# Low Earth Orbit Satellites: Potential to Address the Broadband Digital Divide

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# Low Earth Orbit Satellites: Potential to Address the Broadband Digital Divide

SUMMARY

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As the Coronavirus Disease 2019 (COVID-19) pandemic began to unfold, many federal, state, and local governments, in addition to large and small businesses, implemented remote working or distance learning options to help abate the spread of the virus. As these decisions were made, some of the population had the option and the capability to shift activities online, while others did not. The term *digital divide* is used to characterize the gap between those who have access to telecommunications and information technologies and those who do not. One subset of the digital divide debate concerns access to high-speed internet service, also known as broadband.

Broadband technologies are currently being deployed, primarily by the private sector, throughout the United States. While the number of new broadband subscribers continues to grow, rural areas—and tribal areas in particular—tend to lag behind urban and suburban areas in broadband deployment and the speed of service offered. Federal support has been provided for broadband infrastructure deployment. While that funding has contributed to progress in closing the digital divide, there are some parts of the United States—particularly rural and remote areas—that still lack access to broadband. These are typically areas where it is difficult to deploy terrestrial broadband technologies, such as fiber optic cable or cable modem, due to build out challenges with terrain or cost. Broadband offered through satellite technologies may be the only option for some such communities at present, but service provided by satellites in geostationary orbit (GEO) may not be as reliable and resilient as wired broadband technologies, such as fiber.

A newer satellite broadband technology—provided by satellites in low Earth orbit (LEO)—may hold promise for further addressing the digital divide, especially in remote or rural areas. With the introduction of LEO satellites, which are positioned at a much lower altitude than GEO satellites, there is potential for satellite broadband to deliver speeds closer to those that can be achieved with fiber, as well as lower lag times or latency.

Companies are in the process of developing, testing, and deploying LEO satellites for broadband delivery with the hope that they may provide higher speeds, lower latency, and expanded coverage. There are many unknowns—for example, whether LEO satellites can consistently provide the anticipated lower latency and higher speeds. Other uncertainties include what LEO satellite provider competition might look like, or how affordable broadband service provided by LEO satellites may—or may not—be. As the development, testing, and deployment of LEO satellites progress, considerations for Congress may include:

- the potential to narrow—or widen—the digital divide,
- evolving regulatory policies,
- reaching fiber-like speeds and other performance challenges,
- competition, and
- selected pilot programs.

If LEO satellites provide fiber-like speeds and low latency to remote and rural areas, providing ubiquitous broadband, related issues may become ripe for congressional consideration—such as the potential for broadband infrastructure to reach all consumers or broadband adoption and affordability issues.

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# Introduction

Access to high-speed internet, known as broadband, has become increasingly essential as more aspects of daily life move online. This trend has become particularly apparent during the Coronavirus Disease 2019 (COVID-19) pandemic, as employers in some sectors transitioned their workers from on-site work to telework and schools migrated their students from classrooms to distance learning. As these decisions were made, some had the option and the capability to shift activities online, while others did not. This is known as the *digital divide*, a term used to characterize the gap between those who have access to telecommunications and information technologies and those who do not.

Broadband is deployed primarily by the private sector. The comparatively lower population density of rural and tribal areas, along with difficult topography in some cases, contributes to lower broadband penetration rates relative to urban and suburban areas. According to the Federal Communications Commission (FCC), there is "significant ongoing progress" in broadband deployment, but "it remains the case that rural and Tribal areas continue to lag behind."[1]

Federal agencies such as the FCC, the National Telecommunications and Information Administration (NTIA, an agency at the Department of Commerce), and the Rural Utilities Service (RUS, an agency at the U.S. Department of Agriculture) have directed financial resources to help increase broadband availability—chiefly for infrastructure buildout. While this funding helps to increase availability, reliable methods to close the digital divide are considered inadequate in some areas due to geographic limitations.

Communications satellites have been operating in low Earth orbit (LEO) since the early 2000s; previous large-scale plans were cancelled or reduced due to high costs and limited demand.[2] With higher demand for broadband service—especially in light of the COVID-19 pandemic—and to overcome some of these geographic limitations, several companies are developing constellations of satellites in low Earth orbit to provide broadband service from space. These newer LEO satellite constellations for broadband are in the initial stages of development, testing, and deployment, and the companies involved propose to offer broadband speeds comparable to those of fiber or cable internet service. LEO satellites may play a role in efforts to expand broadband access, encourage investment in new broadband technologies, and help bring more users online—especially in rural or remote areas.

This report discusses selected geostationary (GEO) satellite broadband providers—which have provided space-based broadband for decades—and selected LEO satellite broadband providers, highlighting the differences between the two technologies. Each LEO satellite broadband provider appears to be approaching deployment differently; successful efforts may provide models for future initiatives. The report discusses the potential for LEO satellites to address the digital divide, as well as their potential limitations for achieving that goal. The second half of the report focuses on policy issues and considerations for Congress, such as the possible impacts on current federal broadband programs and evolving regulatory issues.

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[1] Federal Communications Commission, *Fourteenth Broadband Deployment Report*, January 19, 2021, p. 4, available at https://docs.fcc.gov/public/attachments/FCC-21-18A1.pdf.

[2] John Garrity and Arndt Husar, *Digital Connectivity and Low Earth Orbit Satellite Constellations*, Asian Development Bank, April 2021, p. 8, available at https://www.adb.org/sites/default/files/publication/696521/sdwp-076-digital-connectivity-low-earth-orbit-satellite.pdf.

## Broadband Technologies

Broadband is high-speed internet service that is faster than traditional dial-up and always on. It can be delivered through various technologies, such as:

- Digital Subscriber Line (DSL),
- Cable modem,
- Fiber optic cable,
- Wireless,
- Satellite, and
- Broadband over Powerlines (BPL).[3]

Broadband gives users the ability to send and receive data at volumes and speeds that support a wide range of applications, including voice and video communications, entertainment, telemedicine, distance education, telework, and ecommerce.

The FCC has set a minimum speed that it uses to define what it considers broadband service. In 2015, citing changing broadband usage patterns and multiple devices using broadband within single households, the FCC set this benchmark speed at "25/3 Megabits per second" (Mbps), meaning 25 Mbps for downloading data and 3 Mbps for uploading data. 25/3 Mbps is an asymmetric speed, which means higher download speeds may be achieved, but upload speeds will be slower. The speeds needed for adequate performance vary by online activity (e.g., general web browsing and email require less speed than streaming video).

Additional speed may enhance the performance of some online activities.[4] For example, faster speeds would allow multiple users in a household to simultaneously participate in high-definition video conferencing for work or school, browse, stream videos, and play online games. Additionally, faster speeds may allow users to keep up with future bandwidth demands associated with a shift of many household functions online, such as phone and television service, thermostats, video doorbells and security cameras, and connected appliances. Broadband speeds vary significantly depending on the technology. For example, fiber can provide faster download and upload speeds than DSL or cable (see **Table 1**).

[3] DSL uses copper telephone wires to transmit data. Cable modem uses coaxial cables—the same used for cable television. Fiber optic cable uses pulses of light shot by lasers through thin strands of glass. Wireless uses a radio connection between a user and a service provider's terrestrial antennae. Satellite uses a radio connection between a user and a service provider's space-based antenna. BPL uses power lines. For further information, see FCC, "Types of Broadband Connections," June 23, 2014, available at https://www.fcc.gov/general/types-broadband-connections.

[4] Federal Communications Commission, *Broadband Speed Guide*, available at https://www.fcc.gov/consumers/guides/broadband-speed-guide.

**Table 1. Broadband Download and Upload Speed Ranges**

Selected Technologies

| Broadband Technology | Download Speed Range | Upload Speed Range |
|---|---|---|
| DSL | 5-35 Mbps | 1-10 Mbps |
| Cable | 10-500 Mbps | 5-50 Mbps |
| Fiber | 250-1,000 Mbps | 250-1,000 Mbps |

**Source:** Tyler Cooper, *DSL vs Cable vs Fiber: Comparing Internet Options*, BroadbandNow, May 3, 2021, available at https://broadbandnow.com/guides/dsl-vs-cable-vs-fiber.

**Notes:** Mbps means megabits per second.

Consumers typically prefer fiber, if available, because of its potential for faster speeds and lower latency (i.e., lag time). A challenge to providing broadband through fiber to some rural areas is installation cost. Statistics compiled by the Department of Transportation put the average cost of laying fiber at $27,000 per mile.[5] Another challenge is the potential for a lower return on investment for broadband providers in sparsely populated areas with fewer potential customers. Individuals, households, businesses, and institutions in rural areas that do not have access to fiber broadband may have access to other options, such as satellite, cellular hotspot, or dial-up internet service, but at speeds that are likely to be slower than the speeds achieved by fiber.[6]

## The Digital Divide

The term *digital divide* describes the gap between those who have access to broadband and those who do not. During the COVID-19 pandemic, many federal, state, and local governments, in addition to large and small businesses, implemented remote working or distance learning policies to help mitigate the spread of the disease. The pandemic thus highlighted the importance of internet access. For millions of children, it means access to education. For many workers, it means being able to perform their jobs remotely. For patients, it means being able to speak with a doctor. Additionally, the internet is increasingly how citizens access government services, seek employment, find homes, and stay connected with friends, family, and hobbies.[7]

### Challenges to Deploying Broadband in Remote Areas

The digital divide exists in both urban and rural areas, but substantial segments of rural and tribal areas lack the infrastructure needed to access high-speed internet service.[8] Many rural and tribal areas are remote, have low numbers of geographically dispersed potential users relative to more densely populated urban and suburban areas, and may have terrain, such as mountain ranges or ground that is frozen for long periods of time, which makes deployment difficult. Challenging topography can also increase deployment costs.

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[5] Sally Aman, *Dig Once: A Solution for Rural Broadband*, USTelecom, April 12, 2017, available at https://www.ustelecom.org/dig-once-a-solution-for-rural-broadband/.

[6] Government Technology, *Rural Communities Suffer the Most Without Access to the Web*, available at https://www.govtech.com/network/rural-communities-suffer-the-most-without-access-to-the-web.html.

[7] Emily Stewart, *Give Everybody the Internet*, Vox, September 10, 2020, available at https://www.vox.com/recode/2020/9/10/21426810/internet-access-covid-19-chattanooga-municipal-broadband-fcc.

[8] Andrew Perrin, *Digital Gap Between Rural and Nonrural America Persists*, Pew Research Center, May 31, 2019, available at https://www.pewresearch.org/fact-tank/2019/05/31/digital-gap-between-rural-and-nonrural-america-persists/.

Another challenge is the return on investment for broadband service providers. For wireline broadband technologies—such as cable and fiber—in particular, greater geographical distance between customers reduces a provider's ability to spread costs over a large subscriber base. Additionally, broadband providers are often motivated, especially in the near term, by the need to demonstrate profitability and attract investors,[9] which may impact their incentives to invest in broadband in high-cost and low-density rural and tribal areas relative to urban and suburban areas.

### Federal Broadband Programs to Address the Digital Divide

Because the infrastructure cost per connection in rural areas is often high, broadband deployment in those areas may not be economically feasible without federal or state subsidies.[10] Subsidies for broadband deployment have therefore been the main way the federal and state governments have addressed the digital divide.

Federal support for broadband deployment is provided primarily through the Universal Service Fund (USF) programs administered by the FCC, the broadband and telecommunications programs of RUS, and NTIA.[11] A number of other federal programs also provide subsidies to expand broadband.[12] Although these programs have helped increase broadband deployment and coverage—especially as many of the programs focus on rural, unserved, and underserved areas—approximately 14.5 million Americans still live in areas without access to broadband at speeds of at least 25/3 Mbps.[13] Addressing—and ultimately closing—the digital divide may depend on technological innovation. Providing broadband service using low Earth orbit satellites is one option that some experts say is promising.[14]

## Satellite Broadband

Satellite broadband is, as the name indicates, the provision of broadband internet service from satellites either in geostationary or geosynchronous orbit (GEO) or low Earth orbit (LEO). Satellites use specific segments or "bands" of spectrum—radio frequencies used to transmit signals wirelessly from one facility or device to another. [15] Use of radio frequencies[16] is regulated to avoid interference between users. In the United States, two agencies manage spectrum use—NTIA and the FCC. NTIA manages federal agency use of spectrum (e.g., use by the Army, the

[9] Ernesto Falcon, Cory Doctorow, and Katharine Trendacosta, *Frontier's Bankruptcy Reveals Why Big ISPs Choose to Deny Fiber to So Much of America*, Electronic Frontier Foundation, April 30, 2020, available at https://www.eff.org/deeplinks/2020/04/frontiers-bankruptcy-reveals-cynical-choice-deny-profitable-fiber-millions.

[10] Rich Contreras, *Making Rural Fiber Deployments Cost Effective*, PPC Broadband, available at https://www.ppc-online.com/blog/making-rural-fiber-deployments-cost-effective.

[11] For more information, see CRS Report R46613, *The Digital Divide: What Is It, Where Is It, and Federal Assistance Programs*, by Colby Leigh Rachfal.

[12] BroadbandUSA, *Federal Funding*, available at https://broadbandusa.ntia.doc.gov/resources/federal/federal-funding.

[13] Federal Communications Commission, *Fourteenth Broadband Deployment Report*, January 19, 2021, p. 2, available at https://docs.fcc.gov/public/attachments/FCC-21-18A1.pdf.

[14] Jared Lindzon, *Remote Work Can't Change Everything Until We Fix this $80 Billion Problem*, Fast Company, November 30, 2020, available at https://www.fastcompany.com/90578964/rural-internet-broadband-access.

[15] Riley Davis, *What is Spectrum? A Brief Explainer*, CTIA, June 5, 2018, available at https://www.ctia.org/news/what-is-spectrum-a-brief-explainer.

[16] Radio spectrum is the range of radio frequencies that are used for communicating.

Federal Aviation Administration, the Federal Bureau of Investigation).[17] The FCC administers spectrum for nonfederal use (i.e., commercial use, state and local government use). As an example of how the FCC manages spectrum, in March 2018, the FCC approved SpaceX's application to use certain frequencies to deploy and operate 4,425 LEO communications satellites.[18] In July 2020, the FCC granted approval for Amazon to deploy and operate 3,236 satellites for Project Kuiper, an initiative to build a LEO satellite constellation.[19]

To deploy a satellite constellation, a provider needs spectrum rights;[20] and to use satellite broadband, a consumer must have:

- an antenna, known as a satellite dish or base station, typically two to three feet in diameter,
- a satellite internet modem, and
- a clear line of sight to the provider's satellite(s).[21]

The first commercial communications satellite, Telstar, was launched on July 10, 1962.[22] More than 2,000 commercial communications satellites are now in orbit.[23] These satellites can be categorized by their orbits. GEO satellites have provided commercial internet access since the early 2000s. For information on selected major GEO satellite providers, see **Table 2**. The provision of broadband from LEO satellites is in the testing, development, and early deployment phases.[24]

## Geostationary Satellites

GEO satellites orbit the Earth above the equator at an altitude of 22,236 miles, so that their orbital motion exactly matches Earth's rotation. As a result, they stay in the same position relative to points on the Earth's surface—a useful feature for applications such as weather monitoring, communications, and surveillance.[25] According to the FCC, broadband service from GEO satellites at speeds of 25/3 Mbps is available to nearly the entire U.S. population.[26] GEO satellites

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[17] Federal Communications Commission, *Radio Spectrum Allocation*, available at https://www.fcc.gov/engineering-technology/policy-and-rules-division/general/radio-spectrum-allocation.

[18] Federal Communications Commission, *FCC Authorizes SpaceX to Provide Broadband Satellite Services*, March 29, 2018, p. 1, available at https://www.fcc.gov/document/fcc-authorizes-spacex-provide-broadband-satellite-services.

[19] Amazon, *Amazon Receives FCC Approval for Project Kuiper Satellite Constellation*, July 30, 2020, available at https://www.aboutamazon.com/news/company-news/amazon-receives-fcc-approval-for-project-kuiper-satellite-constellation.

[20] For more information, see "Evolving Regulatory Policies."

[21] Federal Communications Commission, *Getting Broadband Q&A*, available at https://www.fcc.gov/consumers/guides/getting-broadband-qa.

[22] Alex Miller, *Satellite Internet: Reaching Across the Globe to Connect the Unconnected*, Viasat, March 5, 2020, available at https://www.viasat.com/about/newsroom/blog/connect-the-unconnected/.

[23] Union of Concerned Scientists, UCS Satellite Database, https://www.ucsusa.org/resources/satellite-database, updated January 1, 2021.

[24] John Dilley, *The Past, Present, and Future of Satellite Internet*, SatelliteInternet, April 26, 2019, available at https://www.satelliteinternet.com/resources/history-and-future-of-satellite-internet/.

[25] Elizabeth Howell, *What Is a Geosynchronous Orbit*, Space.com, available at https://www.space.com/29222-geosynchronous-orbit.html.

[26] Federal Communications Commission, *2020 Broadband Deployment Report*, April 20, 2020, p. 15, available at https://docs.fcc.gov/public/attachments/FCC-20-50A1.pdf.

require just three satellites for the equivalent coverage of the earth, as compared to LEO satellites, which have anywhere from 40 to over 600 satellites in their earth coverage constellation.[27]

There are some limitations for GEO satellite providers, as satellites are expensive to launch and have a roughly 15-year service life in orbit.[28] There are also some limitations of GEO satellite broadband that may make it less desirable for users than technologies such as fiber or cable. For example, due to the distance the data must travel to a satellite in orbit and back, consumers using GEO satellite service can experience greater latency—a delay between when an action is taken (e.g., clicking on a link to visit a website) and when the result is shown—than other forms of internet service. Latency varies by broadband technology.[29] Additionally, weather conditions (such as snow) and mountainous or heavily forested terrain may also cause interruptions in service due to the requirement that the satellite be in view of both the customer's and the provider's ground stations.[30] Cost can also be a limitation. The average cost of a GEO satellite broadband plan in the United States is about $123 per month—significantly more than the average cost of a cable or fiber plan, which is about $52-$59 per month (see **Table 4**). Satellite equipment fees are also higher than the equipment fees associated with cable and fiber (see **Table 5**).

**Table 2. Selected Major GEO Satellite Providers in the United States**

| GEO Provider | Maximum Advertised Speeds | Average Latency |
|---|---|---|
| Hughes Network Systems | 25/3 Mbps | 638 ms |
| Viasat | 100/3 Mbps | 638 ms |

**Source:** HughesNet, *How Fast Is HughesNet Gen5?*, available at https://www.hughesnet.com/get-started; Viasat, *Reliable, High-Speed Satellite Home Internet Plans*, available at https://www.viasat.com/home-internet/plans/; Alex Miller, *Satellite Internet Latency: What's the Big Deal?*, Viasat, September 5, 2017, available at https://www.viasat.com/about/newsroom/blog/satellite-internet-latency-whats-the-big-deal/.

**Notes:** Mbps means megabits per second and ms means milliseconds. The HughesNet website states, "The HughesNet Gen5 service plans are designed to deliver download speeds of 25 Mbps and upload speeds of 3 Mbps, but individual customers may experience different speeds at different times of the day. Speeds and uninterrupted use are not guaranteed and may vary based on a variety of factors including: the configuration of your computer, the number of concurrent users, network or Internet congestion, the capabilities and content of the websites you are accessing, network management practices as deemed necessary, and other factors." The Viasat website states, "Speeds and availability may vary by region. Speeds up to 100Mbps available in select areas."

[27] Paul Struhsaker, *The Race to Space: Winners and Losers as Providers Try to Connect the World*, Carnegie Technologies, available at https://www.carnegietechnologies.com/news-updates/the-race-to-space-winners-and-losers-as-providers-try-to-connect-the-world/.

[28] Ibid.

[29] Fiber-to-the-home has the best performance in terms of latency, with a 17 milliseconds (ms) average. Cable averages 28 ms. DSL averages 44 ms and ranges as high as approximately 75 ms. A lower latency number is better than a higher latency number. For more information, see Federal Communications Commission, *Measuring Broadband America, A Report on Consumer Wireline Broadband Performance in the U.S.*, p. 22, available at https://docs.fcc.gov/public/attachments/DOC-308828A1.pdf.

[30] BroadbandNow, *Satellite Internet in the United States*, available at https://broadbandnow.com/Satellite.

## Low Earth Orbit Satellites

LEO satellites operate anywhere from 311 miles to 1,243 miles above the Earth's surface[31]—much lower than GEO satellites, which orbit at 22,236 miles above the Earth.[32] LEO satellites for broadband are in the initial stages of development, testing, and deployment. Because transmitted data does not have to travel as far to reach the satellite and return to Earth, LEO operators expect to offer faster broadband speeds and less latency than GEO satellite service.[33] Unlike GEO satellites, LEO satellites are constantly moving across the sky as seen from the ground and each individual satellite is only within line-of-sight of a fixed point on Earth for a period of time. This requires the use of thousands of satellites to maintain coverage,[34] but it may mitigate loss of coverage due to weather or obstructions. LEO satellites are also not restricted to orbits over the equator, so they may be able to provide better service at high latitudes.[35]

While LEO satellites cost less than GEO satellites,[36] the total cost of a constellation of LEO satellites can be substantial, as hundreds or thousands of satellites may be required to provide global coverage because of their smaller beams.[37] Additionally, satellites in LEO are affected by an atmospheric drag that makes the orbit deteriorate gradually. As a result, the typical lifetime of a LEO satellite is 7-10 years.[38]

Although LEO satellite providers plan to offer higher speeds, lower latency, and greater broadband coverage than GEO satellites, uncertainties remain, including:

- Which companies will be able to achieve sustainable profitability?
- Will user terminal[39] and service plan costs end up being competitive with the equipment and service plans of other broadband technologies?
- Will LEO satellite providers be able to meet broadband service expectations and attract users?[40]

[31] Washington Post, *Why Low-Earth Orbit Satellites Are the New Space Race*, July 10, 2020, available at https://www.washingtonpost.com/business/why-low-earth-orbit-satellites-are-the-new-space-race/2020/07/10/51ef1ff8-c2bb-11ea-8908-68a2b9eae9e0_story.html.

[32] Viasat, *Geostationary Satellites*, available at https://www.viasat.com/space-innovation/space-systems/geo-satellites/.

[33] SatelliteInternet, *The Best Satellite Internet Providers of 2021*, available at https://www.satelliteinternet.com/.

[34] Rob Rutkowski, *5 FAQs About Low Earth Orbit (LEO) Satellite Constellations*, Bliley Technologies, June 29, 2017, available at https://blog.bliley.com/5-faq-answers-new-space-leo-satellite-constellations.

[35] The European Space Agency, *Low Earth Orbit*, February 3, 2020, available at https://www.esa.int/ESA_Multimedia/Images/2020/03/Low_Earth_orbit.

[36] LEO satellites cost approximately $500,000 to $45 million per satellite. GEO satellites cost approximately $100 million to $400 million per satellite. For more information see International Telecommunication Union, *The Last-Mile Internet Connectivity Solutions Guide*, 2020, p. 70, available at https://www.itu.int/en/ITU-D/Technology/Documents/LMC/The%20Last-Mile%20Internet%20Connectivity%20Solutions%20Guide.pdf.

[37] International Telecommunication Union, *The Last-Mile Internet Connectivity Solutions Guide*, 2020, p. 70, available at https://www.itu.int/en/ITU-D/Technology/Documents/LMC/The%20Last-Mile%20Internet%20Connectivity%20Solutions%20Guide.pdf.

[38] ScienceDirect, *Low Earth Orbit*, available at https://www.sciencedirect.com/topics/engineering/low-earth-orbit.

[39] A user terminal is a dish that connects the customer to the satellites and enables broadband access.

[40] David Jarvis, *Five Key Uncertainties Around High-Speed Internet from Low Earth Orbit*, International Telecommunication Union, August 18, 2020, available at https://www.itu.int/en/myitu/News/2020/08/18/07/51/Uncertainties-high-speed-Internet-low-earth-orbit-LEO-satellite-broadband.

**Table 3** provides information about projected speeds and latency for four major companies that are seeking to provide broadband through LEO satellites. These companies are at various stages in development, testing, and deployment:

- SpaceX is delivering "initial beta service" in the United States and other countries under the name Starlink.[41] SpaceX has launched more than 1,730 Starlink satellites, with plans to launch 42,000.[42]
- Amazon's Project Kuiper proposes to deliver high-speed, low-latency broadband services by operating 3,236 LEO satellites.[43] Amazon plans to launch half of these by the end of July 2026.[44]
- OneWeb has 74 LEO satellites. OneWeb plans to launch and operate 1,000 satellites by August 2026, plus an additional 926 by August 2029.[45]
- Telesat's constellation is composed of 298 LEO satellites and may scale to 512 LEO satellites.[46] The first LEO satellite was launched in January 2018 and is supporting live demonstrations across a variety of markets and applications.[47]

**Table 3. Selected Major LEO Satellite Providers**

| LEO Provider | Projected Upload Speeds | Projected Download Speeds | Projected Latency |
|---|---|---|---|
| Amazon | Up to 400 Mbps | Unknown | Unknown |
| OneWeb | Up to 200 Mbps | 50 Mbps | 32 ms |
| SpaceX | 100 Mbps | 20 Mbps | 30 ms |
| Telesat | 50 Mbps | 10 Mbps | 30-60 ms |

**Sources:** Space Exploration Technologies Corporation, *Order Starlink*, available at https://www.starlink.com/; David Goldman, *IBFS File No. SAT-MOD-20200417-00037; RM-11855*, Space Exploration Technologies Corporation, January 22, 2021, available at https://ecfsapi.fcc.gov/file/101220897228398/SpaceX%208th%20Floor%20Ex%20Parte%20(01-22-2021).pdf; Amazon, *Amazon Marks Breakthrough in Project Kuiper Development*, December 16, 2020, available at https://www.aboutamazon.com/news/innovation-at-amazon/amazon-marks-breakthrough-in-project-kuiper-development; Doug Mohney, *SpaceX Gets Connected: Satellite Broadband Meets the Data Center*, Data Center Frontier, February 23, 2021, available at https://datacenterfrontier.com/spacex-gets-connected-satellite-broadband-meets-the-data-center/; Telesat, *Telefónica Puts Telesat's Phase 1 LEO Satellite to the Test*, June 4, 2020, available at https://www.telesat.com/press/

[41] Space Exploration Technologies Corporation, *Order Starlink*, available at https://www.starlink.com/.

[42] Adam Mann, *Starlink: SpaceX's Satellite Internet Project*, Space.com, May 28, 2021, available at https://www.space.com/spacex-starlink-satellites.html.

[43] Federal Communications Commission, *Order and Authorization*, July 29, 2020, p. 2, available at https://docs.fcc.gov/public/attachments/FCC-20-102A1.pdf.

[44] Katherine Anne Long, *Amazon Internet Program, Project Kuiper, to Launch Satellite*, Government Technology, April 20, 2021, available at https://www.govtech.com/news/amazon-internet-program-project-kuiper-to-launch-satellite.html.

[45] Rachel Jewett, *FCC Grants OneWeb Market Access for 2,000-Satellite Constellation*, Via Satellite, August 26, 2020, available at https://www.satellitetoday.com/broadband/2020/08/26/fcc-grants-oneweb-market-access-for-2000-satellite-constellation/.

[46] Caleb Henry, *Telesat Says Ideal LEO Constellation Is 292 Satellites, but Could Be 512*, SpaceNews, September 11, 2018, available at https://spacenews.com/telesat-says-ideal-leo-constellation-is-292-satellites-but-could-be-512/.

[47] Elisabeth Neasmith, *Application for Modification of Market Access Authorization*, Telesat, May 26, 2020, p. 5, available at https://fcc.report/IBFS/SAT-MPL-20200526-00053/2378318.pdf.

press-releases/telefonica-puts-telesats-phase-1-leo-satellite-to-the-test/; Telesat, *Lightspeed*, available at https://www.telesat.com/wp-content/uploads/2020/08/Telesat-Lightspeed-Universal-Connectivity.pdf.

At this point, it is not clear which of these companies, if any, might be able to achieve sustainable profitability. The number of successful competitors in the LEO broadband landscape may depend, in part, on factors such as U.S. and foreign regulations, federal subsidies, and development of standards through the International Telecommunication Union (ITU). Disagreements among satellite operators regarding issues such as spectrum or space traffic management may affect the competitive landscape.[48]

The hardware needed for LEO satellite broadband may be expensive for consumers. For example, SpaceX charges $499 for the Starlink hardware[49] and $99 a month for broadband service, plus shipping and handling and taxes.[50] For comparison, **Table 4** and **Table 5** show equipment and service rates for other broadband technologies.

**Table 4. Estimated Average Monthly Prices for Fixed Broadband Services, 2020**

| Broadband Technology | Estimated Average Monthly Price |
|---|---|
| Digital Subscriber Line (DSL) | $50 |
| Cable Modem | $52 |
| Fiber Optic Cable | $59 |
| Satellite (GEO) | $123 |

**Source:** Allconnect, *What Is the Average Internet Bill?*, April 21, 2021, available at https://www.allconnect.com/blog/cost-of-high-speed-internet.

**Notes:** Excludes equipment rental and other fees.

**Table 5. Average Equipment Fees, 2019-2020**

| Modem | | Wi-Fi Router | | Satellite Equipment | |
|---|---|---|---|---|---|
| Rental Fee | Purchase Fee | Rental Fee | Purchase Fee | Rental Fee | Purchase Fee |
| $9.86 | $126.81 | $6.13 | $0.00 | $9.99-$14.99 | $299.99-$449.99 |

**Source:** New America, *The Cost of Connectivity 2020*, available at https://www.newamerica.org/oti/reports/cost-connectivity-2020/executive-summary; Dave Schafer, *How Much Does Satellite Internet Cost?*, SatelliteInternet, December 2, 2019, available at https://www.satelliteinternet.com/resources/how-much-does-satellite-internet-cost/.

**Notes:** Rental fees are per month.

[48] David Jarvis, *Five Key Uncertainties Around High-Speed Internet from Low Earth Orbit*, International Telecommunication Union, August 18, 2020, available at https://www.itu.int/en/myitu/News/2020/08/18/07/51/Uncertainties-high-speed-Internet-low-earth-orbit-LEO-satellite-broadband. See also "Evolving Regulatory Policies."

[49] While the cost of each Starlink terminal is $499 for consumers, the cost to SpaceX is over $1,000. SpaceX has already cut the terminal cost in half from $3,000 and is aiming to reduce it to the few hundred dollar range within the next year or two. See Joey Roulette, *Elon Musk Counts on 500,000 Starlink Users Within the Next Year*, The Verge, June 29, 2021, available at https://www.theverge.com/2021/6/29/22556031/elon-musk-spacex-starlink-users-next-year-telecom-5g.

[50] Ibid.

# Policy Issues for Congress

Companies are in the process of developing, testing, and deploying LEO satellites with the hopes that these may provide higher speeds, lower latency, and expanded broadband coverage. As this progress continues, considerations for Congress may include:

- the potential of LEO satellite broadband to narrow—or widen—the digital divide,
- evolving regulatory policies,
- reaching fiber-like speeds and other performance challenges,
- competition, and
- selected pilot programs.

## Potential to Narrow—or Widen—the Digital Divide

In addressing the digital divide, existing federal broadband programs tend to encourage the deployment of technologies such as fiber, cable, or fixed wireless, though many programs allow GEO satellite broadband providers—and more recently, LEO satellite broadband providers—to apply for funding and compete at certain performance tiers, such as in the FCC's Rural Digital Opportunity Fund (RDOF).[51] With the advent of LEO satellites for broadband, it is unclear—due to unknown factors such as the ability to reach fiber-like speeds, what the competition landscape may look like, or if LEO satellite broadband service will be affordable—whether the inclusion of LEO satellite broadband providers would help address the digital divide through their participation in federal broadband programs.

### RDOF Performance Tiers

Through RDOF, the FCC plans to commit $20.4 billion to bring high-speed fixed broadband service to rural homes and small businesses in two phases. The Phase I auction, which began on October 29, 2020, and ended on November 25, 2020, awarded support to bring broadband to over five million homes and businesses in census blocks that were entirely unserved by voice and broadband with download speeds of at least 25 Mbps.[52] Broadband service providers had the option to bid at particular performance tiers (i.e., the speed and latency (high or low) they intended to deliver). See **Table 6** and **Table 7**.

[51] For more information on the RDOF, see CRS Report R46501, *Rural Digital Opportunity Fund: Requirements and Selected Policy Issues*, by Colby Leigh Rachfal.

[52] Federal Communications Commission, *Auction 904: Rural Digital Opportunity Fund*, https://www.fcc.gov/auction/904.

**Table 6. Service Tiers for RDOF Phase I Auction**

| Performance Tier | Speed | Weight |
|---|---|---|
| Minimum | ≥ 25/3 Mbps | 50 |
| Baseline | ≥ 50/5 Mbps | 35 |
| Above Baseline | ≥ 100/20 Mbps | 20 |
| Gigabit | ≥ 1 Gbps/500 Mbps | 0 |

**Source:** Federal Communications Commission, *Auction 904: Rural Digital Opportunity Fund*, Fact Sheet, available at https://www.fcc.gov/auction/904/factsheet.

**Notes:** Mbps means megabits per second. ≥ means greater than or equal to.

**Table 7. RDOF Latency Requirements**

| Latency | Requirement | Weight |
|---|---|---|
| Low Latency | ≤ 100 ms | 0 |
| High Latency | ≤ 750 ms and MOS of ≥4 | 40 |

**Source:** Federal Communications Commission, *Auction 904: Rural Digital Opportunity Fund*, Fact Sheet, available at https://www.fcc.gov/auction/904/factsheet.

**Notes:** ms means milliseconds. ≤ means less than or equal to. MOS means mean opinion score to predict voice over internet protocol (VoIP) call quality.

Some broadband service providers bid at high performance tiers, e.g., gigabit or above baseline (≥ 100/20 Mbps), which would likely be delivered with a technology such as fiber optic cable. Other broadband service providers bid at other tiers, such as minimum (≥ 25/3 Mbps) or baseline (≥ 50/5 Mbps). Broadband service providers were encouraged to select performance tier and latency combinations that they could reasonably expect to meet and were required to make a certification that they are technically qualified to meet the obligations for each performance tier and latency combination.[53] The FCC prioritized bids with lower tier and latency weights.[54]

The tiered service level approach likely means that some communities will be served with broadband at very high speeds (e.g., gigabit) and low latencies, while other communities may be served with broadband at minimum (25/3 Mbps) or slightly higher speeds and higher latencies. The potential service level disparity may be attributable to some areas that may only receive lower tier bids while others receive bids at higher tiers, due to the economics of serving particular areas. For example, remote areas with difficult topography may receive lower service tier bids, while there may be competition among providers for higher service tier bids to potentially more profitable areas.

It is unclear what impact LEO satellite broadband will have on broadband access in rural and tribal areas. The National Rural Electric Cooperative Association (NRECA) and National Rural Telecommunications Cooperative (NRTC) have expressed concerns about whether SpaceX—the

[53] Federal Communications Commission, *Rural Digital Opportunity Phase I Auction Notice and Filing Requirements and Other Procedures for Auction 904*, June 11, 2020, p. 22-23, available at https://docs.fcc.gov/public/attachments/FCC-20-77A1.pdf.

[54] Ibid., p. 71.

only LEO satellite provider who qualified for and bid in the RDOF Auction—can consistently deliver at the performance tiers it bid for.[55] As stated in a NRECA white paper:

> Questions also remain about the ability of LEOs to consistently provide a high level of speed as thousands of subscribers sign up for the service. Again, if this service were commercially available widely, real-world data would be available. But it is not.[56]

SpaceX has a differing perspective on its technology, stating in a petition to the FCC:

> Starlink's performance is not theoretical or experimental. Over 10,000 users in the United States and abroad are using the service today. While its performance is rapidly accelerating in real time as part of its public beta program, the Starlink network has already successfully demonstrated it can surpass the Commission's "Above Baseline" and "Low Latency" performance tiers, including:
>
> - Meeting and exceeding 100/20 megabits per second ("Mbps") throughput to individual users,
> - Demonstrating performance of 95% of network round-trip latency measurements at or below 31 milliseconds,
> - Successfully testing standalone voice service over the Starlink network.[57]

## Nonduplication Policies and Competition

In a January 2020 Report and Order, the FCC adopted a policy that made census blocks ineligible for the RDOF if they have been awarded funding through other, similar federal or state broadband subsidy programs.[58] The FCC stated that the intent behind this policy is to ensure the auction does not award duplicative or unnecessary support, and instead targets RDOF funding in areas that would otherwise not be served by broadband. Other federal broadband programs have similar nonduplication policies.

While these nonduplication policies seek to target federal dollars to areas that have the most need, they also mean that areas that receive satellite broadband funding from one federal program will likely become ineligible to receive future funding from other federal broadband programs. Those areas will therefore not have the opportunity for other broadband providers to participate in federal programs to build out terrestrial broadband technologies, such as fiber optic cable. Nonduplication policies may thus preclude an area from being served with multiple types of broadband service, which, in some cases, may be necessary or helpful to provide adequate access due to topography or the geographic distribution of potential users.

Using the RDOF and the forthcoming 5G Fund for America[59] as potential models, Congress may consider how LEO satellites could participate in national infrastructure investment programs and

[55] SpaceX bid into the above baseline and low latency category.

[56] National Rural Electric Cooperative Association, *The Rural Digital Opportunity Fund: Rural America's Broadband Hopes at Risk*, February 1, 2021, p. 10, available at https://ecfsapi.fcc.gov/file/10202734510982/NRECA.NRTC.RDOF.paper%20PostFinal.02.01.2021.pdf.

[57] Edward Price, *Petition of Starlink Services, LLC for Designation As An Eligible Telecommunications Carrier*, Space Exploration Technologies Corporation, February 3, 2021, available at https://ecfsapi.fcc.gov/file/1020316268311/Starlink%20Services%20LLC%20Application%20for%20ETC%20Designation.pdf.

[58] Federal Communications Commission, *In the Matter of Rural Digital Opportunity Fund Report and Order*, January 30, 2020, p. 7, available at https://docs.fcc.gov/public/attachments/FCC-20-5A1.pdf.

[59] For the FCC's forthcoming 5G Fund for Rural America (5G Fund)—a program which is to make $9 billion available to bring 5G mobile broadband service to rural areas—satellite providers who can deliver service with a latency of 100 milliseconds or less will be eligible to receive funding. See Federal Communications Commission, *Report and Order*,

other federal initiatives to close the digital divide. For example, Congress may examine how LEO satellites could be included in any infrastructure, incentive, or tax policy legislation undertaken to expand broadband access in the United States.[60] Subsidizing the deployment of LEO satellite broadband may help to narrow the digital divide in some communities that are currently unserved or underserved by terrestrial broadband. At the same time, nonduplication policies may potentially inhibit the provision of multiple types of broadband service in some communities where a mix of technologies would increase access, or make some communities ineligible for future federal broadband programs, in which case it might even widen the digital divide in those locations.[61]

## Evolving Regulatory Policies[62]

Radio spectrum is used by wireless technologies to transmit data, and spectrum demands have increased in recent years with the emergence of, and consumer demand for, new wireless technologies and services. Many of these new services are data intensive, such as streaming video and access to cloud storage, and, since wireless technologies are typically limited to specific frequency bands, there is intense demand for spectrum to support them.[63]

As satellites use specific segments or "bands" of spectrum—radio frequencies used to transmit signals wirelessly from one facility or device to another[64]—use of radio frequencies[65] is regulated to avoid interference between users. As the deployment of LEO satellites accelerates, regulations around deployment rate, frequency allocation, and orbital debris mitigation may continue to evolve. There may be disagreements among satellite operators, as well as challenges with regulatory bodies in different countries regarding standards setting and spectrum coordination, affecting the competitive landscape.[66] Congress may consider ways to encourage coordination among agencies that have jurisdiction over space and spectrum.

### Limited Spectrum and Potential Interference Issues

While spectrum rights are not exclusive to any one company, once certain spectrum bands are in use, any new users must design their systems to avoid interference with existing operators.[67]

October 27, 2020, p. 10, available at https://docs.fcc.gov/public/attachments/FCC-20-150A1.pdf.

[60] See, for example, U.S. Congress, Senate Committee on Commerce, Science, and Technology, *Statement of Patricia Cooper, Vice President, Satellite Government Affairs, Space Exploration Technologies Corporation*, 115th Cong., May 2017, pp. 7-8, available at https://www.commerce.senate.gov/services/files/6c08b6c2-fe74-4500-ae1d-a801f53fd279.

[61] Katie Kienbaum, *Satellite Subsidies Will Widen Digital Divide in Rural America*, Community Networks, January 14, 2020, available at https://muninetworks.org/content/satellite-subsidies-will-widen-digital-divide-rural-america.

[62] For more information, see CRS In Focus IF11382, *Small Satellite Boom Poses Challenges for Regulators*, by Alyssa K. King.

[63] For example, in the United States and in South Korea, it has already been decided that the 28 GHz band, located in the Ka band, will be devoted to 5G. For more information, see European Commission, *Low-Earth Orbit Satellites: Spectrum Access*, July 2017, p. 5, available at https://ati.ec.europa.eu/sites/default/files/2020-06/Low-Earth%20Orbit%20satellites%20-%20Spectrum%20access%20%28v1_0%29.pdf.

[64] Riley Davis, *What Is Spectrum? A Brief Explainer*, CTIA, June 5, 2018, available at https://www.ctia.org/news/what-is-spectrum-a-brief-explainer.

[65] Radio spectrum is the range of radio frequencies that are used for communicating.

[66] David Jarvis, *Five Key Uncertainties Around High-Speed Internet from Low Earth Orbit*, International Telecommunication Union, August 18, 2020, available at https://www.itu.int/en/myitu/News/2020/08/18/07/51/Uncertainties-high-speed-Internet-low-earth-orbit-LEO-satellite-broadband.

[67] Sissi Cao, *SpaceX Expands Starlink Project to 42,000 Satellites, 'Drowns' ITU in Filing Paper*, Observer, October

Early in the planning process, companies apply for and obtain licenses from their national regulators (e.g., the FCC in the United States) and a general description of the satellite constellation is filed with the ITU, including the frequencies it will use. A company is required to coordinate with any satellite system that might be affected by its planned constellation, provided the other system was filed before its filing; there is no requirement to coordinate with those whose filings are made after its own filing.[68]

This could potentially lead broadband satellite providers entering the market to encounter increasingly crowded airwaves, as dedicated bands and interference avoidance practices makes spectrum a limited resource. For example, in January 2021, SpaceX asked the FCC for permission to operate Starlink communications satellites at a lower orbit than first planned, and Amazon responded that the move would risk interference (and collisions) with its planned Project Kuiper satellites.[69] On January 20-22, 2021, SpaceX discussed with the FCC a proposal to lower the operating altitudes of some of its satellites.[70] In a statement to CNBC, an Amazon spokesperson said:

> The facts are simple. We designed the Kuiper System to avoid interference with Starlink, and now SpaceX wants to change the design of its system. Those changes not only create a more dangerous environment for collisions in space, but they also increase radio interference for customers. Despite what SpaceX posts on Twitter, it is SpaceX's proposed changes that would hamstring competition among satellite systems. It is clearly in SpaceX's interest to smother competition in the cradle if they can, but it is certainly not in the public's interest.[71]

SpaceX Chief Executive Officer Elon Musk responded in a tweet on January 26, 2021, "It does not serve the public to hamstring Starlink today for an Amazon satellite system that is at best several years away from operation."[72]

The FCC has acknowledged potential challenges surrounding its spectrum administration policies. In a commentary for the *Orlando Sentinel*, FCC Commissioner Geoffrey Starks stated:

> The FCC's stewardship of the public airwaves is one tool the agency can use to promote the delivery of communications services to all Americans. The coming satellite broadband surge challenges us to rethink our policies. In August, the Commission will consider streamlining the process for applications involving small satellites in low-Earth orbit. We should take a similar look at our processes for innovative satellite broadband operations to determine how they promote service to rural America. We must adopt policies that encourage investment in new networks and leave room for new competitive players and new services.[73]

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21, 2019, available at https://observer.com/2019/10/spacex-elon-musk-starlink-satellite-internet-itu-fcc-filing/.

[68] Aaron C. Boley and Michael Byers, *Satellite Mega-Constellations Create Risks in Low Earth Orbit, the Atmosphere and on Earth*, Scientific Reports, May 20, 2021, available at https://www.nature.com/articles/s41598-021-89909-7.

[69] Todd Shields, *World's Richest Men, Musk and Bezos, Fight over Satellite Fleets*, Financial Post, January 26, 2021, available at https://financialpost.com/pmn/business-pmn/worlds-richest-men-musk-and-bezos-fight-over-satellite-fleets.

[70] David Goldman, Space Exploration Technologies Corporation, January 22, 2021, available at https://ecfsapi.fcc.gov/file/101220897228398/SpaceX%208th%20Floor%20Ex%20Parte%20(01-22-2021).pdf.

[71] Michael Sheetz, *Elon Musk Blasts Jeff Bezos' Amazon, Alleging Effort to 'Hamstring' SpaceX's Starlink Satellite Internet*, CNBC, January 26, 2021, available at https://www.cnbc.com/2021/01/26/elon-musk-blasts-jeff-bezos-amazon-competitor-to-spacexs-starlink-.html.

[72] Twitter, January 26, 2021, available at https://twitter.com/elonmusk/status/1354018055014260738.

[73] Geoffrey Starks, *Can Satellite Broadband Solve Rural Internet Inequality?*, Orlando Sentinel, July 25, 2019,

While taking steps toward improving regulatory policies may prove useful for LEO satellite deployments in the long term, disagreements between satellite broadband providers may stifle competition by discouraging new providers from entering the market or delaying launches, and thus delay the deployment of broadband to consumers. Congress may consider providing oversight on these matters and to ensure any disputes are resolved expeditiously.

### Orbital Debris and Space Traffic Management

Along with the potential for radio interference, the growing number of satellites in space has raised concerns with the FCC about orbital congestion and the threat of orbital debris, also known as "space junk."[74] Avoiding collision with other operating satellites and with debris objects is a serious concern as LEO satellites travel at thousands of miles per hour and in-orbit collisions can cause significant to fatal damage to hardware and service. There are millions of pieces of space junk flying in LEO. Most orbital debris comprises human-generated objects, such as pieces of spacecraft, tiny flecks of paint from a spacecraft, parts of rockets, satellites that are no longer working, or explosions of objects in orbit flying around in space at high speeds.[75]

Understanding where objects are (and will be) in space, sharing that information so that satellite operators can avoid collisions, and establishing the "rules of the road" among the community of space users is called space traffic management.[76] The Department of Defense has historically provided the global community with satellite and debris location information. The Obama Administration indicated that it wanted to assign it to the Federal Aviation Administration in the Department of Transportation; it was not done by the end of Obama's presidency.[77] In 2018, the Trump Administration issued Space Policy Directive 3, transferring responsibility for improving space situational awareness and coordinating space traffic management activities to the Department of Commerce.[78]

To determine which federal agency might be best suited to be the lead on space traffic management, Congress asked the National Academy of Public Administration (NAPA) for an independent assessment.[79] Released in August 2020, the resulting NAPA report concluded that the Department of Commerce Office of Space Commerce is best suited to perform non-military space situational awareness and space traffic management tasks.[80] Many policymakers continue to

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available at https://www.orlandosentinel.com/opinion/guest-commentary/os-op-broadband-internet-20190725-xdqcejglzvcoflsfja5ii7jz34-story.html.

[74] See Federal Communications Commission, "Mitigation of Orbital Debris in the New Space Age," 85 *Federal Register* 52422 *Federal Register*, August 25, 2020, available at https://www.federalregister.gov/documents/2020/08/25/2020-13185/mitigation-of-orbital-debris-in-the-new-space-age.

[75] National Aeronautics and Space Administration, *Space Debris*, available at https://www.nasa.gov/centers/hq/library/find/bibliographies/space_debris.

[76] Michael Dominguez, Martin Faga, and Jane Fountain, et al., *Managing Space Traffic in an Increasingly Congested Orbit*, Government Executive, August 20, 2020, available at https://www.govexec.com/management/2020/08/managing-space-traffic-increasingly-congested-orbit/167875/.

[77] Spacepolicyonline.com, *Senate Committee Approves Space Act, but Without a Bureau of Space Commerce*, November 18, 2020, available at https://spacepolicyonline.com/news/senate-committee-approves-space-act-but-without-a-bureau-of-space-commerce/.

[78] White House, *Space Policy Directive-3, National Space Traffic Management Policy*, Presidential Memoranda, June 18, 2018, available at https://trumpwhitehouse.archives.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/.

[79] S.Rept. 116-127, accompanying the Departments of Commerce and Justice, Science, and Related Agencies Appropriations Act, 2020 (S. 2584), p. 67.

[80] National Academy of Public Administration, *Space Traffic Management*, August 2020, p. 19, available at

disagree on this point, however, and that lack of consensus has slowed progress on making a determination on which federal agency should be the lead.[81]

There is sustained congressional interest in space traffic management. For example, the Senate Commerce Subcommittee on Space and Science held a hearing on July 22, 2021, on space traffic management[82] and on May 12, 2021, the Space Preservation and Conjunction Emergency (SPACE) Act of 2021 was approved by the Senate Commerce, Science, and Transportation Committee as an amendment to the United States Innovation and Competition Act of 2021 (S. 1260).[83] In addition to the potential for additional hearings and consideration of legislation to determine space traffic management roles and responsibilities, some have suggested that Congress consider coordinated and sustained funding for space traffic management innovation.[84]

## Reaching Fiber-like Speeds and Capacity Challenges

For rural or remote areas that have little or no access to terrestrial broadband, satellite broadband may be a viable option. GEO satellite broadband speeds do not reach the same maximum speeds achieved by fiber optic cable or cable modem (often up to gigabits per second, or Gbps), and it is currently unclear whether LEO satellite broadband will be able to in the future. SpaceX has stated it plans to deliver 10 Gbps service in the future.[85] If it or any other LEO satellite broadband provider were to achieve such speeds, they would be faster than fiber speeds currently offered to residential customers by broadband providers such as AT&T, Verizon, or Xfinity.[86]

Even if LEO satellite broadband speeds are as fast—or faster—than fiber, LEO satellite broadband may be more of a complementary than competitive technology. Elon Musk, SpaceX's Chief Executive Officer, has stated:

> I want to be clear, it's not like Starlink is some huge threat to telecos. I want to be super clear. It is not. In fact, it will be helpful to telecos because Starlink will serve the hardest-to-serve customers that telecos otherwise have trouble doing with landlines or even with ... cell towers.[87]

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https://napawash.org/uploads/NAPA_OSC_Final_Report.pdf.

[81] Jeff Foust, *Space Traffic Management Idling in First Gear*, SpaceNews, November 3, 2020, available at https://spacenews.com/space-traffic-management-idling-in-first-gear/.

[82] U.S. Senate Committee on Commerce, Science, and Transportation, *Space Situational Awareness, Space Traffic Management, and Orbital Debris: Examining Solutions for Emerging Threats*, hearing, July 22, 2021, available at https://www.commerce.senate.gov/2021/7/space-situational-awareness-space-traffic-management-and-orbital-debris-examining-solutions-for-emerging-threats/819ef822-3e6d-4ab1-9a56-31c6d60969c9.

[83] The SPACE Act of 2021 is included in the June 8, 2021, Senate-passed version of the United States Innovation and Competition Act of 2021 (S. 1260).

[84] Written testimony of Dr. Marcus J. Holzinger, *Hearing on Space Situational Awareness, Space Traffic Management, and Orbital Debris: Examining Solutions for Emerging Threats*, U.S. Senate Committee on Commerce, Science, and Transportation, Subcommittee on Science and Space, July 22, 2021, p. 2, available at https://www.commerce.senate.gov/services/files/244B2DC1-0FEB-4DE4-AF25-53EFBF2E376A.

[85] David Goldman, *Re: IBFS File No. SAT-MOD-20200417-00037; RM-11855*, Space Exploration Technologies Corporation, January 22, 2021, p. 4, available at https://ecfsapi.fcc.gov/file/101220897228398/SpaceX%208th%20Floor%20Ex%20Parte%20(01-22-2021).pdf.

[86] Angelo Ilumba, *Fastest Internet Providers*, WhistleOut, April 16, 2020, available at https://www.whistleout.com/Internet/Guides/fastest-internet-providers.

[87] YouTube, *Elon Musk, Founder and Chief Engineer, SpaceX—SATELLITE 2020 Opening Day Keynote*, Washington, DC, March 9, 2020, available at https://www.youtube.com/watch?v=HPV8Xp3pEpI.

Given the growing demand for bandwidth driven by higher speeds and multiple devices per household, the main uncertainty around Starlink today is capacity, and how this capacity will affect availability, speeds, prices, and data caps. Slots to receive initial beta Starlink service are limited in each geographic region because of capacity limits. As of August 2021, SpaceX said it had shipped 100,000 terminals to customers and received over half a million additional orders for the service.[88] Musk said that SpaceX will face a challenge if it gets millions of orders.[89]

Even with many more satellites deployed, the capacity of each satellite is limited, and a finite number of satellites are expected to be overhead at any given time. In low-density areas this capacity limitation may not be a significant issue, since the total number of users on visible satellites will be low. For denser areas, the capacity of visible satellites could be saturated and may result in Starlink having to do one or more of the following: (1) raise prices to decrease demand, (2) limit availability, (3) lower speeds, (4) implement data caps, or (5) allow over-saturation, resulting in degraded service to some subscribers.[90]

## Competition

In some locations where existing broadband options are expensive, new LEO satellite broadband market entrants could potentially provide competitively priced broadband services, increasing consumer choice and competition. For example, analysis of BroadbandNow U.S. market pricing data suggests that LEO satellite technology could save American households more than $30 billion per year by intensifying broadband competition in places with other providers.[91] When a new competitor, such as a LEO provider, enters an area, existing providers, with large capital costs already invested, may lower prices, provide other incentives, and invest in marketing in an attempt to retain customers.[92]

On the other hand, if a currently unserved area becomes served by only a single LEO satellite broadband provider, the absence of other broadband providers may lead to expensive broadband, leaving some consumers unable to connect despite availability due to cost concerns. Further, if LEO satellite companies are not able to generate sufficient revenue, or if LEO satellites fail at faster rates than anticipated, the result might be a descaling of investments, leading to connectivity and capacity issues.[93]

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[88] Aria Alamalhodaei, *SpaceX Ships 100,000 Starlink Terminals to Customers, Eyes Future Launches Using Starship*, TechCrunch, August 23, 2021, available at https://techcrunch.com/2021/08/23/spacex-ships-100000-starlink-terminals-to-customers-eyes-future-launches-using-starship/.

[89] Jon Brodkin, *Starlink Can Serve 500,000 Users Easily, Several Million "More of a Challenge,"* Arstechnica, May 5, 2021, available at https://arstechnica.com/information-technology/2021/05/spacex-gets-500000-starlink-pre-orders-musk-says-it-can-meet-demand/.

[90] Ben Fineman, *Starlink Summary: February 2021*, Michigan Broadband Alliance, p. 1, available at https://www.washtenaw.org/DocumentCenter/View/19599/Starlink-Summary-Feb-2021.

[91] Julia Tanberk, *Elon Musk and Jeff Bezos Can Save American Households $30+ Billion with LEO Satellites*, BroadbandNow, April 7, 2021, available at https://broadbandnow.com/research/leo-satellite-internet-consumer-savings-study.

[92] Chris Daehnick, Isabel Klinghoffer, and Ben Maritz, et al., *Large LEO Satellite Constellations: Will It Be Different This Time?*, McKinsey & Company, May 4, 2020, available at https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/large-leo-satellite-constellations-will-it-be-different-this-time.

[93] Jeffrey Hill, *The FCC's Path to a U.S. Nationwide 5G Rollout Gets Lost in the Thick of Rural America*, Via Satellite, available at http://interactive.satellitetoday.com/via/february-2021/the-fccs-path-to-a-u-s-nationwide-5g-rollout-gets-lost-in-the-thick-of-rural-america/.

## Selected Pilot Programs

Some pilot programs already underway may help analysts and policymakers evaluate how LEO satellite broadband might actually affect the digital divide. Among these pilot programs are examples in North Carolina and Texas.

On March 4, 2021, the office of North Carolina Governor Roy Cooper announced in a press release that school districts in Hyde and Swain counties would be implementing the "Satellite Internet Technologies for Student Connectivity Pilot," which is to allow students to access SpaceX Starlink service. According to the press release:

> "This pilot with SpaceX has the potential to help students on Ocracoke Island and in Swain Counties who, because of geographic barriers, have been unable to connect to high-speed internet and effectively participate in remote learning," Jeff Sural, BIO Director, said. "We are looking forward to testing this emerging technology and evaluating its effectiveness for our residents."[94]

On October 20, 2020, Ector County Independent School District (ECISD), a public school district based in Odessa, TX, announced in a press release that it would be the first school district in the United States to work with SpaceX and its Starlink satellite constellation to deliver high-speed, low-latency internet access for ECISD students. According to the press release:

> When COVID-19 forced the closure of school buildings last spring, it really brought to the forefront just how large the digital divide is in Ector County. As ECISD leaders dove into surveys of teachers, students and families, they found some 39% of families have limited to no Internet access.[95]

LEO satellite pilots could hold promise for connecting students to broadband. As the technology is largely still in the testing and development phases, the effectiveness and success of these pilots is likely to warrant evaluation before implementation on a larger scale. Congress may opt to consider potential inclusion in federal broadband programs, such as the FCC's schools and libraries universal service support program—known as the E-rate program—which helps schools and libraries obtain affordable broadband.[96]

## Addressing the Digital Divide: What Happens Next?

If LEO satellites can provide fiber-like speeds and low latency to remote rural and tribal areas where there are no physical impediments to access, Congress may consider how to best foster access to terrestrial and space-based broadband service for all users. In a January 2017 white paper on improving the nation's digital infrastructure, the FCC stated, "The primary goal of federal actions with respect to digital infrastructure should be to increase and accelerate profitable, incremental, private-sector investment to achieve at least 98% nationwide deployment of future-proofed, fixed broadband networks."[97] In the white paper, the FCC estimated that the

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[94] NC.gov, *New Satellite Internet Pilot Program to Connect Students in Two N.C. Counties*, March 4, 2021, available at https://governor.nc.gov/news/new-satellite-internet-pilot-program-connect-students-two-nc-counties.

[95] Ector County Independent School District, *ECISD Becomes First School District to Utilize SpaceX Satellites to Provide Internet for Students*, October 20, 2020, available at https://www.ectorcountyisd.org/cms/lib/TX50000506/Centricity/ModuleInstance/51/ECISD%20partnership%20to%20bring%20SpaceX%20satellite%20Internet%20to%20students.pdf.

[96] For more information on the E-rate program, see Federal Communications Commission, *E-Rate—Schools and Libraries USF Program*, available at https://www.fcc.gov/general/e-rate-schools-libraries-usf-program.

[97] Federal Communications Commission, *Improving the Nation's Digital Infrastructure*, January 19, 2017, p. 2,

total upfront capital expenditures required to deploy fiber to the premises[98] in the 14% of locations lacking access would be approximately $80 billion, and 98% coverage could be attained for $40 billion.[99] Recent Administration and congressional proposals seek to address this. The Biden Administration's American Jobs Plan seeks to bring affordable, reliable, high-speed broadband to every American through an investment of $100 billion, including building high-speed broadband infrastructure to reach 100% coverage.[100] Bills introduced in the 117th Congress would provide funding to address the buildout of infrastructure. For example:

- The Leading Infrastructure For Tomorrow's America Act (H.R. 1848) would provide $80 billion for the deployment of secure and resilient high-speed broadband to expand access nationwide.[101]
- The Accessible, Affordable Internet for All Act (H.R. 1783/S. 745) would provide over $94 billion to build high-speed broadband infrastructure in unserved and underserved communities.[102]

Installing fiber networks is expensive, and though this funding would help to further build out broadband infrastructure, whether it would be enough funding, or whether it is possible to connect every American—especially in areas that have difficult terrain or geographic restrictions—remains an open question. Congress may consider ways that satellite and terrestrial broadband can complement each other in order to increase coverage and create competition, which, in turn, may also help to address affordability issues.

## Broadband Adoption

While broadband infrastructure addresses a large component of the digital divide by increasing availability, there are additional geographic, social, and economic factors that affect broadband—for example, affordability and adoption rates. While broadband accessibility across the United States—especially in rural and tribal areas—has been a continuing challenge, barriers to broadband adoption, even where service is available, remain. Broadband adoption can be defined as residential subscribership to high-speed internet access.[103] Barriers that may prevent consumers from adopting broadband include the affordability of service, and unfamiliarity with digital devices and the services they support.

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available at https://www.fcc.gov/document/improving-nations-digital-infrastructure.

[98] Fiber to the Premises is a form of fiber optic communication delivery in which an optical fiber is run directly onto customers' premises. For more information, see Christina Hansen, *Understanding Fiber to the Premises (FTTP)*, CableOrganizer, available at https://www.cableorganizer.com/learning-center/articles/fiber-optics-tutorial/understanding-fttp.html.

[99] Ibid.

[100] The White House, *FACT SHEET: The American Jobs Plan*, March 31, 2021, available at https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/.

[101] House Committee on Energy and Commerce, *E&C Democrats Introduce LIFT AMERICA Act That Invests in Clean Energy, Broadband & Public Health Infrastructure*, March 11, 2021, available at https://energycommerce.house.gov/newsroom/press-releases/ec-democrats-introduce-lift-america-act-that-invests-in-clean-energy.

[102] Senator Amy Klobuchar, "Klobuchar, Clyburn Introduce Comprehensive Broadband Infrastructure Legislation to Expand Access to Affordable High-Speed Internet," March 11, 2021, available at https://www.klobuchar.senate.gov/public/index.cfm/2021/3/klobuchar-clyburn-introduce-comprehensive-broadband-infrastructure-legislation-to-expand-access-to-affordable-high-speed-internet.

[103] Colin Rhinesmith, Ph.D, *Digital Inclusion and Meaningful Broadband Adoption Initiatives*, Benton Foundation, Evanston, IL, January 2016, p. 8, https://www.benton.org/sites/default/files/broadbandinclusion.pdf.

The price of commercial home broadband service is among the most significant barriers to broadband adoption—especially for lower income consumers, who are far less likely to have home internet subscriptions than their middle- and upper-income neighbors (including in urban and suburban areas as well as in under-connected rural and tribal areas).[104] The FCC's Lifeline and temporary Emergency Broadband Benefit (EBB) Programs address broadband affordability. Congress may consider making the EBB program permanent, or create additional federal programs that address broadband affordability. Additionally, incorporating price and adoption data into broadband mapping—overlaying the data with the current FCC data on broadband availability to identify existing service gaps and adoption trends across the United States—may help the FCC, RUS, and NTIA better target programs designed to address the digital divide.

# Concluding Observations

Broadband availability is unevenly distributed throughout the United States. During the COVID-19 pandemic, broadband has been used for some aspects of daily life, such as remote work or schooling. Congress has shown an interest in ensuring that all citizens have access to broadband with the enactment of the Coronavirus Aid, Relief, and Economic Security Act (P.L. 116-136), the Consolidated Appropriations Act, 2021 (P.L. 116-260), and the American Rescue Plan Act of 2021 (P.L. 117-2), each of which contains provisions for broadband.

There are numerous federal broadband programs that attempt to address the digital divide and there are a number of technologies that may help expand access—however, there are still geographic and economic challenges to closing the digital divide. One potential option to provide broadband service in those remote areas is through LEO satellite broadband. As an emerging industry, dynamics that will affect affordability and adoption—technology development, sectoral competition, spectrum availability, and regulation—are still in flux. Congress may assess the potential impact of funding satellite broadband on federal broadband programs, whether LEO satellites appear to have the potential to close or widen the digital divide, and whether legislation is needed to address regulatory challenges.

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[104] National Digital Inclusion Alliance, *Policy*, available at https://www.digitalinclusion.org/policy/.

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