Low Earth Orbit (LEO) Satellite Feasibility Report

Washington State Department of Commerce

Pursuant to Chapter 474, Laws of 2023, SB 5200. Sec. 1037 (2023)

THE WASHINGTON STATE BROADBAND OFFICE (WSBO)

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Report to the Legislature

Director Mike Fong

v3.4

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Key terminology

- **Broadband; Broadband Service:** The term "broadband" or "broadband service" has the meaning given the term "broadband internet access service" in Section 8.1(b) of title 47, Code of Federal Regulations, meaning it is a mass-market retail service by wire or radio that provides the capability to transmit data to and receive data from all or substantially all internet endpoints, including any capabilities that are incidental to and enable the operation of the communications service, but excluding dial-up internet access service. This term also encompasses any service that the Federal Communications Commission (FCC) finds to be providing a functional equivalent of the service described in the previous sentence. [1]
- **Broadband Serviceable Location (BSL):** A business or residential location in the United States at which fixed broadband internet access service is, or can be, installed. [2]
- **Extremely High Cost per Location Threshold (EHCT):** The extremely high-cost threshold is a Broadband, Equity, Access, and Deployment (BEAD) Program subsidy cost per location to be established and utilized during the program's subgrantee selection process. Although BEAD prioritizes projects designed to provide fiber to the end user, the state may decline to select a proposal that exceeds the EHCT if using an alternative technology that meets the BEAD Program's technical requirements would be less expensive. [3]
- **High-Cost Area:** As defined by the National Telecommunications and Information Administration (NTIA), constitutes an unserved area in which the cost of building out broadband service is higher, as compared with the average cost of building out broadband service in unserved areas in the United States, incorporating factors that include: (1) the remote location; (2) the lack of population density; (3) the unique topography; (4) a high rate of poverty; or (5) any other factor determined by the NTIA Assistant Secretary, in consultation with the Federal Communications Commission (FCC), that contributes to the higher cost of deploying broadband service in the area. [4]
- **Low Earth Orbit (LEO) satellite:** LEO satellites represent the next generation of satellite technology that provides a low-latency (fast connection with minimal delay), high-speed connection, supporting real-time communication.[5] They operate anywhere from 311 miles to 1,243 miles above the Earth's surface - much lower than traditional geostationary (GEO) satellites or medium earth orbit (MEO) satellites. Like traditional satellites, LEO satellites function by transmitting wireless signals using "bands" of spectrum (i.e., radio frequencies) between a satellite in LEO and a dish positioned to pick up that signal. LEO satellite internet does not rely on wired infrastructure to operate and requires only an electrical connection and Wi-Fi modem. Today, the primary intention of LEO satellite is to serve communications markets.[6]
- **Reliable Broadband Service:** broadband service that the Broadband DATA Maps show is accessible to a location via: (i) fiber-optic technology; (ii) cable modem/hybrid fiber-coaxial technology; (iii) digital subscriber line (DSL) technology; or (iv) terrestrial fixed wireless technology utilizing entirely licensed spectrum or using a hybrid of licensed and unlicensed spectrum. The list of technologies notably excludes satellite service, including that delivered by LEO satellite technology. [7]

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[1] Broadband Breakfast, "LEO Technology Could Connect the Unconnected, Although Capacity Questions Remain," (2022), https://broadbandbreakfast.com/2022/12/leo-technology-could-connect-the-unconnected-although-capacity-questions-remain/
[2] National Telecommunications and Information Administration, "Broadband Equity, Access, and Deployment Notice of Funding Opportunity," (2022), https://broadbandusa.ntia.doc.gov/sites/default/files/2022-05/BEAD%20NOFO.pdf
[3] NTIA (2022)
[4] NTIA (2022)
[5] SES, " GEO, MEO, and LEO - How orbital altitude impacts network performance in satellite data services," (2023), https://www.satellitetoday.com/content-collection/ses-hub-geo-meo-and-leo/
[6] NTIA (2022)
[7] NTIA (2022)

Executive Summary

Overview

The National Telecommunications and Information Administration's (NTIA) allocated Washington approximately $1.23 billion in federal broadband infrastructure funding through the Broadband, Equity, Access, and Deployment (BEAD) Program. The intent of the BEAD program is to achieve universal broadband access and equitable build-out of last-mile broadband infrastructure, prioritizing areas of the state that are currently unserved or underserved. This is no easy task. Analysis by the Washington State Broadband Office (WSBO) finds that the cost of deploying high-speed fiber technology to all unserved and underserved locations exceeds available BEAD funding by at least $500 million.[8]

NTIA's recently published National Broadband Availability Map (NBAM) high-cost threshold tool estimates that the investment cost of deploying fiber to all unserved and underserved locations in Washington exceeds the state's BEAD allocation by $624.1 million, an even bigger potential gap. In these areas, the high cost of installing fiber infrastructure and low anticipated revenue are barriers to broadband deployment. In turn, these high-cost locations may instead be better served by alternative broadband technologies, such as fixed wireless or satellite, depending on the context.

This report explores the feasibility of one such alternative deployment option, Low Earth Orbit (LEO) satellite technology, as a potential solution to provide high-speed broadband access for residents living in these areas.

What is Low Earth Orbit (LEO) satellite technology?

LEO satellites are an emerging technology that offers higher speeds and faster response times (lower latency) than traditional geostationary (GEO) satellites. LEO satellites operate at much lower altitudes than GEO ones, requiring more satellites to form a "constellation" and provide global coverage. [9] SpaceX activated Starlink service in the United States in October 2020 and now operates internationally. It is currently the only LEO broadband service provider in the U.S. and operates in Washington. Amazon's Project Kuiper recently launched their prototype satellites to start building their network, but it is not operational yet.[10] LEO offers key advantages to GEO satellites or fixed terrestrial broadband technology in remote areas with low density and challenging topography. It can be quickly and flexibly deployed to areas of the state that lack connectivity and can support network resilience in emergency management contexts.

Key findings impacting Washington broadband infrastructure plans:

Applicability of LEO within BEAD implementation

- LEO satellite technology has made significant advances in recent years, and there are promising examples of its use in Washington. This technology should be considered in conjunction with other broadband access technologies as part of the state's strategy to achieve universal broadband access.
- LEO satellite technology is presently not considered a reliable broadband service in the BEAD Notice of Funding Opportunity (NOFO).

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[8] Department of Commerce, "Internet for All in Washington - Five Year Action Plan for Broadband Equity, Access, and Deployment," (2023), https://deptofcommerce.app.box.com/s/yr03ll1kw1rpd7x4w4wk0z5g6gdah90n

[9] TLGS Consulting Group, " LEO-Satellite Constellations: The Future of High Speed Comms?" (2023), https://tlgs.consulting/2023/07/19/leo-satellite-constellations-the-future-of-high-speed-comms/

[10] The FCC approved Amazon's network in 2020 and gave the company a deadline to launch and operate 50% of its satellites no later than July 30, 2026. More information can be found at: https://docs.fcc.gov/public/attachments/FCC-20-102A1_Rcd.pdf

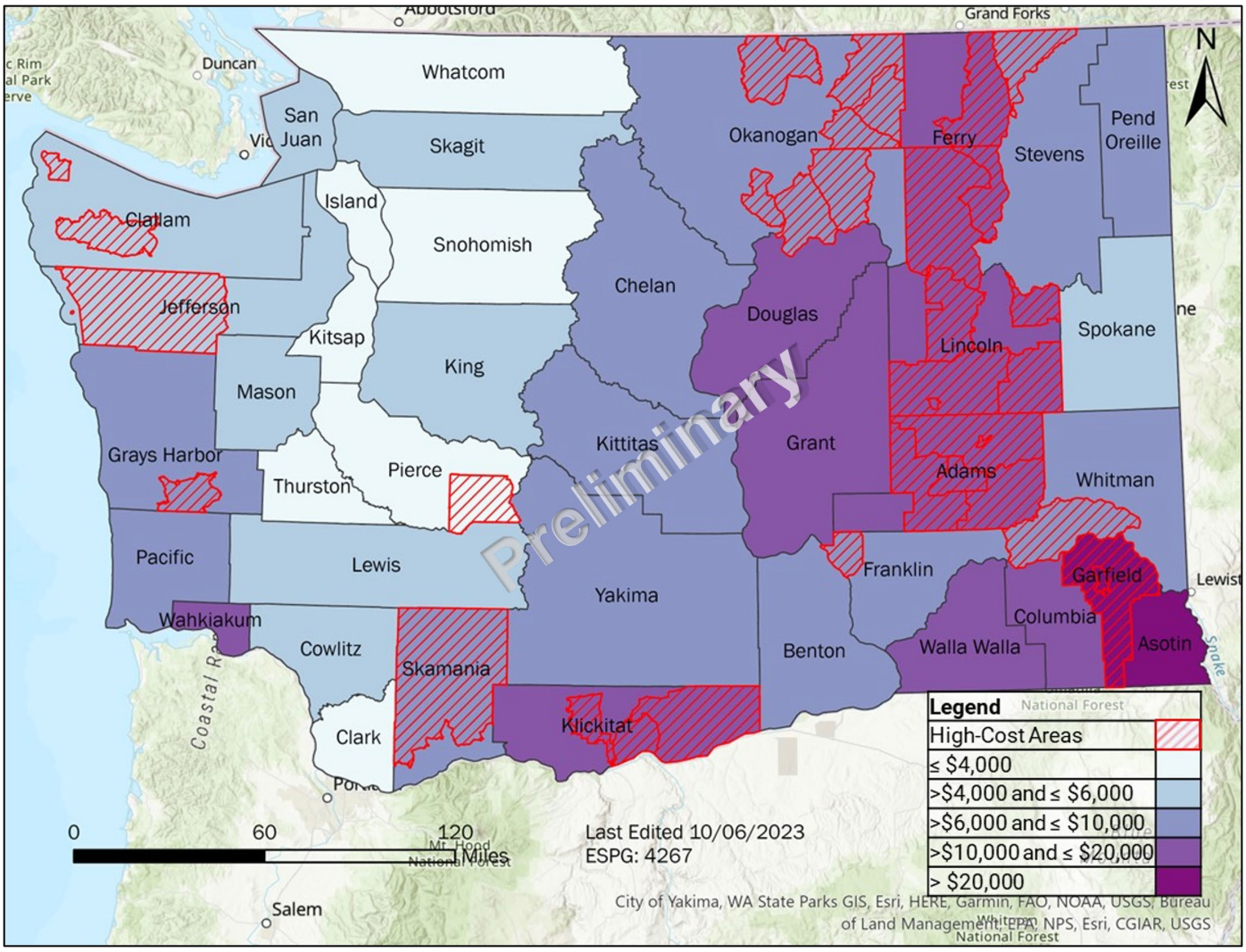
- **Therefore, LEO satellite BEAD applications will only be considered after applications from reliable alternative technologies (such as licensed, fixed wireless) are reviewed. The WSBO will be able to select alternative technologies to fiber for any location where proposals exceed the Extremely High Cost Per Location Threshold (EHCT). The WSBO will set the EHCT after receiving BEAD applications in mid to late 2024.**

Cost comparison of fiber and LEO deployment

- The current advertised price point does not reflect the network infrastructure cost of expanding LEO service. Current per-location infrastructure cost estimates for Starlink's BEAD offering range from $3,750 to $5,000.[11] While this remains lower than what many end-to-end fiber costs per location will be, it is still much higher than the $600 initial capital costs that households may be familiar with. [12]
- Analysis of the latest NBAM data indicates that the cost per location of deploying fiber ranges from $3,234 to $31,486, depending on the county. A Benton Institute report on deploying licensed fixed wireless indicates that network infrastructure costs can range from $465 to $3,950 depending on rurality.[13] However, it is necessary to consider factors such as the maintenance and total cost of ownership of each technology option as part of investment decision-making. Figure 2 illustrates this cost comparison.
- In certain areas of the state where it is not cost-effective or feasible to deploy fiber, fixed wireless, or other technologies, LEO might have a part to play in servicing high-cost locations. Figure 1 highlights preliminary high-cost areas by county, indicated in the NBAM data, many of which are located in counties where the average cost of fiber deployment per broadband serviceable location (BSL) exceeds $20,000.
- **Therefore, Washington should encourage applications from LEO providers as part of the BEAD process and apply the EHCT as a way to stretch BEAD funds for each eligible location.**

[11] Starlink, "Starlink BEAD Offering to Washington," (presentation delivered 8/25/23; not published)
[12] Starlink, "Order Starlink," (2023), https://www.starlink.com/
[13] Benton, "Fixed Wireless Technologies and Their Suitability for Broadband," (2022), https://www.benton.org/sites/default/files/FixedWireless.pdf

Figure 1: Average cost per broadband serviceable location, by county[14] [15]



How these findings might evolve as Washington enters the next phase of the BEAD process

LEO satellites will continue to be a part of the state's broadband ecosystem; however, unless its designation as an unreliable technology is changed, its inclusion in the state's BEAD plans will be limited to special, high-cost circumstances.

The WSBO is presently in the Initial Proposal phase of the BEAD program, which describes the competitive process the state proposes to use to select subgrantees. The WSBO will continue to monitor reliability determinations from the NTIA and encourage applications from all types of internet service providers when it opens its subgrantee selection process in 2024. By allowing and encouraging applications in addition to fiber, the state will give itself more options to achieve universal access for all unserved and underserved locations with the allocated funding.

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[14] The National Broadband Availability Map, "WA_BSL_ProjArea," (2023)
https://experience.arcgis.com/experience/634f354d7004487a9bc6617efcde6646

[15] Note: The Subgrantee Selection Tool provided in the Eligible Entity Planning toolkit offers investment cost data for unserved and underserved BSLs in Washington. After deduplication analysis, NBAM reports 236,136 unserved and 85,433 underserved BSLs. The Subgrantee Selection toolkit has investment cost information for only 206,101 unserved and 83,379 underserved BSLs.

Introduction

In November 2021, President Biden signed the Bipartisan Infrastructure Law (BIL), or Infrastructure Investment and Jobs Act, into law. The BIL established more than $42 billion for broadband infrastructure investment nationwide through the Broadband Equity, Access and Deployment (BEAD) Program. Washington's allocation is $1.23 billion with the goal to bring high-speed broadband service to all unserved and underserved areas statewide. Similarly, Washington has a 2028 goal to provide universal high-speed access to all homes and businesses. However, preliminary state and federal estimates project Washington will require $500 to $600 million more to fulfill our shared goals for universal high-speed access.

The 2023 Washington State Legislature[16] required the Washington State Broadband Office (WSBO) to undertake a feasibility study on how Low Earth Orbit satellite (LEO) may add to the state's broadband deployment capabilities, including its intersection, if any, with BEAD. Specifically:

> [The] state broadband office to study and report on the feasibility of increasing broadband access in unserved and underserved areas of the state through low-orbit satellite networks. The study must evaluate factors such as unique topography, lack of population density, remote location, and other considerations related to cost-effective broadband service delivery. The study must include, at a minimum:
>
> (a) A comparison of the estimated costs of satellite network build-out with the design and construction costs of other broadband service infrastructure types such as fiber optic and wireless technologies in unique geographic areas; and
>
> (b) Identification of areas not prioritized for federal support in the five-year action plan submitted by the office in accordance with the broadband equity, access, and deployment program funded under P.L. 117-58 (infrastructure investment and jobs act) and recommendations for how to improve broadband service in those areas.
>
> (2) The office must report findings and recommendations resulting from the study to the governor and the appropriate committees of the legislature by December 1, 2023.

As part of this research, the WSBO's report explores factors that impact the cost-effectiveness of broadband service delivery, such as topography, remoteness, and population density. The final report and analysis conducted by the WSBO are informed by a combination of research, interviews, and quantitative analysis. Current research on Low Earth Orbit (LEO) satellite technology and its applications is derived from academic research papers, government reports, news articles, and industry and service providers. Representatives from SpaceX (Starlink) and Amazon (Project Kuiper) were interviewed to understand better current and forthcoming LEO service offerings in Washington and perspectives on how LEO service might fit into the state's broadband infrastructure portfolio. Additionally, leaders from the Hoh Tribe in western Washington were interviewed to learn about their experience using Starlink service. Together, this information helped to provide a baseline assessment of LEO technology.

Additionally, this report relies on the latest Federal Communications Commission (FCC) Broadband Data Collection (BDC) data and National Broadband Availability Map (NBAM) to assess the cost of deploying last-mile fiber service to unserved and underserved locations in Washington. This data is supplemented by LEO provider infrastructure cost data, when available, to conduct a comparative assessment of the costs of alternative deployment options. This can help identify areas of the state where LEO satellite service may be explored as a broadband access solution.

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[16] Chapter 474, Laws of 2023

Current state of LEO technology and applications

LEO satellite broadband technology may hold promise for further addressing internet availability gaps in Washington, especially in remote or rural areas. With the introduction of LEO satellites, there is potential for satellite broadband to deliver speeds closer to those that can be achieved by technologies like fixed wireless or cable, as well as shorter response times (lower latency) than traditional GEO satellites.

However, given that commercial LEO technology development, testing, and deployment for telecommunications is still in relatively early stages, it may not be as reliable or resilient as other broadband technologies such as fiber.[17] Companies seek to refine LEO technology to deliver higher speeds, lower latency, and expanded coverage. There remains much to discover and improve with LEO technology. As the state explores the provision of broadband internet through LEO satellites, it can consider key questions facing this new era of satellite communications. For example, will user terminals and service plan costs be competitive with other broadband technologies' equipment and service plans, and will LEO satellite providers meet broadband service expectations and attract many end-users

Satellite infrastructure[18]

What is satellite broadband and how does it work?

Satellite internet service is provided by geostationary orbit (GEO), medium Earth orbit (MEO), or low Earth orbit (LEO) using specific bands of radio spectrum. Not all satellite technologies can currently deliver target minimum broadband level speeds and latency as established in the BEAD Notice of Funding Opportunity (NOFO) -- a minimum of 100 Mbps download and 20 Mbps upload with no more than 100 milliseconds latency. The satellite classifications are based on their orbital characteristics -- described in greater detail below. Satellites use specific segments or "bands" of the spectrum, which are radio frequencies that transmit signals wirelessly from one facility or device to another.[19] It works like this, "the process begins with Internet Service Providers (ISPs) sending satellites into space to orbit around the earth. That ISP then relies on a signal routed through one of those satellites in low- or high-Earth orbit and a receiver dish that picks up that signal. The receiver is typically placed on one's home or business in a spot with as unobstructed access to the sky as possible." [20] Connecting a modem to that dish will translate the incoming signal into a workable internet connection. Electricity is also required to power the receiver dish. Unlike fixed terrestrial broadband infrastructure, satellite internet is not dependent on cable wire infrastructure.

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." A satellite orbiting over the equator will remain above the same ground location throughout its orbit, which is referred to as a geostationary orbit. 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,

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[17] Congressional Research Service, "Low Earth Orbit Satellites: Potential to Address the Broadband Digital Divide," (2022), https://crsreports.congress.gov/product/pdf/R/R46896

[18] Congressional Research Service, "Low Earth Orbit Satellites: Potential to Address the Broadband Digital Divide," (2022), https://crsreports.congress.gov/product/pdf/R/R46896

[19] CTIA, "What is Spectrum? A Brief Explainer," (2018), https://www.ctia.org/news/what-is-spectrum-a-brief-explainer

[20] CNET, "Wondering How Satellite Internet Works? CNET Explains," (2022), https://www.cnet.com/home/internet/satellite-internet-explained/

communications, and surveillance. According to the FCC, broadband service from GEO satellites can offer speeds of 25/3 Mbps to nearly the entire U.S. population."[21]

Based on coverage, the top two GEO satellite providers in the U.S. and Washington are Viasat and HughesNet. HughesNet has service plans that range in advertised download speeds from 15 Mbps to 50 Mbps and data caps ranging from 15 GB to 200 GB. Viasat offers plans with download speeds ranging from 25 Mbps to 100 Mbps and data caps ranging from 60 GB to 500 GB. Higher speed plans are not universally available and are priced higher than Starlink on a per Mbps basis (see Appendix Table 3 for plan information).[22]

Other GEO operators include Eutelsat, Inmarsat, and Intersat. GEO satellites are typically the size of a bus. They are large and expensive to build, but because they are more than 22,000 miles above earth, they can provide global coverage with just a few satellites. Configuring their antennas is also relatively straightforward because geostationary satellites move in the same direction as the earth rotates and always appear in the same location in the sky.[23]

Medium Earth orbit (MEO) satellites

Medium Earth orbit (MEO) satellites operate at altitudes between 1,242 miles to 22,236 miles, but most satellites range between 11,200 miles to 14,900 miles above the earth's surface.[24] For example, the Global Positioning System (GPS) constellation orbits at 12,550 miles.

Low Earth orbit (LEO) satellites

LEO satellites operate from approximately 311 miles to 1,243 miles above the earth's surface -- much lower than GEO satellites. Because transmitted data does not have to travel as far to reach the satellite and return to Earth, LEO satellite companies advertise and provide faster broadband speeds and lower latency than GEO satellite service.[25] Standard Starlink plans offer speeds of 25 Mbps to 100 Mbps; priority plans offer speeds of 40 Mbps to 220 Mbps. 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 hundreds or thousands of satellites to maintain coverage but may mitigate loss of coverage due to weather or obstructions.[26] While individual LEO satellites cost less than GEO satellites, thousands are required to provide global coverage because their beams are smaller. Therefore, the total cost of a LEO satellite constellation is quite substantial. The typical lifespan of a LEO satellite is 7–10 years due to factors such as atmospheric drag, the atmospheric force acting opposite to the relative motion of an object.[27]

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[21] Congressional Research Service, "Low Earth Orbit Satellites: Potential to Address the Broadband Digital Divide," (2022), https://crsreports.congress.gov/product/pdf/R/R46896

[22] FCC, National Broadband Map, 2023, https://broadbandmap.fcc.gov/home; Viasat, Home Internet Plans, https://www.viasat.com/satellite-internet/plans/ (accessed August 2023); HughesNet, Home Internet Plans, https://www.hughesnet.com/get-started (accessed August 2023)

[23] Internet Society, "Perspectives on LEO satellites," (2022), Perspectives on LEO Satellites - Using Low Earth Orbit Satellites for Internet Access (internetsociety.org)

[24] U.S. Space Systems Command, "LEO, MEO or GEO? Diversifying orbits is not a one-size-fits-all mission (Part 2 of 3)

[25] Ookla, "New Speedtest Data Shows Starlink Users Love Their Provider," (2023), https://www.ookla.com/articles/starlink-hughesnet-viasat-performance-q1-2023; Starlink, HughesNet, and Viasat provider websites (see Appendix Table)

[26] Internet Society, "Perspectives on LEO satellites," (2022), Perspectives on LEO Satellites - Using Low Earth Orbit Satellites for Internet Access (internetsociety.org)

[27] Master Class, "What Is Atmospheric Drag? Learn How Atmospheric Drag Works and Its Impact on Space Missions," (2021), https://www.masterclass.com/articles/what-is-atmospheric-drag

There are three primary components of a LEO system: satellites, user terminals, and ground stations. All three components communicate with each other using federally licensed spectrum frequencies. A description of each LEO system component is provided below:

- **Satellite constellation:** Satellites that are launched into orbit and typically arranged into different arrangements at different altitudes.
- **User terminal:** Sometimes referred to as a ground terminal or simply an antenna or dish, this component allows users to receive data from and transmit data to the satellites. LEO companies selling to consumers may also package additional equipment with the terminal, such as a Wi-Fi router. LEO ground terminals must be able to track and work with multiple LEO satellites within the LEO constellation.
- **Ground stations:** Sometimes called gateways, these terrestrial radio stations connect the satellites to the rest of the internet. LEO satellites typically need to be within range of a ground station to send or receive data. This can limit the availability of a LEO system in a region with no ground station available. Inter-satellite links can help to mitigate this issue.[28]

Market analysis

GEO satellites have provided satellite broadband service for decades, while LEO satellite systems currently constitute a small segment of the satellite broadband market share and an even smaller segment of the overall broadband market. Companies such as SpaceX's Starlink, Viasat, Amazon's Project Kuiper, and EchoStar's HughesNet are growing the LEO satellite services market and connecting new households. At the forefront of the LEO expansion is Starlink. . According to one estimate, 50% to 70% of Starlink's base is from growing the satellite internet market rather than taking market share from other satellite providers.[29] The 2022 American Community Survey 5-Year Summary provides that 6% of Washington residents (183,322) currently rely on satellite internet, an almost 10% increase since 2018.[30] There is currently no available data to determine what percentage of that is LEO satellite service; however, based on trends, LEO satellite systems are expanding their share. This represents a significant market opportunity given the projected growth of the satellite internet market at a compound annual growth rate (CAGR) of 33.7% between 2023 to 2028.[31] At present, Starlink reportedly serves more than 2 million subscribers across 60 countries.[32]

Starlink is currently the only LEO operator providing residential broadband service in the U.S. This is expected to change with the introduction of Amazon's Project Kuiper in the coming years. In 2018, the FCC approved SpaceX's application to use certain radio frequencies to deploy and operate 4,425 communications satellites for Starlink.[33] In 2019, SpaceX launched the first batch of 60 functional LEO satellites and activated its beta

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[28] Internet Society, "Perspectives on LEO satellites," (2022), Perspectives on LEO Satellites - Using Low Earth Orbit Satellites for Internet Access (internetsociety.org)
[29] CNBC, "Investing in Space: Is SpaceX's Starlink growing satellite internet market share, or taking it?" (2023), Investing in Space: Where SpaceX's Starlink is growing market share (cnbc.com)
[30] U.S. Census, American Community Survey 2022 and 2018 5-Year Summary Estimates, S2801 Types of Computers and Internet Subscriptions, "Percentage of households with satellite internet service," https://data.census.gov/table?q=broadband&g=040XX00US53
[31] Markets and Markets, "Satellite Internet Market by Orbit," (2022), https://www.marketsandmarkets.com/Market-Reports/satellite-internet-market-139239513.html
[32] Starlink, "Starlink Overview," (presentation delivered 8/25/23; not published)
[33] FCC, "FCC Authorizes SpaceX to Provide Broadband Satellite Services," (2022), https://docs.fcc.gov/public/attachments/FCC-18-38A1_Rcd.pdf

service in October 2020.[34] Amazon received approval from the FCC in 2020 to deploy 3,236 satellites for Project Kuiper by July 2026.[35] Amazon intends to start providing beta service by the end of 2024.[36]

Availability

Traditional GEO satellite service is the most widely available service offering throughout the state. In terms of coverage in Washington, FCC BDC data indicates that Viasat service is available at 99.65% of broadband serviceable locations, HughesNet service is available at 100% of broadband serviceable locations (BSLs), and Starlink service is available at 99.98% of locations. Despite widespread coverage, satellite represents a relatively low broadband market share. Most (80.8%) of broadband internet subscribers in Washington are connected via wireline technologies such as cable or fiber.[37]

Affordability

Affordability of service is also a factor to consider in determining whether LEO satellite service is a sustainable solution to bridge the digital divide. The current monthly price of LEO satellite service (such as, Starlink) exceeds the cost of most fiber and fixed wireless plans offering comparable speeds, data, and latency. Residential Starlink service currently ranges from $110 to $120 per month plus a one-time $600 hardware fee.[38] Although Starlink has higher startup and monthly service costs, there is no contract commitment. See Appendix Table 3 for more details. In comparison, the price of fiber service plans ranges from $55 to $75, and the price of fixed wireless service plans ranges from $50 to $90.[39] The price of the Wi-Fi equipment is included in the monthly service fee in most cases. This demonstrates that despite various technical advantages, affordability may represent a concern related to LEO broadband services.

Competition

Starlink is currently the only LEO satellite provider offering residential broadband service in the U.S. market. Its primary consumer base is residential users accessing everyday internet applications. It is available to remote and rural locations, representing key focus areas for the BEAD Program. The features distinguishing Starlink's LEO service from GEO satellites include lower latency, higher overall network capacity, and higher bandwidths.

In comparison, HughesNet has a lower monthly cost ($64.99–$149.99) but requires a 24-month commitment while giving the option to rent or purchase the equipment.[40] Another distinction is that HughesNet offers the minimum broadband level speeds for upload and download, which may dip below advertised speeds at peak hours of usage. The number of competitors in the LEO satellite market may ultimately depend on factors such as U.S. and foreign regulations and federal subsidies.

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[34] Starlink, "Starlink Overview," (presentation delivered 8/25/23; not published)
[35] FCC, "FCC Authorizes Kuiper Satellite Constellation," (2020), https://docs.fcc.gov/public/attachments/FCC-20-102A1_Rcd.pdf
[36] Amazon, "How Amazon's Project Kuiper is preparing for its first satellite test mission, and what we hope to learn," (2023), https://www.aboutamazon.com/news/innovation-at-amazon/project-kuiper-prototype-satellite-test-mission
[37] U.S. Census, American Community Survey 2022 and 2018 5-Year Summary Estimates, S2801 Types of Computers and Internet Subscriptions, "Percentage of households with broadband such as cable, fiber, or DSL," https://data.census.gov/table?q=broadband&g=040XX00US53
[38] Starlink, "Order Starlink," (2023), https://www.starlink.com/
[39] Verizon, T-Mobile, CenturyLink
[40] estNet, "Home Internet Plans", (2023) https://www.hughesnet.com/get-started

Example alternative applications

Beyond the provision of direct residential internet service, LEO satellites have additional applications in multiple domains, including but not limited to disaster response, agriculture, and rural health care. Satellites are gaining traction in Internet of Things[41] (IoT) applications, such as detecting and responding to earthquakes, fires, and floods.[42] They play a pivotal role in areas difficult to reach or evacuate quickly. Beyond disaster response, LEO satellite-enabled sensors have additional applications for climate change research, water management, drone surveillance, and wildlife monitoring.[43]

LEO satellites also support access to everyday resources and opportunities. They are increasingly used to provide connectivity and telemedicine services in remote areas. Unlike their GEO counterparts, LEO satellites offer lower-latency and higher-speed communication channels, which can better facilitate the transmission of medical data.[44] This can support improved access to healthcare, particularly for rural individuals who currently must travel long distances to access critical medical advice or specialty consultations.

Satellite solutions can also play a key role in the agriculture industry. Given the remote nature of most agricultural operations, satellites can represent a connectivity solution for farmers due to the portability and longevity of associated equipment.[45] More specifically, LEO satellites allow terminals with a long battery life and portable design. This can allow for more efficient tracking of equipment and livestock using small tracking devices, which previously may have been much more costly and required additional heavy equipment to monitor.

Policy and regulatory landscape

Given the rise of internet adoption, e-commerce, and social media activity, modern society's bandwidth needs and applications are vastly different from those of the recent past. The expanding market for LEO satellite systems may address many of these modern applications and the general increase in demand for connectivity. However, the widespread expansion of broadband internet offered through LEO hinges upon an ever-expanding constellation of space services. These rely on radio frequency spectrum and satellite orbits—limited natural resources increasingly in demand as radio communication services expand worldwide.[46] The "space in space" needs to be well managed to allow for its sustainability.[47]

United States Federal regulations

To deploy a satellite constellation, a LEO operator, first and foremost, needs to obtain spectrum rights. The use of spectrum (radio frequencies) is regulated to avoid interference among users. In the U.S., the FCC and the

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[41] "The networking capability that allows information to be sent to and received from objects and devices (such as fixtures and kitchen appliances) using the Internet." Merriam-Webster.com Dictionary, s.v. “Internet of Things,” accessed November 21, 2023, https://www.merriam-webster.com/dictionary/Internet%20of%20Things.

[42] TS2, "The Role of LEO Satellites in Disaster Management and Emergency Response," (2023), https://ts2.space/en/the-role-of-leo-satellites-in-disaster-management-and-emergency-response/

[43] Dragonfly Aerospace, "What are Some Applications of a LEO Satellite," (2022), https://dragonflyaerospace.com/what-are-some-applications-of-a-leo-satellite/

[44] IP Access International, "LEO Satellites--Bridging Healthcare Gaps," (2023), https://www.ipinternational.net/how-satellite-telemedicine-saves-lives/

[45] Eutelsat Group, "A Revolution in IOT for Farmers," (2023), https://www.eutelsat.com/en/blog/revolution-in-iot-for-agriculture.html

[46] The UN Specialized Agency for ICTs, " WRS-22: Regulation of satellites in Earth’s orbit," (2022), https://www.itu.int/hub/2023/01/satellite-regulation-leo-geo-wrs/

[47] Note: Another policy topic that is often brought up related to LEO satellite expansion is space debris. In fact, the FCC recently adopted a new 5-Year Rule for Deorbiting Satellites in September 2022. This new rule shortens the timeframe required for satellite post-mission disposal from 25 to 5 years. The previous rule recommended that operators with satellites in low Earth orbit ensure their spacecraft will re-enter Earth's atmosphere within 25 years following the completion of their mission.

NTIA regulate and manage spectrum use. The FCC manages non-federal use (e.g., commercial, state, and local government), while the NTIA manages federal use. Space services' increasing demand and complexity have prompted the FCC to revisit current policies. Earlier this year, FCC Chairwoman Jessica Rosenworcel indicated that the FCC will vote on new rules to "…expedite the processing of space and earth station applications [which] will promote competition and innovation by making it easier for new companies to enter the market."[48]

Funding landscape

The growth and sustainability of the LEO satellite market depends in part on the availability of public funding to subsidize the high upfront capital investment. However, LEO satellite solutions have been excluded from recent federal funding opportunities. This included the recent decision of the FCC to withdraw its $885 million grant in Rural Digital Opportunity Fund (RDOF) funding to Starlink. The FCC argued that its initial decision was "flawed as a matter of both law and policy." Although Starlink filed an Application for Review with the Commission, its bid to connect more than 640,000 unserved locations across 35 states was rejected.[49] "The Commission determined that these applications failed to demonstrate that the providers could deliver the promised service. Funding these vast proposed networks would not be the best use of Universal Service Fund dollars." The Chairwoman commented, "Starlink's technology has real promise…. But the question before us was whether to publicly subsidize its still developing technology for consumer broadband."[50]

Broadband, Equity, Access, and Deployment (BEAD) Program

The BEAD program, a $42.45 billion broadband infrastructure grant program, of which Washington has been allocated nearly $1.23 billion, funded by the Bipartisan Infrastructure Law (BIL), does not recognize LEO internet service as 'Reliable Broadband Service', rendering it lower in priority for federal funds. The BEAD NOFO states that for the BEAD Program, locations served exclusively by satellite services using entirely licensed spectrum or a technology not specified by the FCC for purposes of the Broadband DATA Maps do not meet the criteria for Reliable Broadband Service and will be considered "unserved."[51]

Acknowledging that some locations may be cost-prohibitive to serve with fiber, the BEAD NOFO stipulates that states may establish an "Extremely High Cost Per Location Threshold above which an Eligible Entity may decline to select a proposal if use of an alternative technology meeting the BEAD Program's technical requirements would be less expensive."[52] In these circumstances, the state can select applications for alternative technologies deemed reliable, such as licensed fixed wireless. However, where it may not be feasible to deploy such technologies, LEO satellite broadband services may represent a viable alternative. In conjunction to the Extremely High Cost Per Location Threshold, High-Cost Areas, as defined by the NTIA, may have implications on broadband technology determinations within applicable areas. The NTIA defines an area

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[48] Federal Communications Commission, " Chairwoman Rosenworcel Remarks to the Global Aerospace Summit," (2023), Chairwoman Rosenworcel Remarks to the Global Aerospace Summit | Federal Communications Commission (fcc.gov)
[49] Fierce Telecom, "Starlink appeals FCC denial of $885M RDOF subsidy," (2022), https://www.fiercetelecom.com/telecom/starlink-appeals-fcc-denial-885m-rdof-subsidy#:~:text=Last%20month%2C%20the%20FCC%20rejected,unserved%20locations%20in%2035%20states.
[50] Federal Communications Commission, " FCC Rejects Applications of LTD Broadband and Starlink for Rural Digital Opportunity Fund Subsidies," (2022), https://docs.fcc.gov/public/attachments/DOC-386140A1.pdf
[51] National Telecommunications and Information Administration, "Broadband Equity, Access, and Deployment Notice of Funding Opportunity," (2022), https://broadbandusa.ntia.doc.gov/sites/default/files/2022-05/BEAD%20NOFO.pdf
[52] National Telecommunications and Information Administration, "Broadband Equity, Access, and Deployment Notice of Funding Opportunity," (2022), https://broadbandusa.ntia.doc.gov/sites/default/files/2022-05/BEAD%20NOFO.pdf

as "high-cost" if the cost of building out broadband service is higher than the national average cost of building out broadband service in unserved areas.[53]

As the state evaluates opportunities to use LEO satellite systems for broadband service, it is important to consider when LEO satellites represent the optimal solution for connectivity gaps. LEO satellite technology might be beneficial for locations where it may be difficult to install fiber or fixed wireless technologies due to extremely high costs. Topography may also play a factor when it is challenging for a fixed wireless application to have line-of-sight to a location. This may not be feasible in parts of the state that are bisected by mountains, forests, or other unique, challenging terrain.

Beyond feasibility considerations, it is imperative also to consider the speed of deployment and service quality of the internet offered through LEO satellites compared to that of alternative technologies. Regarding capacity, fiber remains the optimal solution, as this technology type is not affected by the same capacity issues as fixed wireless or satellite service. A benefit of deploying LEO satellite service is that residents will likely be able to receive service relatively quickly. In comparison, fiber solutions may take years to deploy. In the interim, satellite service may represent a stop-gap solution.

From a technical standpoint, LEO satellite solutions could be a good fit for the BEAD Program as an alternative technology option. Current LEO technologies can meet the parameters of speed, cost, and deployment timeline. However, the NTIA is prioritizing fiber connectivity and it is still unclear whether the federal government will deem LEO broadband providers reliable, particularly after the recent reversal of the RDOF subsidy for Starlink.[54]

Washington case studies

Two case study applications of LEO satellite service highlight the positive impact of this technology on delivering connections to unserved areas, especially during and after a natural disaster event.

Case Study: Malden, Washington[55]

After a wildfire event destroyed most broadband infrastructure, seven Starlink satellite terminals were installed to enable connectivity to this rural Washington town in September 2020. Firefighters utilized the terminals in their incident command vehicles to request resources, organize daily activities and make decisions, such as ordering helicopters for wildfire fighting activities. Residents were able to utilize terminals too.

Case Study: Hoh Indian Reservation[56]

The Hoh Indian Reservation is situated in the western part of the state, approximately 23 miles south of Forks. Broadband infrastructure availability is the primary constraint to internet access and digital equity for the tribe. The tribe is about 70 miles away from the closest middle-mile fiber infrastructure. Since September 2020,

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[53] Note: Other factors include: (1) the remote location; (2) the lack of population density; (3) the unique topography; (4) a high rate of poverty; or (5) any other factor determined by the NTIA Assistant Secretary, in consultation with the Federal Communications Commission (Commission), which contributes to the higher cost of deploying broadband service in the area.
[54] Kratos Defense, " US to Spend $42B on Broadband Equity: Will Satellite Be Included?," (2023), https://www.kratosdefense.com/constellations/articles/us-to-spend-42b-on-broadband-equity-will-satellite-be-included
[55] Government Technology, " SpaceX Connects Rural Washington Communities Via Satellite," (2020), SpaceX Connects Rural Washington Communities Via Satellite (govtech.com)
[56] Community Networks, " Starlink's Beta Program Connects the Remote Hoh Tribe in Washington State," (2020), Starlink's Beta Program Connects the Remote Hoh Tribe in Washington State | Welcome to Community Networks (communitynets.org)

through a connection facilitated by the WSBO, the tribe has utilized Starlink, with no other ISPs currently servicing the reservation.

In 2020, the Hoh Indian Reservation received LEO satellite service for reservation residents in a three-year contract. Starlink Beta service offered a quick solution to address the broadband service gap, and the reservation was well positioned to the satellites that Starlink had in orbit at the time. It took approximately a month to set up the terminals. Subsequently, Starlink hosted virtual meetings to provide an overview of the technology, set-up process, and service. Eighteen of 23 community members signed up for Starlink's Beta trial service. The set-up process was simple and efficient, according to a Hoh Tribe representative. Funding for Starlink's service was allocated from COVID-19 relief funding; however, exact pricing information is not available.

The installation of Starlink terminals on the reservation has been a lifeline for residents, particularly students and adults learning and working from home during the pandemic. In the first few weeks of service, household speed tests indicated service levels between 58 and 65 Mbps for each household. One article stated that the most recent speeds have achieved 179 Mbps. A stakeholder noted that Starlink was extremely helpful for her family, especially for remote learning and work during the pandemic. Individuals depended on Starlink during the pandemic for telehealth as well.[57]

Councilmembers have indicated that they expect most residents will continue paying for the service upon contract expiration this year. However, for low-income, unemployed and underemployed residents, the $120 monthly subscription fee may be cost prohibitive.

[57] Interview with Hoh Tribe member conducted September 13, 2023.

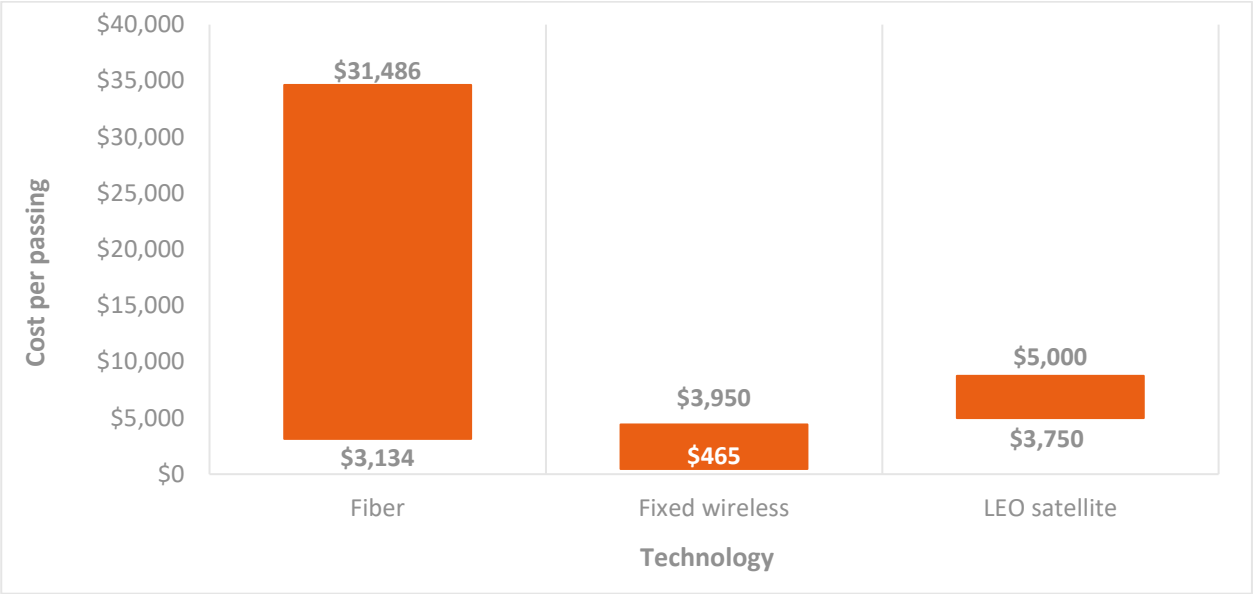
Cost comparison

A motivation for this analysis is to help inform how the state can optimally allocate nearly $1.23 billion in BEAD funding to achieve universal broadband service. The cost analysis included as part of Washington's BEAD Five-Year Action Plan revealed that the cost of serving every location with fiber would exceed the state's allocation by nearly $500 million. Similarly, the NTIA's National Broadband Availability Map (NBAM) high-cost threshold tool estimates that the investment cost of deploying fiber to all unserved and underserved locations in Washington exceeds the state's BEAD allocation by $624.1 million. Therefore, the state will need to determine how to distribute funding to maximize the number of locations served by fiber while retaining enough funding to provide service to every remaining location. The final mix of technologies may include fixed wireless and alternative technology solutions, such as LEO satellite service.

Although costs to serve the unserved and underserved locations will ultimately be determined in 2024 during the subgrantee selection process by internet service provider applicants, the state can begin understanding preliminary cost estimates. The NBAM tool, while imperfect, is one of the primary analysis tools offered by the NTIA and provides estimates for end-to-end fiber. The average estimated costs per passing, or potential end-user connection, for each county ranges from $3,134 in Snohomish to $31,486 in Garfield (see Appendix Table 4). The WSBO anticipates some locations will require even higher amounts for end-to-end fiber; however, this provides a starting point for the work. Fixed wireless will be a common technology that is considered if end-to-end fiber is deemed cost-prohibitive for the location. The estimated cost per passing for fixed wireless is lower than fiber at $465 in small towns to $3,950 in very rural areas (areas with greater density than small towns are assumed to be even more cost-effective per passing).[58] LEO satellite presents a potential alternative to fixed wireless when fixed wireless is not technically or financially feasible. While residential pricing packages are $600 for startups, this cost per passing is expected to increase to $3,750–$5,000 per passing due to the need for additional infrastructure investment.[59] These are still estimates and are subject to change depending on actual applications received during the subgrantee selection phase of the BEAD Program.

[58] Benton, "Fixed Wireless Technologies and their Sustainability for Broadband Deliver," (2022), https://www.benton.org/sites/default/files/FixedWireless.pdf
[59] Starlink, "Starlink Overview," (presentation delivered 8/25/23; not published)

Figure 2: Estimated cost per passing range for fiber, fixed wireless, and LEO Satellite



Ongoing costs and total cost of ownership

Ongoing operational and maintenance costs and the technological lifetime of broadband infrastructure networks is an additional consideration when making broadband solution determinations. Although fiber has the highest upfront capital cost, the expected typical lifetime of fiber network ranges from 20–40 years.[60] Fiber is also future-proof, as a fiber network can easily scale speeds over time to meet the evolving connectivity needs of households and businesses and support the deployment of new technologies.[61] In comparison, the typical lifetime of fixed wireless networks is 10 years and the expected typical operating lifetime of a LEO satellite is 7–10 years.[62] The operational costs for fixed wireless are greater than fiber because of the need to replace wireless equipment. A Benton Institute report estimates that 40–80% of a fixed wireless network's capital costs must be replaced every five years; whereas 1–10% of the capital cost of a fiber network needs to be replaced every 10 years.[63] The annual operational and maintenance costs considered in Benton Institute's analysis include staff, replacement, maintenance, leases, and wholesale internet for fiber and fixed wireless networks. While the costs of leases and wholesale internet per location for fiber is uniform across density categories, the cost of staff, replacement, and maintenance is markedly higher than fixed wireless. For example, replacing fiber is more costly in rural areas because of the longer mileage to the premises. For fixed wireless, the cost of replacing the equipment demonstrates the greatest variation by density category.

Table 1 compares the estimated maintenance and operational costs for a fiber and a fixed wireless network.

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[60] Benton, "Fixed Wireless Technologies and their Sustainability for Broadband Deliver," (2022), https://www.benton.org/sites/default/files/FixedWireless.pdf; The Fiber Optic Association, Inc., "Q&A from FOA Readers," (2023), Fiber FAQs - Frequently Asked Questions - The Fiber Optic Association (thefoa.org)

[61] National Telecommunications and Information Administration, "Broadband Equity, Access, and Deployment Notice of Funding Opportunity," (2022), https://broadbandusa.ntia.doc.gov/sites/default/files/2022-05/BEAD%20NOFO.pdf

[62] Congressional Budget Office, " Large Constellations of Low-Altitude Satellites: A Primer," (2023), https://www.cbo.gov/publication/59175

[63] Benton, "Fixed Wireless Technologies and Their Sustainability for Broadband Delivery," (2022), https://www.benton.org/sites/default/files/FixedWireless.pdf

Table 1: Annual operations and maintenance cost comparison (ongoing cost per location)[64] [65]

Density	Fiber	Fixed wireless
Very low density rural	$710 to $1690	$955 to $1,440
Low density rural	$710 to 1690	$655 to $1,140
Medium density rural	$44 to $880	$510 to $1,000
Small town	$240 to $570	$170 to $495

There is minimal information available related to the operational costs of a LEO satellite constellation. Operating a satellite constellation includes the cost of the software used to control and monitor the satellite constellation. One estimate suggests that this cost ranges from $500,000–$1 million per satellite per year.[66] The per-unit operational cost may decline as more efficient constellation management systems are developed.

Areas for consideration

This analysis explores the areas of the state where it may not be economically conducive to building fiber networks due to geographic remoteness or low population density. In these areas, alternative technologies such as LEO satellite service or fixed wireless may be more cost-effective to deploy. This analysis may need to be refined after the challenge and subgrantee selection processes of the BEAD program are completed, as the number of eligible unserved and underserved locations will likely be updated.

The NTIA NBAM indicates that there are more than 320,000 (230,000+ unserved and 85,000+ underserved) unserved and underserved locations in Washington (FCC BDC data as of 9/26/23)..[67] The BEAD Program is designed on the premise that all unserved and underserved will be addressed through BEAD funding. To achieve universal access, the state must determine which areas should be prioritized for fiber build-out and which areas may be more cost-effectively served by fixed wireless or another technology like LEO satellite service. The analysis of the cost per passing of different technology types indicates that NTIA-defined, high-cost areas may present opportunities for the state to explore alternatives to fiber.

Approximately 15,000 unserved and underserved locations are within high-cost areas in Washington, primarily in the eastern regions of the state. Figure 3 depicts the geographical distribution of high-cost areas. These areas are likely to have higher than average fiber deployment costs due to factors such as low population density and unique topography. This may necessitate using alternative technologies to maintain the economic

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[64] Benton, "Fixed Wireless Technologies and Their Suitability for Broadband," (2022), https://www.benton.org/sites/default/files/FixedWireless.pdf

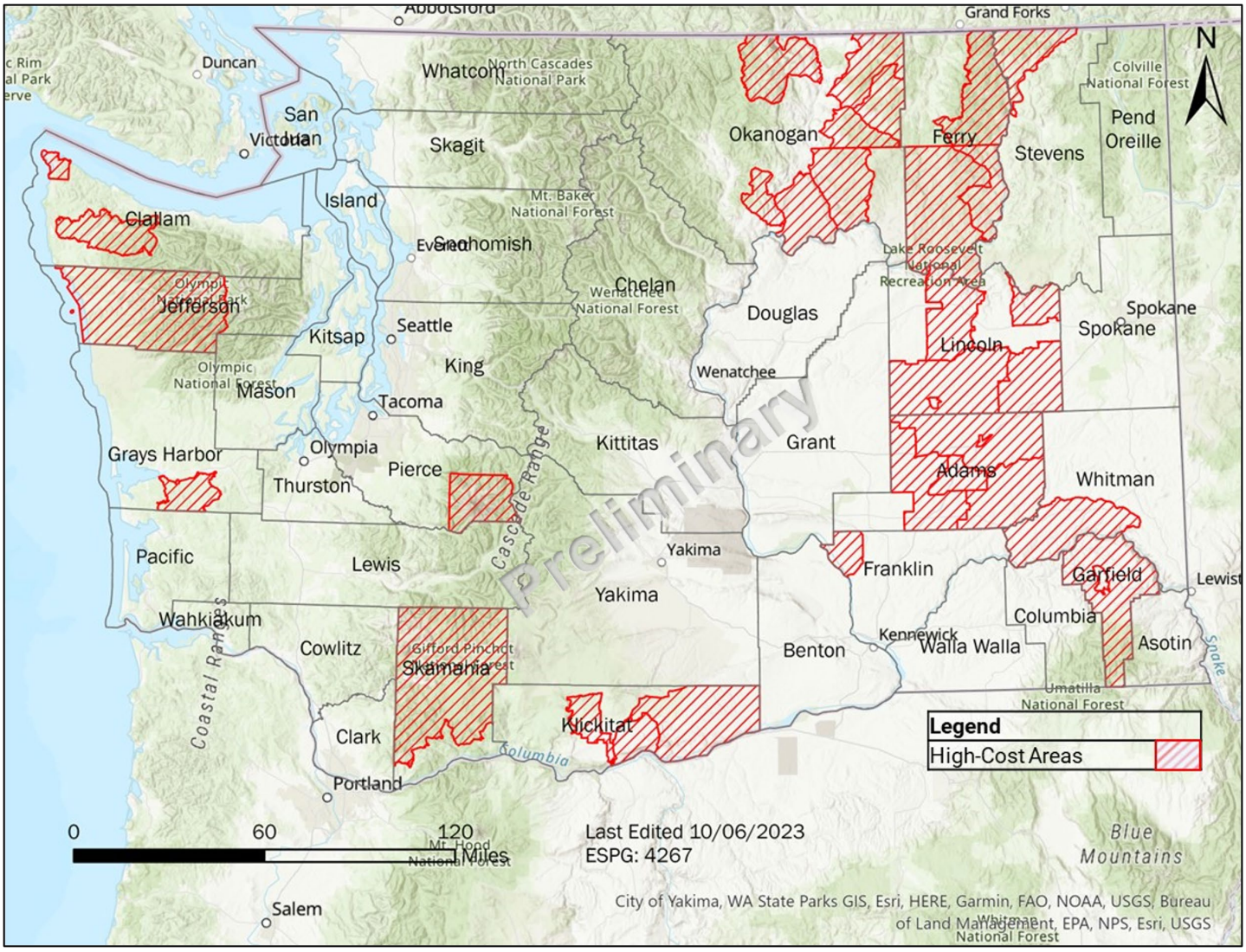
[65] Note: Benton Institute paper defined very low density as 2,399 passings, at five homes per mile; low density as 2,445 passings, at 9 homes per mile); medium density as 2,279 passings, 15 homes per mile; small town (not defined)

[66] Space News, "What could happen to the LEO broadband constellations?" (2021), https://spacenews.com/op-ed-what-could-happen-to-the-leo-broadband-constellations/#:~:text=Operating%20the%20constellation%20requires%20sophisticated,million%20per%20satellite%20per%20year

[67] Note: This figure is before any adjustment for duplication of locations that are already subject to enforceable commitments to provide service, and which are either in the planning or construction phase. The Subgrantee Selection Tool provided in the Eligible Entity Planning toolkit offers investment cost data for unserved and underserved BSLs in Washington. After deduplication analysis, NBAM reports 236,136 unserved and 85,433 underserved BSLs. The Subgrantee Selection toolkit has investment cost information for only 206,101 unserved and 83,379 underserved BSLs.

viability of the BEAD Program. The state should solicit and consider projects of all technology types in these regions. Fiber applications should still be accepted and considered, given the program's goal to maximize fiber deployment wherever feasible. Nonetheless, these high-cost areas will require additional consideration during the subgrantee selection process, allowing the WSBO to select the technology type that maximizes the impact of Washington's BEAD funds.

Figure 3: NTIA-Defined high-cost areas [68]

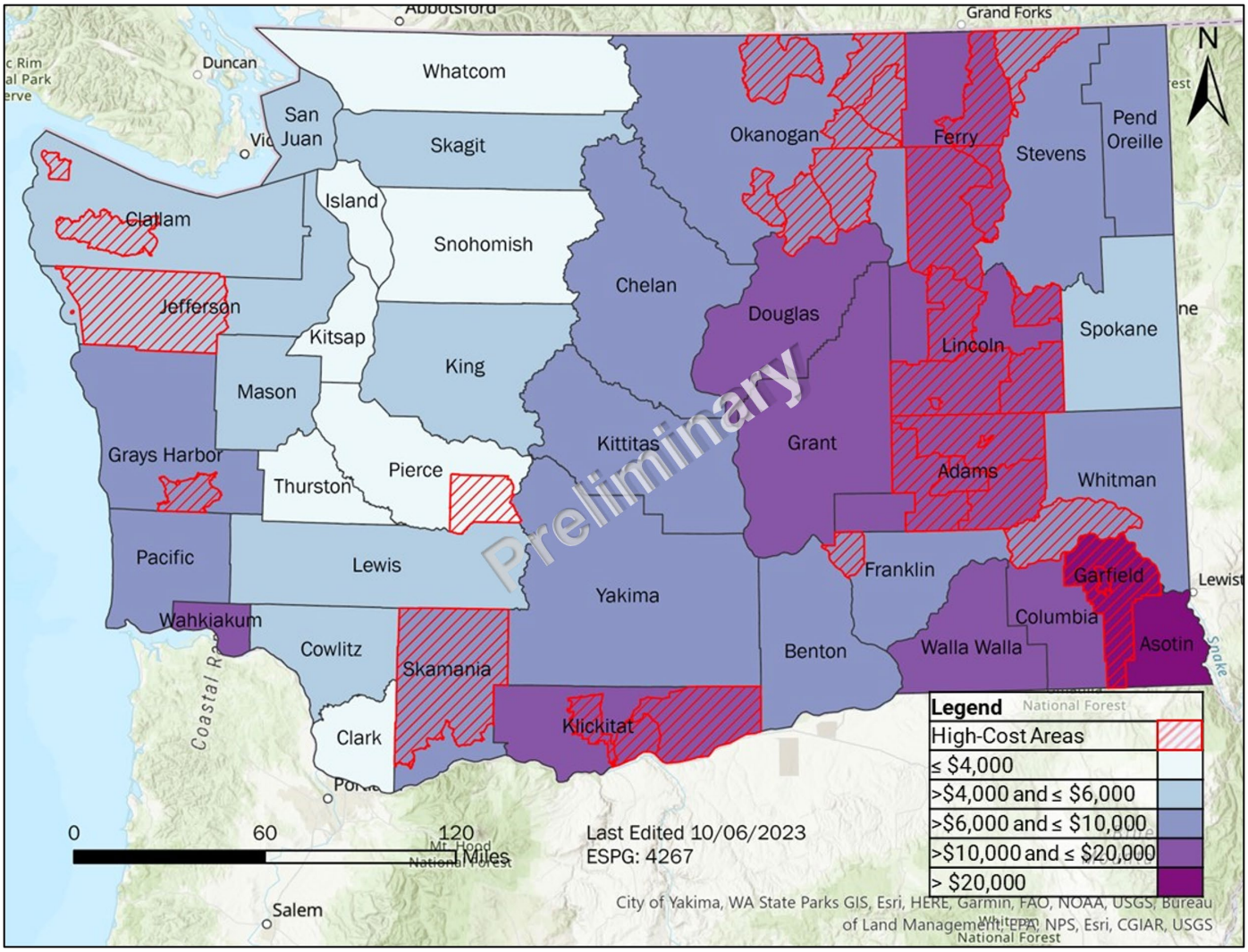


Although preliminary high-cost areas identified by the NTIA Extremely High-Cost Threshold tool indicate the locations that should be considered for alternative technologies, other costly areas above the estimated average cost per passing, or potential end-user connection, should also be considered. To gain additional insight into these regions, the average investment cost per BSL was considered by county, as illustrated in Appendix Table 4. The areas highlighted as costly tend to overlap with the areas outlined in Table 3, above. For example, Garfield County has the highest estimated average cost per BSL and the entire county, excluding Pomeroy, is considered a high-cost area by the NTIA. However, based on average costs per BSL, costly areas

[68] The National Broadband Availability Map, "High-Cost Areas," (2023) https://experience.arcgis.com/experience/634f354d7004487a9bc6617efcde6646

exist outside of these high-cost areas. Asotin, Douglas, and Walla Walla counties do not contain high-cost areas but have average costs per BSL exceeding $15,000 (see Figure 4). See Appendix Table 4 for more details. The WSBO can take a similar approach to assess these areas during the subgrantee selection process, which will occur in 2024.

Figure 4: Average cost per BSL by county[69] [70]



Within identified areas where fiber deployment may not be feasible due to costs, the state could consider the topographical features to determine if locations will be best served by fixed wireless or LEO satellites. For example, fixed wireless service may perform poorly in areas with significant obstructions such as hills, buildings, trees, and other features that block the signal between a service location and a nearby radio tower.[71]

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[69] The National Broadband Availability Map, (2023) National Broadband Availability Map | National Telecommunications and Information Administration (ntia.gov)

[70] Note: Note: The Subgrantee Selection Tool provided in the Eligible Entity Planning toolkit offers investment cost data for unserved and underserved BSLs in Washington. After deduplication analysis, NBAM reports 236,136 unserved and 85,433 underserved BSLs. The Subgrantee Selection toolkit has investment cost information for only 206,101 unserved and 83,379 underserved BSLs.

[71] Benton, "Fixed Wireless Technologies and Their Suitability for Broadband," (2022), https://www.benton.org/sites/default/files/FixedWireless.pdf

This can result in slower speeds and higher latency. This differs from LEO satellite service, which requires a clear view of the sky.

This analysis provides a preliminary indication of the areas in Washington that may not be feasible to serve with fiber while also reserving funds for all unserved and underserved locations utilizing BEAD funding. In these areas, the WSBO should strive to solicit applications for different technology types, including LEO satellite services. This strategy offers two key benefits. First, incentivizing bids for multiple technology types will maximize the state's capacity to select the most cost-efficient and impactful solutions based on technical merits. Second, this approach will allow the WSBO to optimize its extremely high-cost threshold. This is because additional data points from various application types will support a clearer picture of the likely project costs to serve these areas.. The WSBO will be better equipped to serve all Washington locations with high-speed internet using the state's BEAD funds.

Appendix A:

Table 2: Satellite provider coverage

Provider	Type	Coverage	Advertised speed range (download)
Viasat[72]	GEO	99.65%	25–150 Mbps
HughesNet [73]	GEO	100%	15–50 Mbps
SpaceX[74]	LEO	99.98%	Fixed 25–100 Mbps (standard) 40–220 (priority) Mobile 5–50 Mbps (standard); 40–220 Mbps (priority)

Table 3: Provider plans and prices[75]

Provider	Plan details	Price
Viasat[76]	25Mbps 60 GB of high-speed data; unlimited standard data	$49.99/month; $69.99 for first 3 months
	50 Mbps 100 GB high-speed data; unlimited standard data	$69.99/month; $99.99 after first 3 months
	75 Mbps 150 GB of high-speed data; unlimited standard data	$99.99/month; $149.99 after first 3 months
	100 Mbps 300 GB of high-speed data; unlimited standard data	$149.99/month; $199.99/month after first 3 months
	100 Mbps 500 GB of high-speed data; unlimited standard data	$199.99/month; $299.99/month after first 3 months
HughesNet[77]	15 Mbps 15 GB of high-speed data; No hard data limits	$49.99

[72] Viasat, "Home Internet Plans," (2023) https://www.viasat.com/satellite-internet/plans/;
[73] HughesNet, "Home Internet Plans", (2023) https://www.hughesnet.com/get-started
[74] Starlink, "Starlink Specifications," (2023), https://www.starlink.com/legal/documents/DOC-1400-28829-70
[75] Note: Provider plans includes only a subset of providers advertising service availability to at least 25% of broadband serviceable locations (BSLs) in Washington
[76] Viasat, "Home Internet Plans," (2023) https://www.viasat.com/satellite-internet/plans/;
[77] HughesNet, "Home Internet Plans", (2023) https://www.hughesnet.com/get-started

Provider	Plan details	Price
	25 Mbps 50 GB of high-speed data; No hard data limits	$49.99 for first 6 months; $74.99 thereafter
	25 Mbps Fusion - combines satellite and wireless technologies 100 GB of high-speed data; No hard data limits	$74.99 for first 6 months; $99.99 thereafter
	50 Mbps Fusion - combines satellite and wireless technologies 200GB of high-speed data; no hard data limits	$149.99/month for first 6 months; $174.99 thereafter
SpaceX[78]	Fixed Standard: 25-100 Mbps (download); 5–10 Mbps (upload); latency: 25–60 ms Priority: 40-220 Mbps (download); 8-25 Mbps (upload); latency: 25–60 ms Mobile Standard: 5-50 Mbps (download); 2–10 Mbps (upload); latency <99 ms Priority: 40-220 Mbps (download); 8–25 Mbps (upload); latency: <99 ms	**Current: $120/month + $600/kit** **BEAD middle-class affordability option:** Standard plan: $75 –$85/month (includes kit) Per location cost of $3,750–$5,000 factors in cost of increase satellite deployment, terrestrial gateways, increased points of presence, state specific enrollment portals, next gen Starlink kits, reduced price service offering for 3 years; BEAD compliant reporting *Starlink does not currently participate in ACP ** Starlink has no contracts or early termination fees
T-Mobile[79]	Up to 1000 Mbps (download)	Plans starting $50/month
Verizon[80]	300 Mbps to 1 Gbps	$50–$90/month

[78] Starlink, "Starlink Specifications," (2023), https://www.starlink.com/legal/documents/DOC-1400-28829-70
[79] T-Mobile, "T-Mobile Internet Plans," (2023), https://www.t-mobile.com/home-internet/plans
[80] Verizon, "Verizon Home Internet," (2023), https://www.verizon.com/home/internet/

Provider	Plan details	Price
Lumen[81]	Fiber Speeds offered: 500 to 940 Mbps	$50–$75; Wi-Fi equipment provided with no monthly charge
Comcast[82]	Cable Speeds offered: 75 to1200 Mbps	$35/month (1 year) for 100 Mbps plan

Table 4: Average cost per BSL by county[83]

Rank	County	Number of unserved and underserved BSLs	Average cost per BSL
1	Garfield	696	$31,486
2	Asotin	976	$29,426
3	Douglas	1,197	$18,883
4	Walla Walla	2,637	$15,122
5	Adams	4,374	$14,448
6	Wahkiakum	219	$13,643
7	Klickitat	7,204	$12,702
8	Lincoln	7,620	$12,351
9	Ferry	3,608	$12,266
10	Columbia	2,605	$10,800
11	Grant	1,750	$10,062
12	Whitman	7,917	$9,714
13	Grays Harbor	3,150	$9,571
14	Okanogan	14,023	$9,552
15	Franklin	4,555	$9,540
16	Chelan	3,957	$9,517
17	Benton	3,921	$9,073

[81] CenturyLink, "Home Internet Plans," (2023), https://www.centurylinksavings.com/v2/?ckmid=101207&a=101615&ocid=1015949&agid=&subid=1764952795.&cpid=&cookiereset=1&gclid=&c=109343&_gl=1*9bj3ou*_gcl_au*MTE4MzUwOTkwNS4xNjkxNzk0MjI3
[82] Xfinity, "Home Internet Service, (2023), https://www.xfinity.com/learn/internet-service
[83] The National Broadband Availability Map, "WA_BSL_ProjArea," (2023)

Rank	County	Number of unserved and underserved BSLs	Average cost per BSL
18	Skamania	2,850	$8,315
19	Stevens	15,650	$7,841
20	Yakima	7,281	$7,798
21	Pacific	2,193	$7,711
22	Kittitas	9,467	$7,191
23	Pend Oreille	4,209	$6,391
24	Jefferson	5,698	$5,748
25	San Juan	1,522	$5,501
26	Lewis	16,755	$5,023
27	Cowlitz	7,184	$4,937
28	Skagit	6,923	$4,844
29	Mason	6,451	$4,638
30	Clallam	10,079	$4,481
31	King	11,904	$4,454
32	Spokane	26,373	$4,395
33	Thurston	10,217	$3,728
34	Whatcom	11,765	$3,629
35	Pierce	16,730	$3,595
36	Island	5,661	$3,322
37	Kitsap	7,066	$3,158
38	Clark	15,450	$3,135
39	Snohomish	17,640	$3,134