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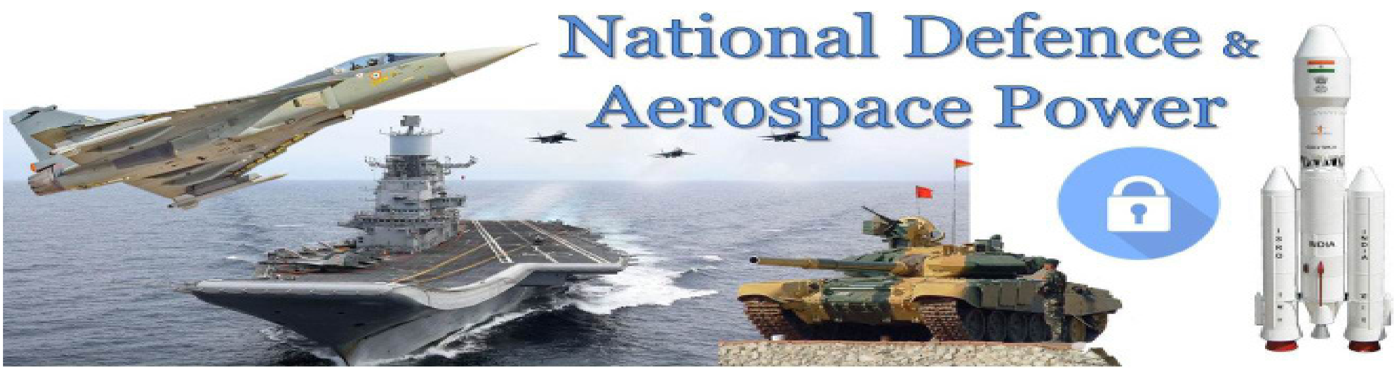

Centre for Air Power Studies ISSUE BRIEF

184/22 27 September 2022

INTERNET THROUGH SPACE: LEO VS GEO DILEMMA

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Spacecraft are designed to perform various roles while in orbital planes depending on the altitude they are assigned. The utilisation of satellites varies in Low Earth Orbit (LEO) in comparison with Geosynchronous Equatorial Orbit (GEO) in many ways, such as orbital velocity, type of application, and availability of real-time data. The availability of satellites during conflicts has created a new dimension during the recent Russo–Ukrainian war. Satellite data is being provided to Ukraine by both governmental and non-governmental agencies.[1]

A use case is the Internet of Things (IoT) services, wherein internet services in Ukraine are being provided by Starlink satellites operating in LEO, and hundreds of these satellites are being launched for the Ukrainian armed forces and for the general public to use the internet.[2]

It has been a dilemma for the government and non-governmental entities as to which of the satellites in LEO or GEO is more efficiently and effectively utilised for providing communications.

Geosynchronous Equatorial Orbit (GEO)

GEO satellites operate at about 36,000 kilometres (22,000 miles) above the surface of the Earth and are also known as 'geostationary satellites'. They orbit along a path parallel to the Earth's rotation, providing coverage to a specific area that takes an average of approximately 24 hours, making it easier for the antenna to track. These are called geostationary because they move at the same angular velocity as the Earth and appear to be fixed at one location. As the satellite appears to be in one position, the antenna is not required to be moved for tracking across space. GEO satellites provide coverage for a limited area of the earth's surface, covering 70 degrees of latitude above or below the earth's equator. These satellites were first used in the year 1964 for NASA's Syncom III launches, providing worldwide television coverage of the Tokyo summer Olympics.[3]

The curvature of the Earth hinders the coverage, and the stationary satellite is unable to reach areas in the extreme north or south, in particular the polar regions of the Earth. However, due to the size of a GEO satellite, each covering a larger surface, it requires only three satellites to give complete communication coverage with an active life cycle of about 15 years.

LEO satellites provide coverage to areas that are extreme north or south of the equator. LEO satellites are positioned in constellations to ensure almost complete coverage of the earth, allowing access to areas such as the pacific or polar regions that aren't accessible to GEO satellites.

Low Earth Orbit (LEO)

LEO satellites operate between 160 – 2000 km above the surface, which is around 22 times closer than GEO. The altitude of the satellites enables them to operate at high speed in orbit with low latency in communications (30 to 50ms), achieving an average delay of just 0.05 seconds. This facilitates stable connectivity with minimal interference as radio waves travel a shorter distance, making them more suitable for IoT applications than GEO. LEO has an inherent reduction in the cost and time of launching the satellites compared to other orbits due to the shorter altitude and flight path. It is a direct outcome of the small size of the satellite, thereby making it at a low cost and fast pace.[4]

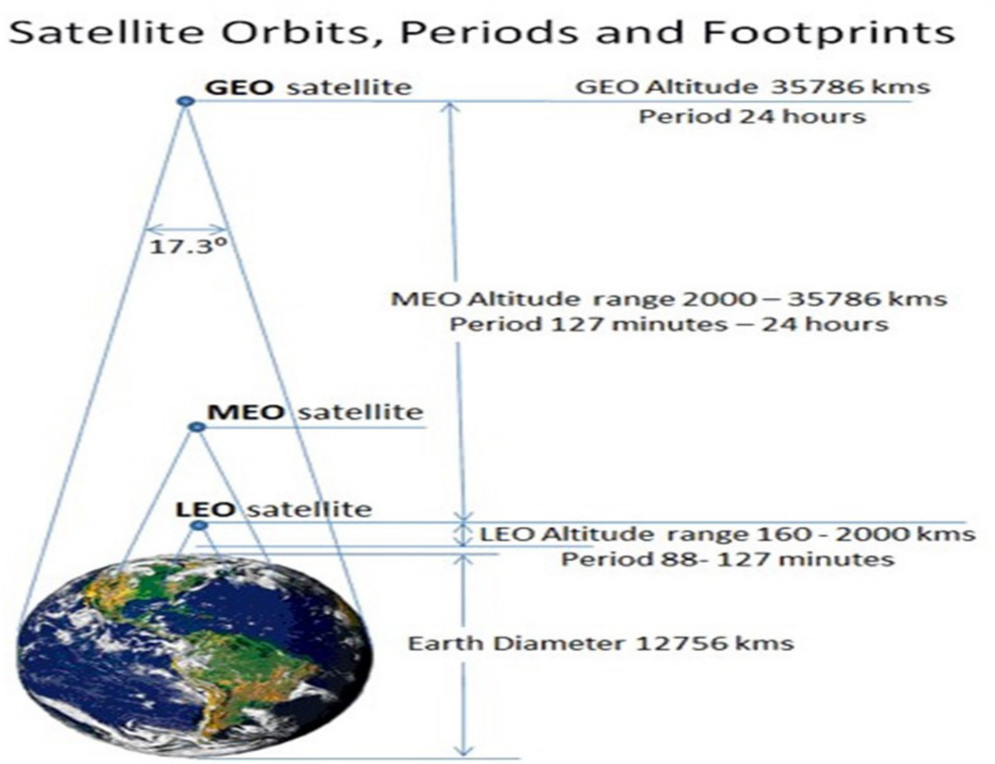
LEO satellites provide coverage to areas that are extreme north or south of the equator. As a result of the small size, LEO satellites are positioned in constellations to ensure almost complete coverage of the earth, allowing access to areas such as the pacific or polar regions that aren't accessible to GEO satellites. Apart from providing more coverage, LEO satellites orbit the earth much faster, performing a full revolution in approximately 93 minutes. This ensures that they are viewed for a short time, and therefore the data exchange amongst each satellite must be rapid to ensure an unhindered link to service providers on earth. Figure 1 provides a pictorial description for better insight.

As stated above, GEO and LEO satellites both have their own advantages and disadvantages. It's important to understand the factors for determining how a LEO or GEO satellite will perform for various communication applications. Some of the factors given below are indicative of LEO and GEO satellite performance:[5]

Latency

LEO inherently has lower latency for time-sensitive applications than GEO due to its proximity to earth. Latency is most important when looking at real-time and interactive applications, such as military applications and certain non-military applications. The impact of the GEO satellite's latency is more pronounced on military applications rather than on other user experiences.[6]

Figure 1: Altitude Classifications for Satellite Orbits



Source: "Satellite Technologies", Electropaedia, https://www.mpoweruk.com/satellites.htm. Accessed on September 02, 2022.

Coverage

LEO satellites provide sufficient coverage only when they are operated in a cluster. However, GEO satellites can provide significant coverage even with one satellite. It is a question of choosing between more satellites in the LEO orbit with less power, less coverage and smaller size or using fewer, larger and more powerful GEO satellites.[7]

Efficiency

LEO satellites are closer to the Earth, hence rapidly moving relative to the Earth. This automatically leads to spending a lot of time over oceans and other unpopulated areas. However, this remains the best option for scanning a larger geographical area as opposed to GEO satellites. GEO satellites appear to be in one spot relative to the earth, which makes GEO more suitable for smaller, more focused regions.

Cost

LEO satellites are comparatively less expensive to assemble and launch, although a cluster is required for efficient and stable communication operations. In contrast, GEO satellites are larger in size with more capability but are able to effectively operate in small numbers. Due to emerging technologies, it is expected that new innovations in this domain will help to significantly reduce their operating costs in all applications. Innovation and modernisation

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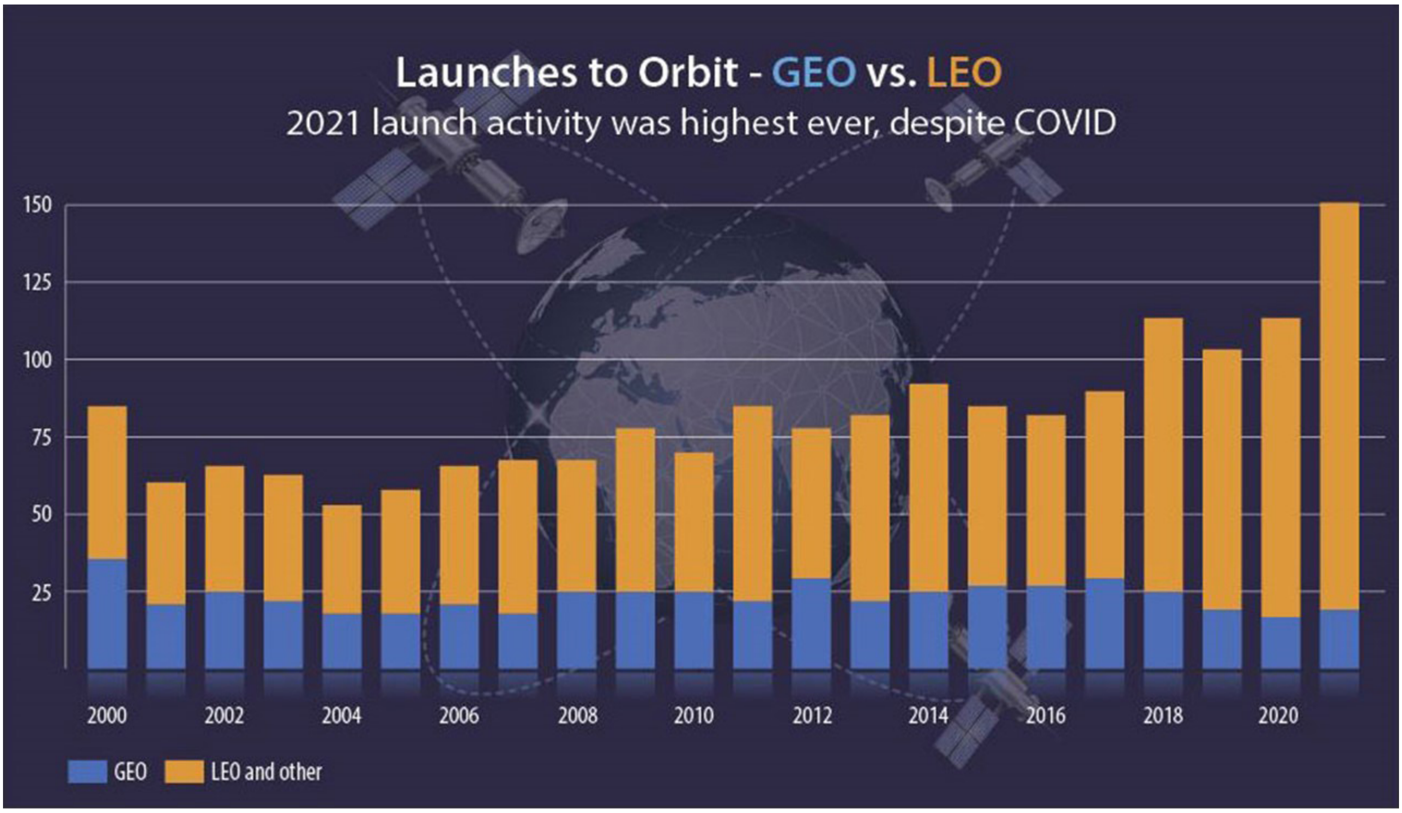
apply not only to GEO satellites but the entire satellite industry.

A study by space insurance agency AXA XL (Figure 2) indicates that most satellites continue to operate in LEO and that satellite launches, especially in LEO, continue to increase.[8]

Figure 2: Satellite Launches Continue to Increase, Especially in LEO



Source: "The Changing Risk Landscape in LEO vs. GEO ", *Kratos*, https://www.kratosdefense.com/constellations-podcast/articles/the-changing-risk-landscape-in-leo-vs-geo. Accessed on August 25, 2022.

One critical point emerges as to how LEO-congested space is providing the most to the user community, along with the inherent risk of space debris and spacecraft collisions. There is a need to understand the risks and dangers involved in these operations so that the global community can work toward space safety and sustainability.[9]

Problem of Space Debris

The U.S. Space Surveillance Network tracks around 25,000 objects circling the earth. As per the data available in 2019, a total of approximately 20,000 objects were tracked. To ensure that there is no contact with space debris, the International Space Station (ISS) regularly conducts debris-avoiding manoeuvres and in the year 2020, three such activities were noticed.[10] NASA and European Space Agency (ESA) have consistently identified space debris as the primary threat to space

LEO has the advantages of quick deployment, greater coverage, low cost, and high latency with a very great risk of space debris and traffic management compared to GEO, which has a high cost, restricted coverage, greater life cycle, and established communication infrastructure.

vehicles and astronauts.

In November 2021, Russia's anti-satellite missile test (ASAT) hurled approx. 1,700 pieces of known and trackable orbital debris and thousands of untrackable fragments into LEO, thereby greatly enhancing collision hazards to spacecraft and astronauts, resulting in an increase of space debris to an alarming level[11].

As per the present traffic enhancement, with the increase in congestion of LEO, the prediction probability decreases for potential collisions. In May 2022, a study by the Boston Consulting Group assessed that the probability of a collision in LEO will increase many times by 2030.[12]

Space Traffic Management

There is a need to utilise autonomous systems that can help avoid these costly collisions. It is understood that *Kayhan Space*, a space collision avoidance and space traffic management company, is developing a new autonomous satellite collision avoidance system that eliminates human intervention from the critical path, thereby increasing response time by 90 per cent compared to manual human efforts today.[13]

Apart from anti-collision systems, the latest technology for on-orbit servicing, the concept of repairing satellites rather than launching a replacement, including manoeuvring defunct satellites out of busy orbits, should be able to provide safer LEO operations. Anticipating this trend, Astroscale, an orbital debris removal company, has developed a docking plate that can be mounted on the outside of satellites to facilitate their removal when they reach the end of life.[14]

There is a need to formulate guidelines and a framework for ensuring a sustainable space environment. The space sustainability rating, as spearheaded by the World Economic Forum and the ESA, is the right step in this direction.[15]

As brought out with respect to IoT services, LEO has the advantages of quick deployment, greater coverage, low cost, and high latency with a very great risk of space debris and traffic management compared to GEO, which has a high cost, restricted coverage, greater life cycle, and established communication infrastructure. New technology with multi-orbit operations and on-orbit servicing is making GEO more sustainable as compared to LEO.[16]

Implications for India

In the Indian context, space operations and applications in the past have been predominantly under government control. However, with the formulation of the latest policy decisions in space, remote sensing, and earth observation, non-governmental agencies are coming into the foray of providing IoT services. Recently, OneWeb, a British company in collaboration with an Indian company, Bharti Enterprises, announced the launch of LEO satellites from India.[17] The establishment of the Indian National Space Promotion and Authorization Centre (IN-SPACe) under the Indian Space Research

Organization (ISRO) is a welcome step. This area of disruptive technology must be fully utilised by Indian agencies and especially start-ups for optimum results in military and non-military fields.

LEO, in the recent past, has increasingly come to the forefront of providing internet due to the Russia-Ukraine war, but GEO has been the backbone of communication for a long time and has proved itself. Due to the increasingly disruptive and emerging technologies resulting in ease of operations and issues involved in space sustainability for LEO, the actual efficacy of utilising LEO or GEO has to be seen in the future.

Notes:

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3 “GEO/MEO/LEO satellites: Why GEO is winning”, Satellite Evolution Group, June 08, 2020. https://www.satelliteevolution.com/post/2020/06/08/geomeoleo-satellites-why-geo-is-winning. Accessed on August 25,2022.

4 Anne Wainscott-Sargent, “The Changing Risk Landscape in LEO vs. GEO: Differences Impact Service, Response, Mitigation and Sustainability”, *Kratos*, https://www.kratosdefense.com/constellations-podcast/articles/the-changing-risk-landscape-in-leo-vs-geo; “Low-Earth Orbit (LEO) Vs Geostationary Earth Orbit (GEO)”, *Clarus Networks,* October 28, 2022, https://www.clarusleo.com/2021/10/28/low-earth-orbit-leo-v-geostationary-earth-orbit-geo/; Tommy Reed, “7 Key Elements of LEO and GEO Space Satellites”, *Microwaves&RF*, February 28, 2017, https://www.mwrf.com/markets/commercial/article/. Accessed on August 27, 2022.

5 Reed, n. 4.

6 Ibid.

7 Ibid.

8 Wainscott-Sargent, n. 4.

9 “GEO/MEO/LEO satellites: Why GEO is winning”, Satellite Evolution Group, June 08, 2020, https://www.satelliteevolution.com/post/2020/06/08/geomeoleo-satellites-why-geo-is-winning; Jeff Foust, “GEO operators say they can compete against LEO systems on cost”, *Space News*, March 22, 2022, https://spacenews.com/geo-operators-say-they-can-compete-against-leo-systems-on-cost. Accessed on August 28, 2022.

10 Wainscott-Sargent, n. 4.

11 Ibid.

12 Jeff Foust, “GEO satellite operators seek multi-orbit strategies”, *Space News,* January 26, 2022, https://spacenews.com/geo-satellite-operators-seek-multi-orbit-strategies/. Accessed on August 28, 2022.

13 Wainscott-Sargent, n. 4.

14 Ibid.

[15] "How do Geocentric types of satellites (LEO, MEO) differ from Geostationary satellites (GEOs)?", *PXCom*, May 02, 2022, https://pxcom.aero/geostationary-satellite/. Accessed on August 28, 2022.

[16] Ibid; "Space Sustainability Rating", World Economic Forum, https://www.weforum.org/projects/space-sustainability-rating. Accessed on August 28, 2022.

[17] "OneWeb and NSIL / ISRO announce satellite arrival ahead of historic launch in India", OneWeb, September 20, 2022. https://oneweb.net/resources/oneweb-and-nsil-isro-announce-satellite-arrival-ahead-historic-launch-india. Accessed on September 20, 2022.

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