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Understanding Low Earth Orbit (LEO) Satellites and Policy Issues

Dan York[1]

Internet access from systems such as Starlink and OneWeb in low Earth orbit (LEO) is changing people's lives and enabling many more people to join the online world. How do LEO systems work and what are the intersections with policy work?

The Basics of Satellite Internet Access

We have been using satellites for communications since the 1960s. Until recent years, almost all of those satellites were in a "geostationary" (GEO) orbit[2] at around 36,000 km from the surface of the Earth. A special aspect of this orbit is that a satellite orbits the Earth at the same rate as the Earth rotates, and so the satellite appears to be "parked" over a specific spot on the Earth's surface. This makes it easy for interacting with the GEO satellite. You can simply point a satellite dish on the ground at the satellite's position and communication can begin.

A GEO satellite communication system used for Internet access involves three components:

- **Satellite —** The satellite located at a specific location in geosynchronous orbit.
- **Satellite dish —**Typically referred to as a "user terminal", this is the device on the ground that enables users to connect to the satellite. For a consumer, it might be connected to a WiFi access point or other similar system. For a larger company, it might be connected to that company's network.
- **Ground station —** A location on the ground typically with large dishes/antennas that connects out to the Internet.

1 Internet Society, United States.

2 Note that in UN and International Telecommunications Union (ITU) policy terminology, satellites in geosynchronous orbit are referenced as "GSO" satellites versus "GEO" satellites.

A user in a home connected to a GEO satellite would connect to their local WiFi network. Their Internet requests go from their local satellite dish up to the GEO satellite and back down to a ground station, where they then go out across the Internet. Responses follow the same path, coming back to the ground station, up to the satellite, and down to the user's local satellite dish. This is often called a "bent pipe" connection.

From a policy point of view, for a GEO satellite to provide Internet access in a country, the local regulators will need to approve:

- **Spectrum allocation**—the usage of appropriate frequencies for both the "uplink" from the user's equipment and the "downlink" from the satellite to the ground station.
- **Consumer equipment**—the "user terminal" (aka "satellite dish") must receive the appropriate consumer electronics permissions to be used in the country or region.
- **Ground station(s)**—the satellite operator must obtain "landing rights" to operate a ground station within a country.

Based on treaties and conventions within the International Telecommunications Union (ITU), this set of approvals must be done within each country in order for a GEO satellite provider to operate.

Additionally, because there are only so many locations ("slots") possible within the geosynchronous orbit of the earth, the ITU is responsible for regulating those locations. A satellite operator must get permission from the ITU before it can launch a satellite into a specific GEO location.

An advantage of GEO satellites is that because they are "parked" over a specific location on the Earth, many governments have invested in launching satellites that are located over their country and provide communication and Internet services to their country. Additionally, because they are so far from Earth and have such a large field of view of the planet, a company looking to provide global service can use as few as three GEO satellites to cover most of the world. GEO satellites also typically have a life expectancy of 15–20 years before they need replacement.

The Rise of LEOs

The fundamental challenge with using GEO satellites for Internet access is the enormous distance from the surface of the Earth. It can take a packet at least 600 milliseconds (ms) to travel from the Earth to a satellite and back—in some cases it can be even longer.

In a world in which we have become accustomed to online video calls and so many other forms of real-time communication, this amount of "latency" (sometimes called "lag") simply will not support the kind of communication we use every day. Most voice or video calls need less than 150 ms of latency to work. Similarly, modern use of online gaming, e-sports, virtual worlds/metaverse, high-speed trading, and just regular messaging need to have significantly lower amounts of latency. A typical fiber or cable broadband connection can be more in the range of 10–50 ms of latency, and many Internet service providers (ISPs) are continually working to create even faster connections with lower latency.

The solution for faster, lower-latency satellite-based Internet is to move the satellites closer to Earth. Starting in the 1990s, multiple government and commercial organizations started looking at using satellites in Low Earth Orbit (LEO) below 2000 km from the Earth's surface and also Medium Earth Orbit (MEO) from 2,000–36,000 km (everything between LEO and GEO).[3]

A challenge with LEO satellites is that they orbit faster than the Earth's rotation, and so instead of just having one satellite "parked" above a location, you need to have 100's or 1,000's in order for a satellite dish to always have access.

The LEO systems in the 1990s from companies such as Teledesic, Iridium, and Globalstar were not commercially successful at that time but research continued. In the 2000s and 2010s new companies emerged including O3B, OneWeb, SpaceX. Ultimately it was the launch of SpaceX's Starlink in 2020 and 2021 that made people everywhere see the potential in high-speed, low-latency connectivity from LEO orbits.

The Difference with LEOs

As noted above, the major difference with LEO-based systems is that instead of a single GEO satellite or a small number of GEO satellites, a company operating a LEO system must launch a "constellation" of hundreds or thousands of satellites. Additionally, because the satellites are closer to the Earth, they are subject to more gravitational pull and atmospheric drag and therefore only have about a five-year lifespan. The operator of a LEO system must be prepared to be constantly launching new satellites to replace older ones.

As of August 2025, SpaceX has over 8,100 Starlink satellites in orbits ranging from around 450–550 km from Earth. Eutelsat has around 650 OneWeb satellites in orbits around 1,200 km. Multiple other LEO constellation operators are beginning to launch their satellites.

The satellite dishes for both the user and the ground station must also change. Unlike a GEO satellite where a dish can just be pointed at the location of a satellite and left alone, with a LEO constellation the dish must be constantly tracking multiple different satellites. Rather than physically moving a dish, systems such as Starlink or OneWeb use "electronically steerable"/"phased array" antennas where all the tracking of satellites is done electronically inside of the "dish".

3 In UN and ITU policy terminology, satellites in both LEO and MEO are referred to as "Non-geostationary" or "NGSO" satellites.

Similar to GEO systems, a LEO operator must engage with the regulators in *each* country to obtain spectrum allocations, consumer equipment approvals, and ground station landing rights.

Space Lasers

One challenge for LEO-based systems is the need to be in range of a ground station to connect down to the rest of the Internet. In the initial LEO deployments, this often meant having ground station located every 900 km or so, requiring a rather massive investment in setting up ground stations, with all the necessary government approvals.

A significant innovation with LEO-based systems has been the emergence of inter-satellite lasers (ISLs) connecting between satellites in a constellation. This allows the user to connect to a satellite and then have their traffic go across the "mesh" of the constellation until it gets to a satellite within range of a ground station.

This has enabled connectivity from remote locations such as Antarctica, and also from locations where for various economic or regulatory reasons it is challenging to locate a ground station.

SpaceX's Starlink constellation uses ISLs, and Amazon's Project Kuiper has indicated that they will use ISLs as well. Unfortunately due to the proprietary nature of these systems, not much is known about the capacity and other capabilities of these ISLs.

From a policy point-of-view, the potential use of ISLs has a couple of interesting aspects. On the positive side, ISLs potentially allow a country to quickly get started with Starlink without the investment in one or more ground stations. However, this can be a negative as some countries may use a ground station as a point for enforcement of national security or monitoring.

Deployment Challenge—Launching Rockets

As this article is being written in early 2025, the single largest barrier to deployment of satellites into LEO is not as much a regulatory issue as it a practical matter—there is only one company globally, SpaceX, that is consistently and reliably launching rockets at a pace necessary to operate a LEO constellation.

Given that LEO constellations need to have hundreds, if not thousands or even 10s of thousands, of satellites—and also that LEO satellites only have a lifespan of 5 years before they need to be replaced—LEO constellation operators need to be almost constantly launching new satellites.

Right now SpaceX is the only company continually launching rockets. In 2024 their Falcon 9 rocket was launched over 120 times, frequently carrying around 20 Starlink satellites, but also carrying satellites for other providers. SpaceX has also been launching test flights of its massive Starship rocket which, when in production, is expected to carry possibly hundreds of satellites into LEO.

All of the other traditional launch providers are in a transition between their rockets and had very few launches. United Launch Alliance (ULA), a company formed by Boeing and Lockheed and historically the primary launch partner for NASA, is in the process of transitioning to their Vulcan Centaur rocket—and only had one launch in all of 2024. Similarly, Arianespace, the traditional launch partner for European companies and governments, is transitioning to the Ariane 6 rocket and only had one launch in 2024. Both companies are hoping for more in 2025, but they have a long way to go to catch up to the cadence of SpaceX.

The intense demand for launch services has created an entire ecosystem of new companies seeking to provide launch capacity. Blue Origin, a company from Amazon founder Jeff Bezos, has been seeking to launch its "New Glenn" rocket for several years now. Blue Origin finally succeeded in launching New Glenn in January 2025, but it's not clear how many launches will be possible in 2025. Many other startups have emerged seeking to provide launch services.

However, at this moment in time it is only SpaceX that is capable of consistently providing launch services, and as a result, deployment for other constellations beyond Starlink is waiting on availability from SpaceX for launching.

Policy Issues

Beyond the regulation aspects mentioned earlier, there are a wide range of policy issues around LEO-based systems, many of which will be addressed in other sections of this book. A quick summary includes:

- **Affordability**—Most LEO systems involve a significant up-front cost for the user terminal ("dish") and then a monthly subscription fee. For many parts of the world that need the connectivity the most, these systems are not affordable. In some areas new business models are emerging such as renting out Starlink equipment for a monthly fee. We are also seeing governments or businesses subsidizing the cost of the initial equipment.
- **Competition with terrestrial network operators**—One of the barriers for LEO operators obtaining regulatory approval to operate in a country or region is often the resistance by the existing ground-based network operators. Both mobile/wireless network providers and fixed broadband providers view LEO operators as a competitive threat and will push back using regulatory appeals, lobbying for legislation, or legal maneuvers to block the approvals. Often government officials will agree with the network operators and will seek some way to compensate local network operators.
- **Requirements around local economic participation**—Some regions also have requirements that Internet or telecom operators in a country must have some local economic participation. It could be the requirement to have an

office in the country. It could be that a certain percentage of economic activity must involve local companies. However, the LEO operators are by nature more of global ISPs, and particularly for the companies such as SpaceX that have a direct-to-consumer business model, there is very little need for engaging in the local economy.

- **Economic flow to global corporations—**Which points to the larger challenge that allowing LEO operators into a country means that the equipment and subscription fees will flow not to local companies but instead to global companies such as SpaceX, Eutelsat or Amazon. Most of these companies are based in the US or Europe which often adds another dimension to policy discussions.
- **Lack of competition—**As of early 2025, only SpaceX is operating a LEO constellation that is globally providing service. OneWeb has launched sufficient satellites and has begun offering Internet connectivity in some regions of the world, but is reportedly still struggling to line up all their required ground stations to achieve global connectivity. At this time there is very little competition for LEO-based connectivity. This may change over the years ahead, but we will see.
- **Security/monitoring—**For some countries it is important that there be some capacity for monitoring Internet traffic, potentially for blocking certain sites. This can be a challenge for LEO-based systems given that they are global ISPs, or it can at least introduce delays in regulatory approvals.
- **Spectrum wars—**There are only so many radio frequencies available for transmitting and receiving information. And "sharing" of a frequency is not always possible due to interference between systems. For this reason, radio frequency usage is standardized and regulated through the ITU's Radiocommunications Sector (ITU-R) and through national regulators. At this time there are many competing interests. For instance, some mobile network operators are seeking more frequency ranges for use for 5G or now 6G services. At the same time, LEO satellite operators are seeking more frequency ranges for various services. And the GEO operators are also seeking to ensure their systems are not subject to interference.
- **Technical issues around spectrum—**Some nations have discovered that they have interference issues that must be addressed before LEO systems can operate in their country. In some cases, the frequencies needed by SpaceX are already in use for government or military communication. As sharing can be challenging, and as the LEO satellites use common frequencies globally, the government must consider how it can move local communication to other frequencies so that the satellites can work.
- **Astronomy interference—**Another type of interference of great concern to the scientific community is the interference from the thousands of LEO satellites for both visual and radio measurements for astronomy and other related

research. It is not only the quantity of satellites, but also the size. For instance, the newest satellites from AST Space Mobile are expected to be 223 square meters with their antennas fully extended, which is about the size of half of a basketball court.

- **Space debris—**With LEO satellites only having about a 5-year lifespan, there is great concern about what happens when satellites reach their end-of-life. Will the satellites "de-orbit" correctly and burn up in the upper atmosphere? Separately, what happens if satellites collide or explode and create debris fields? There are efforts underway such as the Zero Debris Charter, but this remains an area of serious concern.[4]
- **Environmental and climate concerns—**Also of concern is what happens to the Earth's atmosphere as all of those satellites reach their end-of-life and burn up in the upper atmosphere. Will that be okay? Or will there be impacts to the upper atmosphere that will cause greater climate effects later on? There are many unknowns here as we collectively enter into this grand experiment of launching 10s of thousands of satellites into LEO.
- **Unproven long-term business model—**This 5-year lifespan also raises the question of how many of these LEO system providers will have a sustainable business model. A LEO operator must pretty much be continually launching new satellites to replace the ones that will be aging out. Hundreds or thousands of satellites will need to be manufactured—and then launched—each year. Will this business model work and be sustainable? We don't know.
- **Fragmentation—**Will all of these systems support the global public Internet? Or will some offer a different experience? Particularly as China launches LEO constellations, will this result in an extension of their restricted network?

All of these and many other policy issues are part of the discussions around this new form of space-based Internet access.[5]

Direct-to-Cell (DTC)/Direct to Device (DTD)

One specific new area for policy discussions is around direct communication between smartphones and satellites based in LEO. Until now, customers have needed to purchase a user terminal ("dish") that they used to connect to the LEO satellites for Internet access.

However, technology has advanced to where a regular smartphone can be used in what is being called "direct-to-cell (DTC)" or "direct-to-device (DTD)" connectivity. No need for dishes—you simply use your mobile phone.

4 European Space Agency, *The Zero Debris Charter*, Brussels 2025. Available at: https://www.esa.int/Space_Safety/Clean_Space/The_Zero_Debris_Charter (accessed: 25/02/2025).

5 For a longer discussion, see: Internet Society, *Perspectives on LEO Satellites. Using Low Earth Orbit Satellites for Internet Access*, Reston, Virginia, 2022. Available at: https://www.internetsociety.org/leos/ (accessed: 23/02/2025).

This capability is being heavily promoted by SpaceX and T-Mobile in the US as a result of a partnership agreement. In response, other US mobile companies such as AT&T and Verizon are looking to partner with another company named AST Space Mobile. In other parts of the world, local mobile companies are signing up to partner with SpaceX and other companies. Apple also has a long-standing relationship with Globalstar, one of the older LEO companies, for some forms of messaging connectivity.

Beyond the prolific marketing, the reality is that the DTC capabilities are still very limited right now. The systems work by having the LEO satellites equipped to transmit on frequencies used by mobile providers in addition to their regular satellite frequencies. By partnering with a local mobile provider, the LEO operator then gains permission to use those frequencies and can transmit and receive directly to and from smartphones. SpaceX has already sent over 400 satellites (of their 8,000+ satellites) into LEO with this capability. Other LEO operators such as AST Space Mobile are seeing this as their primary usage and are marketing themselves as essentially a “cell tower in space”.

There are, however, serious technical challenges. All of us have been on a mobile phone when we’ve gone too far away from a cell tower and had the phone call fall apart and eventually drop. To communicate from space, satellites need larger antennas and different power levels. The substantial distance imposes very real challenges.

Today the systems are mostly limited to sending text messages, and usually only in a situation where no other connectivity is available. However, this offers tremendous capabilities for people to be able to reach someone wherever they may be.

The race is on now for LEO operators to be able to offer text messaging to smartphones, and then to go beyond that into voice calls and eventually Internet access. Some operators are exploring launching satellites into Very Low Earth Orbit (VLEO) below 400 km, which gets them closer to the ground and to users, but also requires more satellites and may impact the lifespan of the satellites. Other operators are looking at how to make satellites with larger antenna areas, which then introduce visibility and interference issues.

There are significant technical challenges, and the business models are not entirely clear, but there is great interest from both mobile operators and LEO operators in making this happen.

From a policy perspective, DTC opens *many* new issues. You now have transmissions to and from satellites on many different frequencies. You have the potential for global telecommunications companies, and you have competition issues with often only one mobile provider being able to partner with a LEO operator. There will be roaming, affordability, and economic issues – and so much more.

Regardless, this capability is well on its way and we are moving closer to a day when we all can potentially just use our smartphone from wherever we are on the planet.

Looking Ahead

The next few years are looking to be extremely busy for LEO. SpaceX is seeking to launch its full "Gen 2" constellation with potentially over 42,000 satellites. Eutelsat's OneWeb should begin global connectivity at some point soon. Amazon has begun launching their 3,000+ satellite Project Kuiper constellation in 2025. The European Union is looking to launch their IRIS2 constellation. The Canadian company Telesat has plans for a 1,500+ satellite Lightspeed constellation. AST Space Mobile is planning to launch 90+ of their massive satellites for smartphone connectivity.

Meanwhile, over in China, at least three different large LEO constellations are in the works. The Qianfan (Thousand Sails) constellation has launched over 70 satellites on their path to 14,000. The GuoWang constellation is being planned for 13,000 satellites, and another Honghu constellation is talking about 10,000 satellites.

Around the world, each week brings word of new startups that are planning to launch even more satellites into LEO. It's not clear how many of these constellations will actually successfully launch into space. Nor is it clear how many will be financially sustainable.

What is clear is that the next few years will be extremely busy for both technology and policy issues related to using Low Earth Orbit for Internet access. There is great potential for bringing truly life-changing connectivity to every location on the planet—IF we can accept the many challenges and tradeoffs.

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