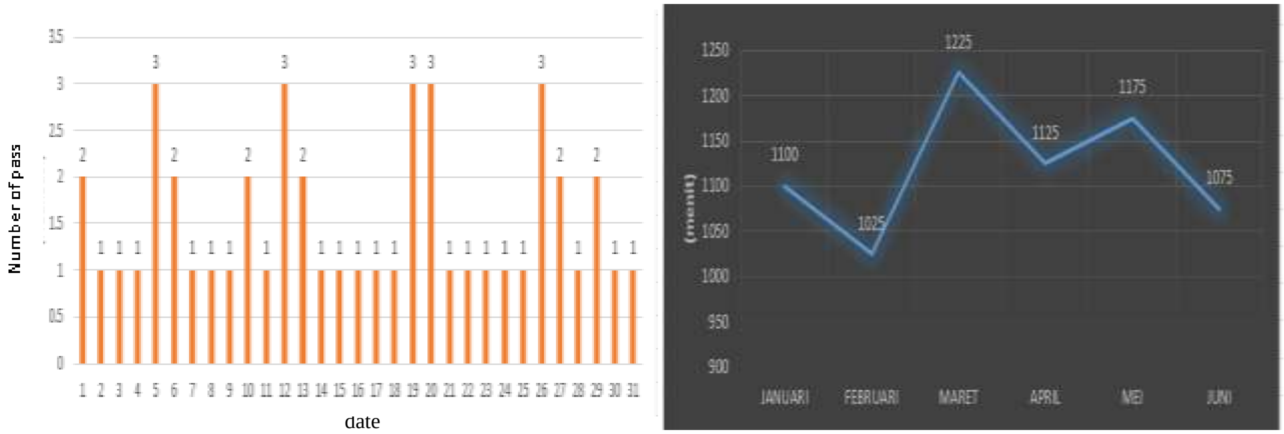

Figure 12. Monthly (in May) and Semesterly Usage Log of LAPAN-A2/ORARI Voice Repeater in 2018

Satellite-based amateur communication service via LAPAN-A2/ORARI, was started in October 2015, one month after the launch of the satellite. The satellite obtains amateur satellite designation of IO-86 from amateur satellite community and has served the amateur communication society in South America, India, and Southeast Asian countries. In 2018, for example, the service schedule is shown in Figure 12 for monthly and semesterly statistics. Example of APRS broadcast can be seen in Figure 13, which was done for celebrating Indonesian Independence Day in 2017.

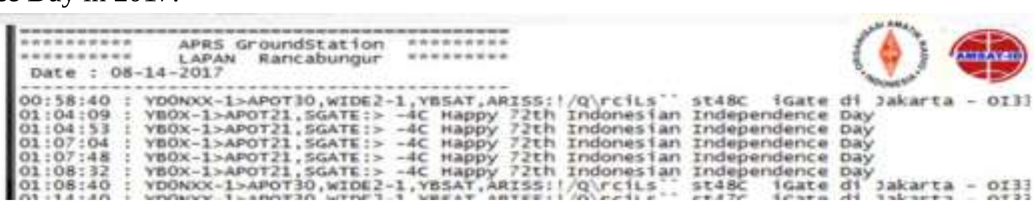

Figure 13. LAPAN-ORARI APRS Broadcast in the Event of Indonesian Independence Day

As designed, the amateur communication payload is intended to provide communication during natural disasters in Indonesia, which often took down terrestrial telecommunication infrastructure. One of such missions is the communication support during the earthquake in Lombok in 2018 (Pusteksat, 2018a). Such service was also done during the Palu earthquake in 2018, which has been successfully used to send information from the affected area in the time when all terrestrial telecommunications were down.

The communication payload is also used, together with Indonesian amateur radio community, to train future engineers in the field of satellite communication. The trainings were done 2–3 times a year, all over the country. One of them was done in Pekanbaru City of Sumatra Island, on August 2018 (Pusteksat, 2018b).

5. Results and Discussions

5.1. Descriptive and Diagnostic Analysis

The data in the chapter 2, i.e., the Current Non-GSO Earth observation satellite operations in Indonesia, can be summarized as in Table 1. The table shows the trend in Indonesian remote sensing is the increase in the use of usage high and very high resolution and SAR. Out of more than 18 Earth observation satellites were used since 1992, only 3 is owned by Indonesia, in which 2 of them were manufactured in Indonesia.

Table 1. Current Non-GSO Earth Observation Satellite Operations in Indonesia

Satellite Name	Type /resolution	Downlink/TTC	Timeline	Ground Stations
Landsat-4/-5 Landsat-7/-8	Multispectral/ 20 m	X-band/NA	1992–2002 2003–now	Parepare, ***Jakarta*** Parepare, Tangerang
SPOT-3 SPOT-4/-5 SPOT-6/-7	Multispectral /5 m	X-band/NA	2002–2007 2008–2014 2015–now	Parepare Parepare, Tangerang
NOAA series	IR/1 km	L and X-band/NA	1992–2007 2007–now	Parepare, ***Jakarta*** Parepare, Tangerang
LAPAN-A1/TUBSAT	RGB/5 m	S-band/UHF	2007–2013	Bogor, Biak, Tangerang
Radarsat	SAR/10 m	X-band/NA	2014–2017	Bali
COSMO-SkyMed	SAR/10 m	X-band/NA	2018–now	Bali
LAPAN-A2/ORARI	RGB/5 m	S-band/UHF	2015–now	Bogor, Biak, Tangerang
LAPAN-A3/IPB	Multispectral/ 20 m	X-band/UHF	2016–now	Bogor, Biak, Tangerang
Pleiades-1/-2	Multispectral/ 0,5 m	X-band/NA	2017–now	Parepare

Note : ground station written in bold and italic is no longer operating due to RF noise restriction

Based on data from chapter 3, Table 2 shows that LAPAN is advancing in providing non-commercial (amateur) telecommunication services, since, to date, no addition telecommunication satellite constellation is deployed after Orbcomm and Iridium.

Table 2. Current Non-GSO Telecommunication Satellite Operations in Indonesia

Mission Type	Satellite Name	Orbit (alt./)	Band/data rate (kbps)	Timeline	Operator
Telephony	Iridium	780 km/ multi	L/NA	-	Amalgam
M2M/asset tracking	Orbcomm	720 km/ multi	VHF/4,8	2006–now	Imani Prima
Amateur (voice/text)	LAPAN-A2/ORARI	650 km/ single	UHF-VHF/NA	2015–now	LAPAN
M2M/Maritime surveillance	LAPAN-A2/ORARI	650 km/ single	VHF/9,6	2015–now	LAPAN
M2M/Maritime surveillance	LAPAN-A3/IPB	550 km/single	VHF/9,6	2016–now	LAPAN

Figure 12 shows the growth of Indonesia NGSO satellite operations since 1992. It shows that for remote sensing application, the increase is almost triple. It is mostly due to the increasing awareness of Indonesian remote sensing users and advancement in technology. As mentioned in chapter 2.1, Indonesia is among the most advanced in remote sensing data users in ASEAN, among others, due to the extensive campaign done by LAPAN to national stakeholders. The use of telecommunication satellite constellations was initiated in 2006, and the growth follows global telecommunication satellite constellations trend, i.e., no new deployment until now.

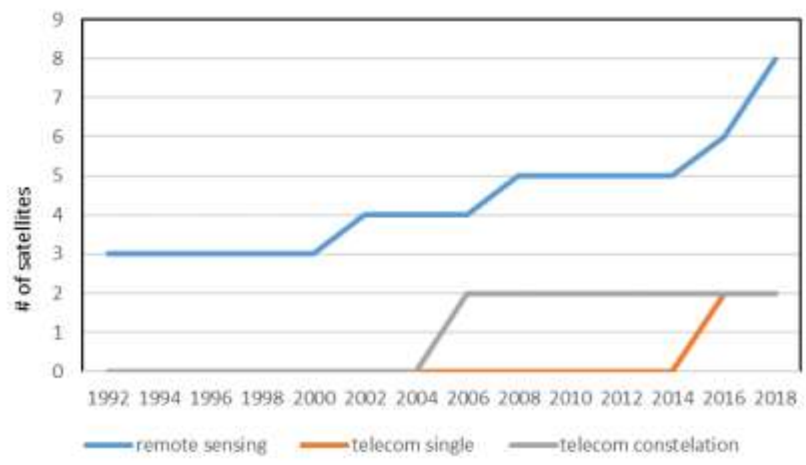

Figure 12. Growth of Indonesian Non-GSO Satellite (per Mission) from 1992–2018

5.2. Descriptive and Predictive Analysis

As seen in Table 1, the international Earth observation satellites used in Indonesia are owned by USA, France, Canada, and Italy. Since the international market of Earth observation satellite's subscription is rather dynamics (procurement will be done by tender), then it is difficult to predict which international satellite to be used in the future. The Earth observation satellites developed in Indonesia, however, can be predicted from the strategic plan of LAPAN. The satellites, however, cannot fulfill all types of remote sensing service currently given to the government institutions and private entities that must be provided continuously, which means still have to be supplied by international vendors. Therefore, in Table 3, for such mission will be noted as TBD in satellite name.

Table 3. Future Non-GSO Earth Observation Satellite Operations in Indonesia

Satellite Name	Type/resolution	Downlink/Uplink	Expected Launch	Ground Stations
TBD (international)	Multispectral/0,5 m	X-band/NA	TBD	Parepare
LAPAN-A4	Multispectral/20 m	X-band/S-band	2020	Bogor, Biak
LAPAN-A5	SAR/10 m	X-band/S-band	2023	Bogor, Biak

Regarding the frequency being used to operate remote sensing satellites, Table 1 and Table 3 shows that for uplink (TTC), it changes from UHF to S-band. For downlink, however, it is consistent in X-band as regulated for Earth observation satellite downlink by ITU. The use of ground stations for Earth observation satellites are mainly in LAPAN facilities in Bogor, Parepare, and Biak. Such operation is consistent with the mandate from Presidential Regulation No. 11/2018, which notes that only LAPAN who can operate ground station to downlink remote sensing data. The regulation is made to ensure the efficiency of government spending on remote sensing images, based on national licensing. Commercial sectors that use remote sensing data could purchase LAPAN's data or procure them from international data vendors, and therefore, does not need any ground station frequency allocation.

Table 4 shows 3 proposals of constellations, i.e., Oneweb, Telesat, and LAPAN's, that will soon add non-GSO telecommunication satellite operation in Indonesia. The table shows that new frequency will be allocated for the operation of the new satellites, except for the uplink of the maritime surveillance mission of LAPAN-A4, where maritime frequency has been defined by ITU. Distributed control ground stations will also be needed to support the constellation operations.

Table 4. Future Additional Non-GSO Telecommunication Satellite Operations in Indonesia

Mission Type	**Satellite Name**	**Orbit alt. (km)/ number of satellite**	**Band**	**Launch**	**Operator**
Broadband internet	Oneweb	1,000 / 900	TBD	2020	
Broadband internet	Telesat	1,000/ 300	TBD	2020	
IoT/M2M	LAPAN's	1,200 / 9	TBD	TBD	LAPAN
M2M/Maritime surveillance	LAPAN-A4	550/1	VHF (uplink)	2020	LAPAN

The growth is expected to continue for remote sensing satellites, since LAPAN will continue to produce Earth observation satellites to replenish its fleet, and more Indonesian entities adopt remote sensing applications. The growth is also expected for telecommunication satellites since more LAPAN's satellite will carry telecommunication payload and new global constellation will be deployed. This growth will add more telecommunication infrastructures in Indonesia, especially for maritime surveillance and tracking services in remote areas.

6. Conclusions and Future Study Recommendation

The research shows that the operation of non-GSO satellites in Indonesia is currently increasing. The highest growth is in remote sensing satellites, whose primary users are government sectors. The growth is due to the increase in the new technology that brings new applications, and the production of Indonesian Earth observation satellites. This growth is expected to continue due to the increasing popularity of remote sensing applications. The growth in non-GSO satellite operation, however, does not significantly increase the use of frequencies and ground stations, since remote sensing satellite frequencies have been strictly defined.

GEO satellites and fiber optics will continue to become the primary backbone in Indonesian telecommunication services. The current non-GSO satellites, single and constellations, provide M2M application services, such as for maritime surveillance and asset tracking. The future of non-GSO telecommunication satellite is in constellations mode, driven by global players trying to provide internet services to rural areas, and national players trying to provide M2M communication services. The increase in the non-GSO telecommunication satellites will need additional vast frequency allocations and ground stations.

It is recommended that further study focuses on radio frequency regulation aspect to anticipating the growth of non-GSO satellite operation in Indonesia.

7. Acknowledgement

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