Perspectives on LEO Satellites

Using Low Earth Orbit Satellites for Internet Access

June 2022

NOTE: This is a draft document for review by the Internet Society community. This is not a final statement or position. We welcome constructive feedback. Please send any comments no later than 4 July 2022 to leo-comments@isoc.org

For nearly one third of the world, on every continent, in rural, remote, and even urban communities, each day without Internet access is a day of lost opportunity. Through our global community, the Internet Society empowers and supports people to bring the Internet to everyone. We work to reduce barriers to access, and to make it reliable, faster and cheaper. Together, we don't just build and maintain connections—we advocate for the right policies so that the Internet can grow.

We see considerable potential in the use of low earth orbit (LEO) satellites for Internet access for unserved or under-served communities, especially where other ways of delivering Internet access are not viable. We also see potential for LEO-based systems to provide another way to deliver Internet access to communities affected by natural or human disaster and to increase the overall resilience of Internet connectivity. But, we also see serious concerns and, as of mid-2022, there are still many unknowns.

As the LEO-based industry matures over the next few years, there is an opportunity to guide the discussion and shape the future of this new form of Internet access. This document outlines opportunities, concerns, and questions for LEO providers, other Internet access providers, policymakers, researchers, journalists, civil society, consumers, and our Internet Society community.

Low Earth Orbit (LEO) Satellites and Internet Access

For many years, Internet access has been available from "geostationary"[1] (GEO or GSO) satellites operated by companies such as Eutelsat, Hughes, Inmarsat, Viasat and many others. These systems are an option for Internet access to regions that lack other connectivity. GEO satellites are typically the size

[1] For information regarding GEOs, see https://www.esa.int/Education/3._The_geostationary_orbit and https://www.sciencedirect.com/topics/earth-and-planetary-sciences/geostationary-satellite. For the difference between a geostationary and a geosynchronous orbit, see https://www.scienceabc.com/nature/universe/what-is-a-geosynchronous-satellite-and-how-is-it-different-from-a-geostationary-satellite.html

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of a bus and are expensive to build and launch, but have the advantage that global coverage can be provided with as few as three satellites. Configuring ground antennas is also very simple because GEO satellites rotate with the Earth and always appear in the same location in the sky.

GEO satellite Internet systems often provide speeds as high as 100Mbps and can provide access for many types of Internet content, including websites, downloadable movies, and other forms of broadcast media.

However, GEO systems have a significant challenge. It takes a long time for signals to travel 36,000 km from Earth to a geosynchronous orbit—and then 36,000 km back. In networking terminology, these connections have a high amount of "latency." This delay does not work well for many modern services, including real-time and video communications, gaming, e-sports, live streaming, financial trading, and emerging virtual and augmented reality ("metaverse") communication systems. It is difficult, if not impossible, to make a Zoom call or be active in a virtual world with the latency present in GEO systems.

In contrast, LEO systems can provide low-latency, high-speed Internet connections[2] because the satellites orbit the Earth at a much closer distance, between 160 and 2000 km. However, with such close orbits LEO satellites move too fast to stay above a single location and are only visible from the ground for a short time during each orbit (typically less than 2 hours[3]). Because of this, a "constellation" of hundreds or thousands of LEO satellites is needed, as well as ground antennas that can track satellites as they pass overhead.

Another challenge is that the LEO region of space is already crowded. The International Space Station (ISS), China's space station, and the Hubble Space Telescope are in the LEO region as are many LEO satellites that are used for imaging, remote sensing, and other observations, or communications (including Internet access). Also, several companies that are promoting human spaceflight regularly launch rockets into low Earth orbit which adds to the intensity of activity in the LEO region.

Earlier attempts to establish a LEO satellite Internet access industry (by companies such as Teledesic) largely failed, but since then, the development of commercial launch systems and other advances in satellite technology have substantially reduced the cost to launch LEO satellite constellations[4]. Many well-resourced companies, as well as several governments, are now seeking to provide Internet access via LEO satellite constellations.

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[2] Ookla analyzed the performance of Starlink connections in Q4 2021 across 15 countries and compared the performance to fixed broadband and geostationary satellites: https://www.ookla.com/articles/starlink-hughesnet-viasat-performance-q4-2021

[3] See https://en.wikipedia.org/wiki/Low_Earth_orbit

[4] See, for example, Figure 1 in *The Recent Large Reduction in Space Launch Cost*, Harry W. Jones, NASA Ames Research Center, Moffett Field, CA, 94035-0001 for the 48th International Conference on Environmental Systems, available at https://ttu-ir.tdl.org/bitstream/handle/2346/74082/ICES_2018_81.pdf

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Nonetheless, the LEO satellite Internet access industry is still very much in its infancy. At this time, there is only one LEO provider supplying Internet access at a relatively large scale (SpaceX's Starlink), but direct competitors are on the horizon. Other providers such as OneWeb, Telesat, and Amazon's Project Kuiper have tests underway or will be launching their satellite constellations over the next two years. Available information[5] indicates that, by 2024, there should be several providers, with some offering services within the same countries or geographical regions.

Sidebar: New technologies are emerging that involve the use of laser beams to exchange data between satellites in orbit. Often called inter-satellite laser links (ISLLs) or optical inter-satellite links, these could potentially offer the ability to provide services within the satellite constellation such as caching, content distribution networks (CDNs), or edge computing, potentially speeding up access to information for users and increasing communication efficiency. However, at this time, these capabilities are still in development or testing and not yet actively used in LEO constellations.

The Opportunities

LEO Internet access systems offer potential benefits to connect the unconnected, provide competitive options for connectivity in underserved communities, or add resilience to existing access. Internet access from LEO systems can have a dramatic improvement or, in some cases, even a life-changing effect on the following users and situations, as illustrated by these examples:

- **Individual consumers:** Individual LEO systems customers in rural or remote locations have reported that they finally have reliable and fast Internet connectivity.
- **Community centers:** Libraries in Indigenous or rural regions of the United States have relayed how LEO Internet access has improved their communities, helped students, and made their lives better. Pilot programs with schools have also highlighted how the improved Internet access greatly helps students.
- **Community networks:** Pilot programs with community networks found LEO systems to be useful for "backhaul" connections to the rest of the Internet.
- **High availability and network resilience:** Natural disasters such as the disconnection of the island nation of Tonga due to a subsea cable break or the destruction of Internet infrastructure in Ukraine, highlight the role that satellite communication can play in providing additional capacity and resilience if LEO systems can be quickly deployed in a new location. LEO systems can add additional or alternate capacity and the ability to provide even more resilience.

[5] See references on https://en.wikipedia.org/wiki/Satellite_internet_constellation

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Other potential use cases include Internet access for remote monitoring (sensors for earthquakes, bush fires and floods), IoT agricultural machinery, inflight WiFi in airplanes, medical centers in remote locations and ocean craft.

The potential is clear. But, for whom and at what cost?

Concerns

Despite the potential benefits, there are some aspects of the emerging LEO satellite Internet access industry which raise some concerns, or at least, require closer consideration.

Business Models and Operations

Affordability – The market remains too immature to understand how affordable, or not, these systems may be, especially for users in unserved or underserved communities. In the direct-to-consumer business model, providers would typically charge an initial fee for the equipment (a "ground terminal") required to connect to the LEO system, possibly an installation fee, and then a monthly fee for the Internet service. The only consumer-grade service currently in operation, Starlink, currently charges a one-time fee of 600 USD for the ground terminal and a monthly fee of 110 USD in most countries. Many individual users, especially those in countries where wages are lower, may not be able to afford this service if the price remains this high. However, it remains to be seen how pricing will be affected as competitors come online, or ground-based Internet services move to fill the gap. It is also not clear what demand and price points will be needed for LEO system operators to sustain viable business models, especially as such systems are often subsidized by government funding, military investment, or other subsidies that may not continue after the initial set-up phase of the LEO satellite Internet access industry.

- Recommendation: To be a useful solution to connect the unconnected, Internet access via LEO systems needs to be affordable for users that need it most.

Competition and Consolidation – The LEO-based Internet access industry is not immune to the concerns about market power and economic consolidation that are prevalent across all sectors of technology. As multiple LEO systems are deployed over the next few years, there is the potential that operators could be acquired by other operators. This consolidation could lead to only a very few companies having control and ownership of all LEO-based Internet access. This would then create potential “choke points” for both control and surveillance. Further, while the emergence of businesses that can integrate satellite production, launch, and operations into a single entity or group may help reduce the costs of deploying LEO systems, such integrated companies could raise competition

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concerns, especially if they gain substantial market power and then potentially use that power to reduce or eliminate competition.

- Recommendation: Policymakers should promote fair competition and enact policies that encourage innovation and allow new entrants. Policymakers should also ensure that there is adequate competition when considering mergers and acquisitions among LEO system operators and with other parts of the Internet access supply chain (e.g., content delivery networks (CDNs), ground-based Internet service providers, data centers).

Emergency deployment – Recent examples such as the disconnection of the island nation of Tonga from the undersea cables providing Internet access to the island illustrate the potential need for satellite access to provide resilient connectivity. As more LEO systems are deployed, governments and organizations may have more options for connectivity in the face of natural disasters.

- Recommendation: Policymakers should ensure the policies and logistics are in place to enable the quick deployment of LEO satellite Internet access if needed in areas of natural disaster. They should also consider setting aside funding for emergency deployment of LEO systems.

Policy

Geographic restrictions (geo-locking) – One of the potential future benefits of LEOs is mobility within a geographic region. This flexibility could be helpful for users who need access over large geographical areas (e.g., conservation parks, agricultural lands) or while in motion (rescue, disaster relief). Starlink initially restricted deployments to the registered user's physical address but in May 2022 added a "portability" option that allows usage anywhere Starlink provides service. Ideally competing future systems will also provide similar mobility.

- Recommendation: LEO system providers should allow movement by users within a defined local area/region.

Geopolitics of low earth orbit access – Governments and others have expressed concern that companies in one country, or a couple of countries, have grown to dominate the Internet industry globally. Further, there is not a level playing field across countries, with some countries' governments offering substantial financial incentives (e.g., the US, Canada, and the UK) and less onerous operating requirements (e.g., for space debris mitigation). In this setting, it is only a matter of time before access to low earth orbits becomes a diplomatic issue. Countries that do not have the interest or the means to use low earth orbits today may be worried that their options will be limited in the future and that *again* a small number of countries will dominate that space.

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- Recommendation: Existing and intending LEO system operators, governments, intergovernmental organizations, astronomers, environmental experts, researchers, civil society, user communities, stakeholders from the Internet community, and others should collaborate to find consensus for fair and equitable use of LEO orbits for LEO systems.

Regulation of orbits and spectrum – No international entity assigns or regulates orbits of LEO satellites and other non-geosynchronous orbit (NGSO) satellites. By contracts, the orbits of satellites in geosynchronous orbit (GSO) are regulated by the International Telecommunications Union (ITU)[6]. LEO system operators apply for spectrum allocations from the national regulator in the country or countries in which they wish to operate. Through that process they obtain an allocation of orbits.[7] As low earth orbits are essentially "first come, first-served," there is no fee for occupying an orbit, and optimal orbits are a finite resource, there is a very strong incentive for early entrants to quickly take over as many orbital slots as possible, leaving later entrants with less optimal choices, or none. Further, as low earth orbit become more crowded, newer entrants may also face stricter licensing or operating requirements (e.g., for space debris mitigation).

- Recommendation: National regulators responsible for the allocation of LEO satellite orbits should coordinate with each other, as well as with LEO providers, astronomers, and other stakeholders, when assigning orbits, to reduce the risk of potential collisions, interference, and other deployment situations that could degrade the Internet access provided by current and future LEO satellites.

Space debris – With multiple potential "shells" of thousands or even tens of thousands of satellites, there will be mechanical or technical failures. Additionally, many LEO satellites are only expected to be in operation for perhaps 5 years. There is a strong potential for a large amount of "debris," both planned and unplanned. This debris could physically damage other systems or cause interference or present a danger to other use of low earth orbit space.

- Recommendation: LEO system providers should take whatever steps are necessary to minimize the number, volume, and type of debris their systems create. We encourage LEO system providers to follow the guidance in the UN Committee on the Peaceful Uses of Outer Space (COPUOS) Space Debris Mitigation Guidelines[8], the International Inter-Agency

[6] Article 44, Constitution of the International Telecommunications Union (ITU). 0.3 Preamble, ITU Radio Regulations - "In using frequency bands for radio services, Members shall bear in mind that radio frequencies and any associated orbits, including the geostationary-satellite orbit are limited natural resources and that they must be used rationally, efficiently and economically, in conformity with the provisions of these Regulations, so that countries or groups of countries may have equitable access to those orbits and frequencies, taking into account the special needs of the developing countries and the geographical situation of particular countries (No. 196 of the Constitution)"

[7] See the sovereign right of each State to regulate its Telecommunication: Page 3, Guidance on the regulatory frameworkfor national spectrum management Report ITU-R SM.2093-4 (06/2021) (https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2093-4-2021-PDF-E.pdf), and the international recognition of these rights by recording the frequency assignments and (if applies) orbital positions used or intended to be used in the Master International Frequency Register.

[8] https://www.unoosa.org/documents/pdf/spacelaw/sd/COPUOS-GuidelinesE.pdf

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Space Debris Coordination Committee (IADC) Debris Mitigation Guidelines[9], and IADC Statement on Large Constellations of Satellites in Low Earth Orbit[10], as well as the ISO standard ISO-24114 Space systems – Space debris mitigation requirements[11]. Further, we encourage LEO system providers to develop enhanced industry best practices to minimize debris and find ways to reduce the impact of their services.

Spectrum allocation – The UN COPUOS non-binding Guidelines for the Long-term Sustainability of Space Activities[12] re-iterate the principles in Article 44 and 45 of the ITU Constitution[13] and emphasize the need to promote the long-term sustainability of outer space activities. Specifically, "so that countries or groups of countries may have equitable access to those orbits and frequencies, taking into account the special needs of developing countries and the geographical situation of particular countries". However, presently there does not yet appear to be well-established international coordination of spectrum allocation for LEO services. There is also tension between satellite and mobile operators in some countries with both competing for the same spectrum allocation. At the World Radio Congress 2019, the increase in LEO satellite projects led to Resolution 35 where ITU Members agreed to a requirement for LEO satellite constellations to have 10 percent of their constellation in orbit within the first two years after the start of deployment, 50 percent in five years and 100 percent in seven years.[14] This decision is intended to prevent unrealized or failed projects from occupying limited and valuable frequency spectrums for extended periods of time, having benefited from the "first-come - first-served" principle. New significant issues concerning spectrum allocation for LEO systems (such as those for inter-satellite links and mobile earth stations) will likely be brought to the World Radio Congress in 2023 (WRC-23).

- Recommendation: Spectrum should be allocated clearly and shared fairly. Government regulators and LEO system operators should collaborate and coordinate through appropriate organizations. Policymakers, civil society organizations, and members of the technical community should work together with national delegations to WRC-23 to ensure that perspectives of Internet network operators and Internet users are included.

[9] https://www.iadc-home.org/documents_public/view/id/172#u

[10] https://www.iadc-home.org/documents_public/view/id/174#u

[11] https://www.iso.org/standard/72383.html

[12] https://www.unoosa.org/res/oosadoc/data/documents/2018/aac_1052018crp/aac_1052018crp_20_0_html/AC105_2018_CRP20E.pdf

[13]]https://www.itu.int/council/pd/constitution.html

[14] ITU News, 'Managing radio frequency spectrum amid a new space race', 12 November 2021 at https://www.itu.int/hub/2021/11/managing-radio-frequency-spectrum-amid-a-new-space-race/

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Technology

Availability and interference – Users need to be able to rely on Internet access systems being available. While direct interference by one LEO provider to another is specifically prohibited by ITU regulations[15], many technical, environmental, and even accidental types of interference could happen. With limited deployment to date, there is insufficient information about what could interfere with systems to make them unavailable.

- Recommendation: LEO system operators, governments, and others should not intentionally engage in frequency jamming or otherwise interfere with LEO system operators' legitimate use of spectrum. Users, technologists, and policymakers should monitor evolving deployments to understand what potential forms of interference may occur. LEO systems operators, governments, and others should coordinate to understand and minimize sources of interference.

Capacity – With only a relatively small number of initial or pilot users in one system (Starlink), LEO systems capacity limits have not yet been put to the test. As deployment increases, it is important to have access to open data so that independent research organizations can measure the capacity of LEO systems in terms of number of users supported, latency, throughput, and reliability.

- Recommendation: LEO system operators should be realistic and transparent about the capacity of their services, as well as their latency and reliability. Policymakers should consider establishing measurable benchmarks for LEO system quality of service. This will facilitate comparison of different services and other forms of Internet access.

Interoperability – Related to open, interoperable standards, the industry appears to be in the process of creating multiple separate and mutually incompatible constellations of LEO satellites. Given the limited number of appropriate orbits and the high cost of operation, we believe LEO systems should be capable of working together in an interoperable way.

- Recommendation: Options for infrastructure sharing within the LEO industry should be explored. For transport and routing, LEO systems need to use the existing Internet core infrastructure to exchange traffic instead of creating a completely separate and potentially incompatible sets of protocols.

[15] ITU Article 45: All stations, whatever their purpose, must be established and operated in such a manner as not to cause harmful interference to the radio services or communications of other Member States or of recognized operating agencies, or of other duly authorized operating agencies which carry on a radio service, and which operate in accordance with the provisions of the Radio Regulations.

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Open Standards – Ideally, the Internet access you receive from a LEO system should provide the equivalent type of connection you would receive over a broadband or mobile connection. It should use the open standards published by the Internet Engineering Task Force (IETF) and other standardization bodies. Starlink, the first operational system, supports most current protocols, although users report inconsistent availability of IPv6[16]. Internet open standards ensure interoperability and provide a common user experience with the rest of the global Internet.

- Recommendation: LEO system operators must support the latest open Internet standards and common, interoperable protocols that enable the open Internet. They should implement industry best current practice for Internet security and resilience, such as those behind the Mutually Agreed Norms for Routing Security (MANRS). Policymakers should encourage operators to use open Internet standards.

Privacy – Users of a LEO system for Internet access should have at least the same level of support for private communication that they have on regular broadband or wireless Internet connections. Technologies such as Transport Layer Security (TLS) should be supported in a way that ensures end-to-end encryption. Overlay networks such as virtual private networks (VPNs), private relay, and other similar privacy services should work without interference or comparable degradation of service. Virtual private networks (VPNs) should work. All LEO systems should provide this support.

- Recommendation: LEO system operators need to ensure that the information transmitted through their systems is kept private and confidential. Encryption should be supported wherever possible.

Security – LEO systems add new layers of complexity to the already complex Internet infrastructure. Like traditional GEO systems, they involve ground stations linking the satellites to the Internet—and ground terminals used by customers to connect to the satellites. As outlined in a recent document from the US government, there are many areas of satellite infrastructure that need to be secured. LEO systems bring the additional challenges that there are so many more satellites, and in the future many of the satellites will be communicating between each other in orbit. Additionally, with the direct-to-consumer model of many LEO operators, they are seeking to manufacture and mass-produce both satellites and ground terminal equipment as cheaply as possible. In the general computing industry, this approach has often involved shortcuts with security, taken to minimize cost.

- Recommendation: LEO system operators must implement the latest practices for physical and network security and ensure their systems are "secure by design" and practice "defense in depth." LEO system operators should ensure that satellites' software can be securely

[16] A search on IPv6 in https://www.reddit.com/r/Starlink/ shows threads

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upgraded remotely. They should encourage security researchers to investigate and report vulnerabilities.

Unknowns

In such an immature market there are more things we do not know compared to what we do know; that is, there are more unknowns than knowns. Some of our greatest questions include the following.

Overall market – Many factors are driving the market for LEO-based Internet access, including:

- Advances in satellite and Internet technologies
- Miniaturization and rapidly decreasing launch costs, coupled with government funding and/or subsidies
- Largely open access orbits
- Highly concentrated wealth and benefits from vertically integrating satellite and launch services

While LEOs may be competitive with other forms of Internet access in terms of latency and capacity in sparsely populated areas, it appears that Internet access provided by LEO systems is not a good substitute for land-based Internet access in densely populated areas. What is the overall available market for LEO-based Internet systems? Will LEO-based Internet access only be useful for remote or underserved regions with few other options? Will LEO-based Internet access be viable for the polar regions, given the current limited coverage by constellation orbits? Will LEO providers be willing to supply their service at an affordable price in lower income countries?

Sustainable business models – In the rush to provide LEO-based Internet access, there has been massive investment in many different LEO constellations targeting different customers. Some focus on direct subscriptions by individual users. Some focus on backhaul to enterprise or terrestrial ISPs. Others aim to supply WiFi to airlines or shipping vessels. At least one is targeting embedded devices, a.k.a. the Internet of Things (IoT). Are the different business models all sustainable? What will happen when some LEO systems are no longer financially viable? Will there be a wave of consolidation into a few large operators? Or will we see inoperable systems? Will there be more than clouds of space debris?

Impact on ground-based Internet service providers – Until we see broader deployment of multiple LEO constellations, we may not know what impact LEO systems will have on current Internet access providers. It may be that subscriptions and equipment for LEO systems will remain expensive and be primarily used in regions without other options. Alternatively, should very low-cost LEO-based access emerge, it could cause ground-based Internet service providers to struggle and potentially go out of business. While this is a natural part of market competition, will this be good for the resilience of the

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overall Internet? If we wound up in the situation where ground-based ISPs are no longer viable and all of our Internet access comes from space-based systems controlled by a few corporations, is that good for the open Internet?

Space weather – At this time it is not clear if threats from "space weather" such as solar storms are well-understood for LEO constellations. In February 2022. Starlink reported the loss of over 40 satellites to a solar storm. If we get a solar storm that is 10X or 100X larger, how would it affect the satellites in LEO constellations? How resilient will LEO systems be to these type of threats?

Externalities, subsidies and the true cost of service – The true cost of providing LEO Internet access may be difficult to assess, not only because of external costs, subsidies, grants, and tax breaks, but also because of military investment. External costs of providing LEOs Internet access include:

- Orbital debris (including increased collision avoidance, tracking, and clean up)
- Light pollution and corruption of astronomy images
- Environmental costs associated with manufacturing, launching, decommissioning, and uncontrolled re-entries
- Potential lack of investment in ground-based broadband technologies

Those external costs are borne by society, and potentially by countries that do not supply or do not use LEO-based Internet access. Further, LEO services that appears financially viable, in reality, may not be commercially sustainable. What is the most efficient, economic and sustainable use of public funds to support Internet access in unserved or underserved communities?

Environment – While not directly related to Internet access, there are serious questions that need to be addressed as a society about the environmental impact of LEO systems. The industry is working to surround our planet in many separate "shells" of satellites. Beyond the space debris concern referenced earlier, there are questions about the environmental cost of the very large number of rocket launches to create all these constellations, and also about the impact to our atmosphere as so many decommissioned satellites burn up during re-entry. In the rush to connect the world through space, we need to give thought to how our world is affected by these systems. We believe LEO system operators must take responsibility for limiting the environmental impact of their systems.

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Analysis

The Internet Society has identified five critical properties that are responsible for the success and adaptability of the Internet. The properties have enabled the economic and technical development the Internet has brought around the world. As we look at LEO-based systems for Internet systems, the question is, will these LEO systems support these five critical properties that make the Internet work? The challenge remains that at the moment we only have limited data for one LEO system. Over the next few years as more LEO systems are deployed, we will be able to bring more certainty to this analysis.

Critical Properties of IWN	Impact
1: An Accessible Infrastructure with a Common Protocol that is open and has low barriers to entry	Uncertain. As highlighted above, affordability remains a concern, and it is not yet known whether all systems will support the common protocols used by the open Internet.
2: Open Architecture of Interoperable and Reusable Building Blocks based on open standards development processes voluntarily adopted by a user community	Uncertain. For example, IPv6 support is not yet consistently available in the only relatively large-scale LEO system in operation (Starlink).
3: Decentralized Management and a Single Distributed Routing System which is scalable and agile	Neutral or uncertain. So far, LEO providers have indicated that routing would work across their networks, as it does across any other Internet access network. However, with limited deployment this can not yet be verified.
4**: Common Global Identifiers** which are unambiguous and universal	Neutral or uncertain. DNS appears to operate across LEO providers as it does across other networks. Again, with limited deployment, results cannot yet be verified.
5: A Technology Neutral, General-Purpose Network which is simple and adaptable	Uncertain. We need further deployment of multiple systems to understand if they will act similarly to ground-based networks.

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Additionally, our mission states our goals for the Internet to be open, globally connected, secure, and trustworthy. We have identified seven enablers that advance those goals. Our question is, will LEO-based systems support these characteristics that enable to Internet to grow and thrive? Or will they potentially decrease these characteristics and reduce the future growth of the Internet?

Enablers of an open, globally connected, secure, and trustworthy Internet	Impact
Easy and unrestricted access	Uncertain. Affordability is a concern.
Unrestricted use and deployment of Internet technologies	Uncertain. Deployment is too limited.
Collaborative development, management, and governance	Negative or uncertain. So far, all LEO systems are being built by commercial companies using proprietary systems. While they may be using open Internet protocols, there may be little transparency into the development and operations of their systems.
Unrestricted reachability	Uncertain. It is not yet clear if LEO systems operators will implement the ability to block content or resources. They may *need* to be able to do so to operate within some countries.
Available capacity	Positive. The growth and deployment of LEO systems should increase the overall capacity of the Internet and enable more connections by more people. This is provided they do not cause reduced investment in ground-based services that could more efficiently and sustainably provide Internet access in the medium to longer term.
Data confidentiality of information, devices, and applications	Uncertain due to limited deployment.
Integrity of information, applications, and services	Uncertain due to limited deployment.

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Reliability, resilience, and availability	Positive or uncertain. We see potential for LEO systems to increase the overall resilience and reliability of the Internet. However, until there is more deployment, this cannot be tested or verified.
Accountability	Negative or uncertain. LEO systems are currently being deployed by commercial companies with limited requirements for accountability or transparency. The LEO providers may become de facto authorities and gatekeepers.
Privacy	Uncertain due to limited deployment.

Summary and Recommendations

We are at a pivotal time in the work of connecting those not yet connected to the Internet. The combination of less expensive launch systems, smaller and mass-produced satellites, better and smaller ground antennas, and all around improved technology has created a situation where large-scale deployment of LEO satellite systems is now possible. There is considerable potential to bridge the digital divide and connect many more people to the Internet.

However, as we highlighted in this document, the industry is still very new and there are many concerns and unanswered questions. The next few years will be critical as many more competing systems are expected to be launched.

If we want to bring the Internet to everyone, and to have people join an Internet that is open, globally connected, secure, and trustworthy, it is critical that all of us address the concerns outlined in this document. We need to pursue these recommendations—and ensure that LEO satellite-based systems will deliver the Internet experience we all need to thrive.

Acknowledgments

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