Operational Use of Non-Terrestrial Network Technology

Networks and Telecommunications Community of Interest
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Synopsis

This paper examines and assesses, through various use cases, whether non-terrestrial network transport can be used to address the needs of government, science, research and education, state, and tribal communities. This requirement was driven by many Federal agencies; science, research and education institutions; and state and tribal communities having network connectivity requirements in regions where terrestrial-based network services are either unavailable, available with only very low capacity, or require lengthy deployment timelines. Additionally, these entities may also have mobile operations or require rapid deployment of network communications not traditionally supported through terrestrial network services.

This report summarizes five case studies using various forms of non-terrestrial connectivity with their lessons learned, cost considerations, and a look at new emerging technologies.

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Introduction and Objectives

The ACT-IAC Networks and Telecommunications Community of Interest developed a project to examine and assess, through various use cases, whether non-terrestrial network transport can be used to address the needs of government, science, research and education, state, and tribal communities.

Many Federal agencies; science, research and education institutions; state; and tribal communities have network connectivity requirements in regions where terrestrial-based network services are not available, are only available with very low capacity, or require lengthy deployment timelines.

Additionally, these entities may also have mobile operations or require rapid deployment of network communications not traditionally supported through terrestrial network services.

This study looks at the real-world application of non-terrestrial network technology in a variety of conditions, locations, and approaches to determine the feasibility of its use as a reliable option for agencies, organizations, and entities who are looking for other means of network service connectivity.

The primary objective of this project was to obtain data and information about the many use cases completed or underway where non-terrestrial networks are being leveraged for primary or sole connectivity.

Methodology

A questionnaire was developed and shared with use case study participants. Participants were given five weeks (from May to June 2024) to complete and return the questionnaire. The following technologies were evaluated from participant use case study submissions:

- **Commercial/Private Cellular 4G/5G (fixed and mobile)** - commercial cellular service is provided for profit and makes interconnected service available to the public, while private cellular service is dedicated to a specific organization or case, customized and not available publicly. A fixed cellular network is dedicated to an on-premises cellular network requiring permission or authentication, while a mobile cellular network is a wireless communication system allowing mobile devices to connect with each other and offers more flexibility in terms of location.
- **Low Earth Orbit (LEO) /Geosynchronous (GEO) Satellites** - LEO satellites are constantly moving relative to earth at any given time, while GEO satellites stay in a single location relative to a fixed spot on earth.
- **Microwave** - a wireless communication system that uses radio frequency waves to transmit information over lengthy distances without the need for wires or cables.

Table 1 below offers a high-level overview of the questionnaire categories, and the information requested for each.

Table 1: Study Questionnaire

Category	Questions/Information Requested
Technology	Satellites (LEO/GEO), microwave, cellular, etc.
Project background	Describe the project that leveraged the selected technology.

Project technical set up	Information on how the specific technology was deployed to establish required end to end connectivity or to meet the desired data delivery needs; include any challenges for the location or site.
Project technical delivery	Information on how the specific technology performed, if the required goals were met, and if this project delivered enough information to ascertain if the technology used can be leveraged for operational use (where "operational" means primary method of communication) or if further research is required; any statics if available to include download/upload speeds, jitter, loss and latency; and whether other technologies were considered.
Other consideration	How the technology/service were procured for the project.

Project Participants

A total of five participants submitted responses to the questionnaire. These include three from the Department of Commerce (DOC), one from the Department of Energy (DOE) and one from the Yukon-Kuskokwim Delta Tribal Broadband Consortium (YKDTBC).

Federal agency contributors included:

- DOC / National Oceanic & Atmospheric Administration (NOAA) / National Weather Service (NWS) / Alaska Region
- DOC / NOAA / NWS / Office of Observations/Surface and Upper-Air division (SUAD) Automated Surface Observing Systems (ASOS)
- DOC / NOAA / Office of Marine and Aviation Operations (OMAO) / Marine Operations
- DOE / Energy Sciences Network (ESnet) / Lawrence Berkeley National Laboratory / Office of Science

Nonprofit organization/tribal nation contributors included:

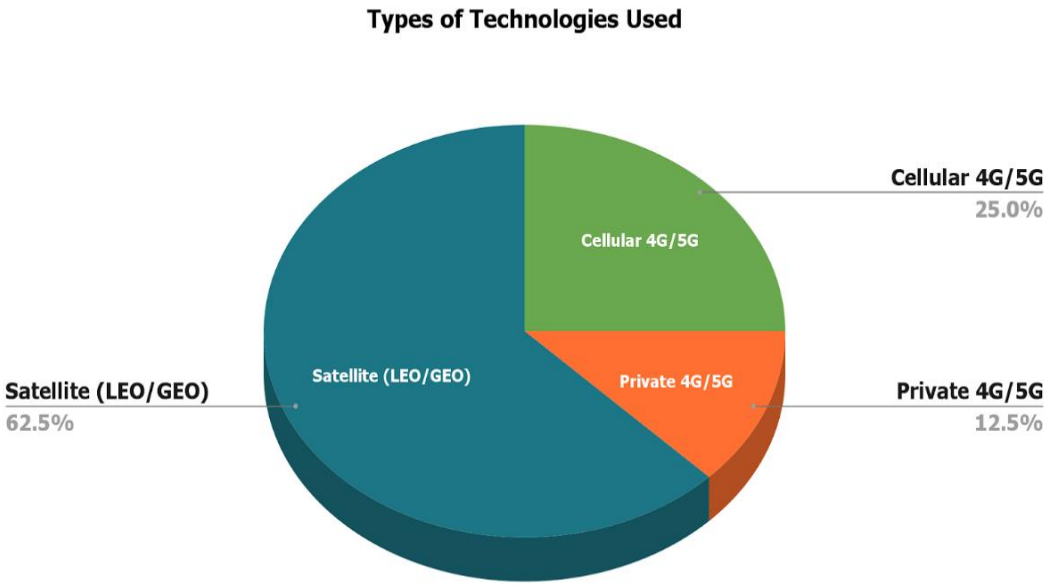
- YKDTBC

Types of Technologies Used

As illustrated in Figure 1, five participants used one or more of the following technology types:

- Commercial Cellular 4G/5G - 2 uses (25%)
- Microwave - 0 uses (0%)
- Private Cellular 4G/5G - 1 use (12.5%)
- Satellite (Low Earth Orbit (LEO)/Geosynchronous (GEO)) - 5 uses (62.5%)

Figure 1



The top two technologies identified in the use cases were LEO/GEO satellites at 62.5% and commercial cellular 4G/5G at 25%.

Use Case Studies

There were five use case study submissions received from four federal agencies and one tribal nation organization as part of this project. Each of their individual submissions showcase the unique lessons learned, opportunities, and challenges from the use of these technologies. Individual case study submissions are provided below (listed alphabetically by organization name).

Use Case #1: DOC / NOAA / NWS / Alaska Region

Agency	DOC / NOAA / NWS / Alaska Region
Submitted by	Per Pedersen, IT Specialist, NOAA/NWS/Office of Dissemination
Website	www.weather.gov/arh/
Technology category(ies) that apply to project	Satellite (LEO)/Geosynchronous (GEO)
Project Background	Given the cost and supportability of traditional telecommunications in Alaska, and the emergence of LEO as a feasible technology for operational systems, the NWS Office of Dissemination and the NWS Alaska Region in cooperation with the DOE and N-Wave embarked on a test of a Starlink system in Kodiak, Alaska. Kodiak was chosen for its location (approx. 57° N, 152° W) and relatively easy access. The system supported was a Vaisala AutoSonde, which is an automated system for launching weather balloons.
Project Technical Set Up	This Starlink terminal was tested at the NWS upper air site on the Coast Guard base in Kodiak Island, Alaska. The test was conducted for approximately 30 days in February 2023.
Project Technical Delivery	Performance was acceptable for a satellite communications (satcom) connection and as Starlink improves its constellation, outages should decrease and performance increase. Issues experienced include: ● It was a consumer terminal model and contract. Because of this, we did not have a static internet protocol (IP) and had to use carrier-grade network address translation (CGNAT). ● Due to these limitations, we were unable to make inbound network connections from the internet to the testing laptop and had to use BeyondTrust (Bomgar) to gain remote access into the testing laptop. ● We received warnings that performance could be impacted because we were using this terminal outside of its registered service area. I do not know how much that affected our testing. I assume we would have seen better performance/throughput with Starlink's high performance terminal with a business/government level service agreement and if it had been registered in the area where we were testing. ● The other issue was it did not come with an ethernet interface or the correct mounting hardware for our install. However, once those were procured the installation went smoothly. The actual install took less than an hour to install with two people; however, it could have been accomplished with a single person.

Project Other Considerations	Since this project was a joint DOE/NOAA N-Wave/NWS project, the system used was a “loaner” and not procured.

Additional Documentation

Figure 2 below shows the location in Kodiak, Alaska for this project.

Figure 2

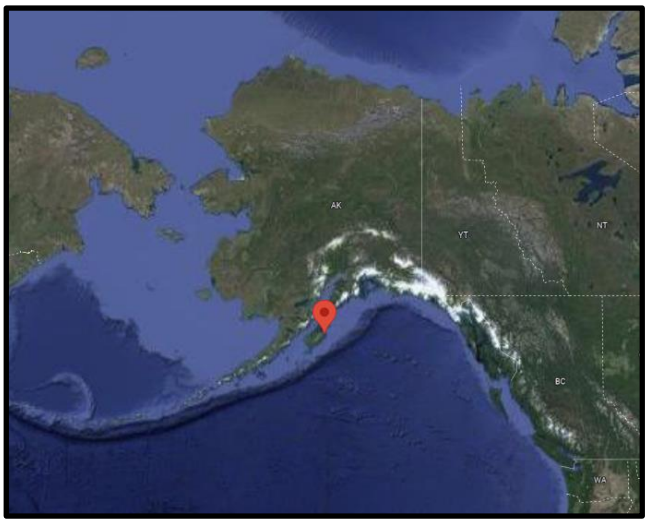


Figure 3 images show the setup of the Starlink device for this project.

Figure 3

Use Case #2: DOC / NOAA / Office of Observations/ SUAD / ASOS

Agency	DOC / NOAA / Office of Observations/ SUAD / ASOS
Submitted by	Richard Vogel, Communications Lead Engineer, OBS/SUAD/Program Management Branch, NOAA / NWS / ASOS
Website	www.weather.gov/asos/
Technology category(ies) that apply	Cellular 4G/5G Satellite (LEO)/Geosynchronous (GEO)
Project Background	NWS ASOS is preparing to upgrade the processing cabinets as part of a Service Life Extension Program (SLEP) initiative. The system is being labeled ASOS 2.0. ● From a communications architecture standpoint, we needed to transition from analog plain old telephone service (POTS) communications and analog dial modems to an IP-based infrastructure with centralized processing. All hardware internal to the system processing and data collection cabinets are being refreshed. ● ASOS is a tri-agency program encompassing the National Weather Service (NWS), Federal Aviation Administration (FAA), and Department of Defense (DoD) (Army/Navy) as the stakeholders. NWS holds the program office and all logistics and maintenance support activities.
Project Technical Set Up	Centralized processing is being established through an Internet of Things (IoT)-based architecture within Amazon Web Services (AWS) Cloud Services. Each of project's technical services are provided below: ● **Amazon Web Services (AWS) Cloud** ○ IoT-based architecture for edge connectivity ○ Edge site and National Centers for Environmental Information (NCEI) connectivity via Message Queuing Telemetry Transport (MQTT) ○ Identity provider (IdP) connectivity via File Transfer Protocol - Secure (FTP-S) ○ AWS IoT Greengrass and AWS System Manager for ASOS system management and edge to cloud transfers/backups ○ Production and Dev/Test environments ○ Internet Protocol version 6 (IPv6) ● **AT&T** - Primary edge transport from ASOS sites to NOAA data centers ○ Utilizing transport via (Cellular, ADI wireline, broadband, OneWeb satellite)

	○ Federal Information Security Modernization Act (FISMA)-moderate compliant management and inherited security controls ○ Internet Protocol Security (IPSec) tunnels from edge sites to data centers. ○ IPv6 ● **Cloudflare** ○ Utilizing DOC Zero-Trust award for zero-trust network access to enable NWS technicians to provide remote maintenance for all ASOS systems ● **NOAA N-Wave** - Primary internal government network provider ○ AT&T router integration for primary 10G circuits to the Boulder, Colorado and Ashburn, Virginia data centers ○ Providing internal government networking and connectivity support ○ Providing connectivity from ASOS and N-Wave virtual routing and forwarding (VRFs) to AWS Cloud ○ IPv6 ● **NOAA Web Operations Center (WOC)** ○ IPv6 domain name services (DNS)
Project Technical Delivery	This will be the primary means of communication, and we are already pressing forward. System Acceptance Testing (SAT) and Operational Test & Evaluation (OT&E) are planned for Fall Fiscal Year 2024 (FY24) through FY25.
Project Other Considerations	All AT&T services were acquired directly through the Enterprise Infrastructure Solutions (EIS) contract. NOAA N-Wave has had a Service Level Agreement (SLA) with the ASOS program for some time. That SLA was just expanded to include the new requirements for this SLEP initiative. Cloudflare Zero Trust Network Access (ZTNA) was acquired using the DOC ZTNA award. The ASOS use case falls within the contract scope and therefore was acquired at no cost to the NWS ASOS program. NOAA Web Operation Center (WOC) services for DNS were provided at no cost and established through a collaborative approach with Cloudflare and NOAA N-Wave.

Additional Documentation

Figure 4 shows an example of an automated surface observing system (ASOS).

Figure 4

Photo credit: NOAA NWS

Use Case #3: DOC / NOAA / OMAO / Marine Operations

Agency	DOC / NOAA / OMAO / Marine Operations
Submitted by	Donald Jones, Chief Emerging Technologies, MO-Engineering, NOAA / OMAO
Website	www.omao.noaa.gov/marine-operations
Technology category(ies) that apply to project	Satellite (LEO)/Geosynchronous (GEO)
Project Background	**Specific Need/Problem**: Broadband internet data service on NOAA ships at sea. **Stakeholders**: There are numerous stakeholders for this project, including NOAA command/leadership personnel; NOAA ship command personnel; NOAA ship crewmembers; scientists working onboard NOAA ships collecting data of interest (climate, oceanographic, fisheries acoustics and sample trawl, hydrographic and benthic habitat seafloor survey); scientists working from shore in collaboration with shipboard scientists (remote access to shipboard data sets, remote access to control/monitor scientific data collection systems on the ships, telepresence or remote chat sessions, etc.); and, others. **Specific Data needs**: The specific data needs include enhanced business processes in managing the NOAA ship operations and maintenance; enhanced crew morale functions (video calls to family/friends, remote/online training opportunities, electronic/digital banking or other "normal" life activities while underway, etc.); movement of data from ship to shore (on-premise storage solution or cloud) for remote access to data; remote access/login to shipboard sensors and systems by shore collaboration partners to either process collected data remotely or to monitor/control actual collection activities by adjusting controls or settings of shipboard sensor systems; and, availability of shipboard data in real-time or near-real-time to stakeholders/decision-makers on shore.
Project Technical Set Up	NOAA ships operate in oceans around the globe and are needed to ensure the selected solution was viable in all of the world's oceans prior to implementation on the ships. The LEO solution needed to be flexible enough to work for all 15 NOAA ships operating in all oceans and in all types of weather conditions. We worked with the OMAO Marine and Aviation Cyber Center and N-Wave network engineers to ensure the LEO solution met all cyber and FISMA requirements for transport of NOAA

	data from ships to the NOAA Trusted Campus Network (TCN) via the implemented LEO solution. It was necessary to ensure the implemented solution met Trusted Internet Connection (TIC)/Trusted Internet Connection Access Point (TICAP) requirements and by working with N-Wave, this solution was configured to meet those requirements.
Project Technical Delivery	The selected LEO solution was the Starlink LEO satellite internet data service provided by SpaceX, and the goals for OMAO in utilizing this system were met. The results were immediately apparent and provided greatly improved at-sea internet services on the NOAA ships. Based on the highly successful initial pilot, this technology has been leveraged for operational use on all NOAA ships. The Starlink solution performed extremely well, and the following statistics capture observed operational characteristics: ● Download Speed: average speed 80 - 150 Mbps (Starlink advertised speed - 230 Mbps) ● Upload Speed: average speed 3.5 - 8 Mbps (Starlink advertised speed - 25 Mbps) ● Latency: average speed 45 - 112 milliseconds (ms) (Starlink advertised - less than 110 ms) ● Jitter: Not measured ● Loss: Not measured There were no other technologies considered because the only other LEO offering did not offer mobility services. They only offered stationary services with a note stating that they were preparing/planning mobility services sometime in 2024.
Project Other Considerations	The technology was initially purchased via a sole-source contract with SpaceX. After the approximately 18-month pilot, a new five-year Indefinite Delivery Indefinite Quantity (IDIQ) contract was awarded to a SpaceX-authorized third-party vendor for Starlink services and equipment. We are currently in the base year period of that IDIQ contract.

Additional Documentation

Figure 5 shows Starlink devices on the NOAA Drix Uncrewed Surface Vehicle; NOAA ship, Fairweather; and, NOAA ship, Henry B. Bigelow.

Figure 5

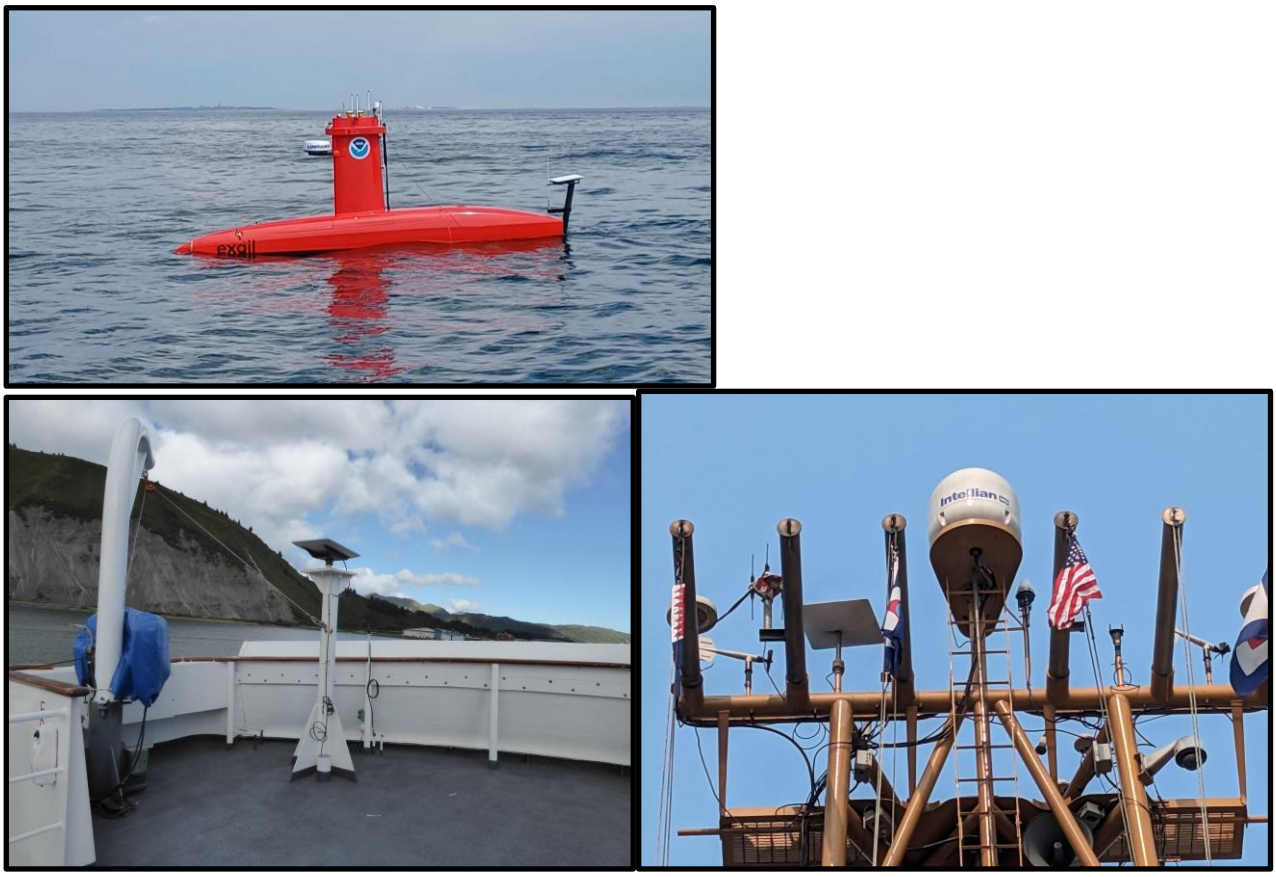


Photo credit: NOAA library

Figure 6 includes images of the NOAA ship Ruben Lasker departing San Francisco Bay, followed by two photos showing Starlink devices on the forward mast of the ship.

Figure 6

Photo credit: NOAA library

Use Case #4: DOE / ESnet / Lawrence Berkeley National Laboratory / Office of Science

Agency	DOE / ESnet / Lawrence Berkeley National Laboratory / Office of Science
Submitted by	Andrew Wiedlea, PhD, Computer Systems Engineer, DOE/ESnet/Science Engagement Group; Jason Zurawski, Science Engagement Engineer, Energy Sciences Network (ESnet) / Scientific Networking Division of the Computing Sciences Directorate / Lawrence Berkeley National Laboratory
Website	www.lbl.gov/
Technology category(ies) that apply to project	Commercial Cellular 4G/5G; Private Cellular 4G/5G; Satellite (LEO)/Geosynchronous (GEO)
Project Background	**ESnet Greenfield Wireless Edge:** The ESnet Greenfield Wireless Edge extends ESnet data movement services and capabilities to where our fiber optic backbone cannot feasibly extend, primarily supporting earth, environment, and energy science applications in remote locations. We are presently using private cellular (citizen broadband radio service (CBRS)) both 4/5G as needed, along with long range (LoRa), off-grid Wi-Fi, and Starlink as needed. Each deployment case is unique and requires different combinations of these services depending on the science need, location and availability of services (electrical, commercial cellular, environmental conditions, site access limitations, etc.) **Specific Need**: The specific need is to provide science programs with better options to move data back to DOE High-Performance Computing (HPC) and other user facilities. **Stakeholders**: The stakeholders are Office of Science organizations, primarily science programs aligned with the Biological and Environmental Research (BER) area, but also the DOE Office of Electricity and possibly other areas in future. Primarily this supports collecting sensor data in remote areas.
Project Technical Set Up	Setup depends on the science needed. In the Watershed Function Science Focus Area around Crested Butte, Colorado, we deployed a private cell tower at 3,500m on Red Lady Mountain. It uses a 5G standalone access point to provide cellular backhaul to a sensor field deployed solar system, providing local area Wi-Fi and LoRa to instruments deployed within the local area. Starlink is used to connect the cell tower back to ESnet.
Project Technical Delivery	This was a test case to study technology options, and a wider roll out is planned in FY25 for other sites in the area. We have successfully operated the system remotely for over a year, and this is essential because access is limited by snow and safety factors during some

	months of the year. Backhaul speeds are around 17Mbps, but this is limited by Starlink; the cellular system is capable of higher speeds.
Project Other Considerations	We served as the system integrator, using several different vendors to provide system components. Contracting was through the Lawrence Berkeley National Laboratory.

Additional Documentation

Figure 7 denotes the solar-powered meteorological and hydrological sensors deployed at the Snodgrass Field Site, Crested Butte, July 2022 at approximately 9,000 ft. elevation.

Figure 7

Photo credit: Andrew Wiedlea

Use Case #5: Yukon-Kuskokwim Delta Tribal Broadband Consortium

Agency	Yukon-Kuskokwim Delta Tribal Broadband Consortium (YKDTBC)
Submitted by	Kevin Hamer, General Manager
Website	ykdtribalbroadband.org
Technology category(ies) that apply to project	Satellite (LEO)/Geosynchronous (GEO)
Project Background	For this project, the challenge is to provide affordable broadband to 56 unserved tribal communities in an area of remote southwest Alaska that is larger than the state of Washington and lacks connecting roads. The nearest fiber terminal is hundreds of miles away and across frozen tundra, mountains, and wildlife refuges. The entire Yukon Kuskokwim Delta (YKD), including the Bethel Census Area (BCA) and the Kusilvak Census Area (KCA)- an area larger than the state of Washington- is unserved by broadband. "Unserved" means without access to broadband internet. The YKD is the second largest unserved area in the United States with the largest unserved general and indigenous populations in the state of Alaska. The unserved YKD tribal communities were left out, left behind, and hardest hit by the COVID-19 pandemic. The digital divide was a chasm of inequality for the unserved YKD Tribes who did not have the same access to information and tools to prepare for, prevent, and respond to the COVID outbreak as did areas with broadband. This inequality is highlighted by the difference in COVID-positive and death rates in Alaska between the 22 census areas with broadband and the seven unserved census areas. If you lived in the unserved BCA, you were twice as likely to contract and die from COVID-19 as those in any of the 22 census areas of Alaska with broadband.
Project Technical Set Up	There was a two-stage process to deliver LEO broadband to tribal communities in the YKD. Stage I (2020-2022) was a broadband feasibility study and LEO proof of concept for the Akiak Native Community (one of the 56 YKD Tribes) in 2020-2022. Stage II is currently underway to expand LEO broadband for nine additional YKD tribes in 2023-2025. **Stage I** Akiak Technology Limited Liability Corporation (LLC), a Small Business Administration (SBA) certified tribal owned 8(a) HUBZone business, is a

subsidiary of Akiak Holdings LLC, which is wholly owned by the Akiak Native Community. The timeline for stage 1:

- 2020 - Akiak Holdings LLC obtains a Federal Communications Commission (FCC) license for 2.5 GHz spectrum covering the Akiak Native Community under the FCC 2.5 Gigahertz (GHz) Rural Tribal Priority Window.
- 2020 Akiak Technology LLC wins a Bureau of Indian Affairs (BIA) National Tribal Broadband Grant to conduct an Akiak Broadband Feasibility Study.
- 2021 National Telecommunications and Information Agency (NTIA) provided one billion dollars ($1B) for Tribal Broadband Connectivity Program grants.
- If Akiak Technology finds a feasible and affordable broadband option, there might be NTIA money to build the infrastructure.

Akiak Technology delivered the Akia Broadband Feasibility Study to the Akiak Native Community Tribal Council on June 21, 2021, with the following recommendations:

- 2021/2022 implementation of LEO 2.5GHz fixed wireless solution in Akiak (Phase I) followed by to-be-determined fiber optic when available in YKD (Phase II).
- Explore creating a YKD Tribal Organization consortium to take maximum advantage of broadband grant funding for YKD including the NTIA Tribal Broadband Connectivity grants (proposals due September 1, 2021).
- In June 2021 – the Akiak LEO project started to deliver OneWeb LEO 75/15 MHz using its 2.5GHz spectrum to deliver fixed wireless broadband to all homes and businesses in the Akiak Native Community.

Stage II

The Yukon-Kuskokwim Delta Tribal Broadband Consortium (YKDTBC), a 501(c)(3) Tribal organization, was established in August 2021 to obtain grant funding to provide affordable broadband to the 17 member YKD tribes. The Akiak Broadband Feasibility Study recommendations and the Akiak OneWeb LEO Project provided the technical foundation for the YKDTBC NTIA Tribal Broadband Connectivity Program grant proposal. Specifically, the NTIA proposal included the following technical approach:

- Build 28 towers to provide OneWeb LEO fixed wireless broadband to all 17 tribal communities. For years one to three,

	there would be immediate broadband using fixed wireless to the home. ● The 28 towers include 11 repeater towers that will provide a redundancy circle using microwave. ● Build an undersea fiber cable from Nome to landing stations in Toksook Bay, Hooper Bay, and Quinhagak (all member Tribes). This will be finished in year three. ● Connect fiber to a redundant tower system, unplug OneWeb LEO and broadcast fiber broadband to all homes through 2.5GHz fixed wireless. This is set for year three and more. ● YKDTBC becomes the tribal internet service provider (ISP) for the network. ● YKDTBC submitted the NTIA proposal on September 1, 2021.
Project Technical Delivery	**Stage I** ● On November 15, 2021, Akiak turned on the first broadband in the YKD and became the first LEO community in the world. 112 homes and 10 businesses/anchor institutions received free broadband for one year. ● The Akiak Native Community used 23 TB of LEO broadband data in the final month of service in 2022. Based on a comparison of data usage under the OneWeb LEO broadband service with the top plan offered by the monopoly non broadband internet service provider, the Akiak Native Community saved over $663,000 in one year of service, with the majority of cost saving in data overage charges. **Stage II** ● NTIA took over two years to award a Tribal Broadband Connectivity Program grant to YKDTBC. The NTIA grant award is for minimal funding to cover only nine tribes instead of the proposed 17 Tribes. ● 2023 - YKDTBC completely changes its technical approach to provide Starlink standard residential units to all homes and Starlink business units to all tribal offices in nine YKD tribal Communities. ● 2024 - National Environmental Policy Act (NEPA) approval is pending for implementation funding, which is expected in August 2024.
Project Other Considerations	In 2021, OneWeb was the only LEO service provider in Alaska. In November 2022, Starlink began offering service in Alaska. OneWeb is not a sustainable, affordable solution for small to midsize tribal communities. Starlink uses a direct-to-consumer model which does not allow for YKDTBC to become an ISP, but it is more affordable and sustainable for our tribal communities. Using Starlink sizes the technical solution to the funding available. While sustainable, it does not provide

	a pathway to fiber, nor does it include tribal ISP ownership over the tribal broadband infrastructure.

Additional Documentation

Figure 8 showcases workers from the Yukon Kuskokwim region setting up the Starlink devices.

Figure 8

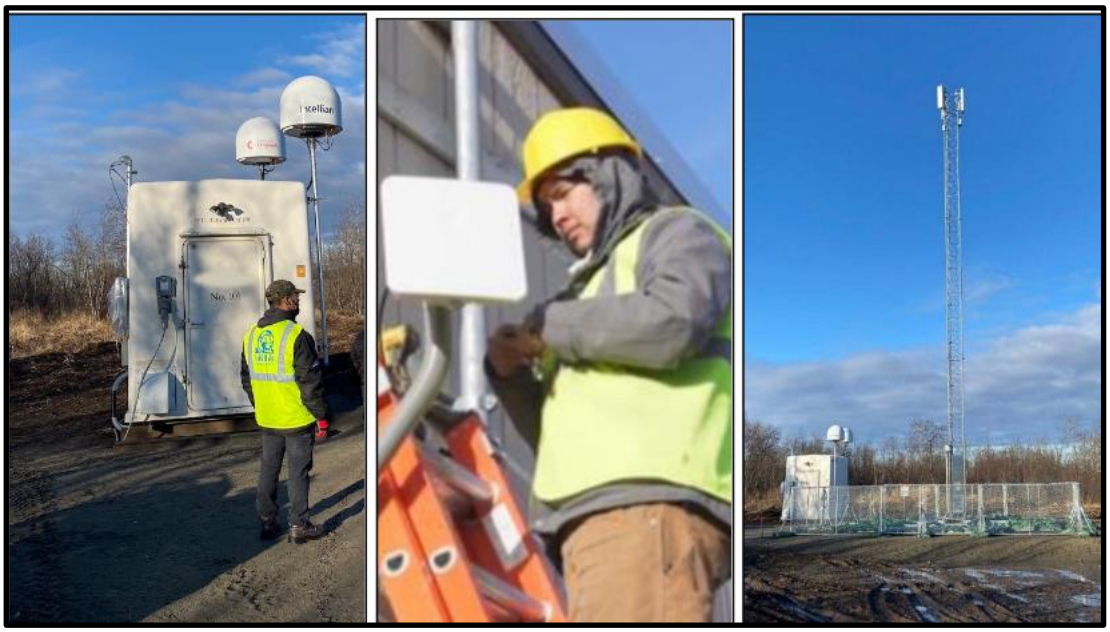


Photo credits: Yukon-Kuskokwim Delta Tribal Broadband Consortium

Cost Considerations

Commercial cellular services are mostly straight forward in pricing. Starlink and OneWeb Technologies have very different models - Starlink is very much a retail business, whereas OneWeb is aimed at supporting ISPs. AWS' Kuiper service was not used in any of the case studies but is a newer service on the market. As noted, where federal broadband funding is involved, there can be long lead times leading to cost shifts. Some service options also require an FCC license with the concomitant cycle time. Where there are long delays, if possible, a technology check should be executed before contract award, in case new products/services are more cost effective or offer superior services.

In general, costs for satellite devices depend on the plan chosen and equipment needed. For instance, Starlink has three main plan types: residential, roam, and boats. Starlink also has a service called Starshield for its military product line. There are government agencies with Starlink contracts, such as the one reported in an October 2023 Space News article noting the U.S. Space Force's $70 million one-year task order for Starlink internet service with other requirements as specified by the Department of Defense. Alternatively, OneWeb Technologies is a GSA authorized federal supply service with a supply schedule price list for multiple types of categories running through April 2027. OneWeb Technologies also revealed in an August 2023 Space Ref article that it was awarded a commercial satellite communications proliferated low-earth orbit (P-LEO) contract from the US Space Force with a $900 million ceiling.

Emerging Technologies on the Horizon

As new technology is developed and diverse applications for its use are realized, it will be important for agencies, organizations, and entities with unique needs to monitor these trends. One particularly interesting emerging technology is the ability to use an ordinary 4G/5G cell handset via a LEO satellite. Starlink is creating a service called "Direct to Cell." According to Starlink's website, its newest satellites will support text messaging in 2024 and voice services in 2025. Apple's soon-to-be-released iOS 18 will support a similar service using Globalstar.

Another private company offering an emerging technology is AST SpaceMobile, which is a Texas-based company building a space-based 4G/5G cellular broadband satellite network accessible to standard smartphones via voice, data, text, and video services. According to the company, it now has agreements and understandings with over 40 mobile network operations (including AT&T & Verizon) who collectively service over 2.5 billion customers. In September 2024, the company, in conjunction with AT&T, launched the first of its five commercial satellites.

These services will have a tremendous impact on safety in remote areas both terrestrial, oceanic, and in air space. They will also have an impact on remote sensing devices with low and/or sporadic bandwidth needs. With these services just ramping up, each provider has strengths and weaknesses that end users will need to consider. Undoubtedly, other LEO operators will be adding similar services.

Conclusion

In closing, the use case studies reviewed in this report clearly show how federal agencies and tribal nations are taking advantage of non-terrestrial network technology to address specific needs, whether it be for enhancing communication efforts, data collection, or providing reliable broadband service to underserved communities in rural areas. These technologies continue to expand in scope as new ways to apply them become more well known. For most use cases in this report, satellites and cellular service - either alone or used in conjunction with each other - have provided the best results in reliability, ease of use, and compatibility with existing network technology. Some of the LEO constellation and availability is still maturing as seen by the NWS and in other federal agencies. This can be expected with new technology and may require working with the provider to validate every aspect of the new service.

Overcoming concerns and issues surrounding costs, customer service interactions, supply chain limitations, and contracting restrictions are some of the drawbacks encountered when utilizing these technologies. However, as they become a larger component in an overall network strategy for the federal government and with other entities, these concerns should be lessened as more usage of the technologies is realized and private companies offering them as a service work to better this process.

As new technologies evolve, they will continue to provide federal agencies, organizations, and other entities with alternatives to traditional terrestrial-based network technology solutions.

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This white paper was written by a consortium of government and industry. The organizational affiliations of these contributors are included for information purposes only. The views expressed in this document do not necessarily represent the official views of the individuals and organizations that participated in its development.

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References / Additional Resources

- DOE website - www.energy.gov
- ESnet - www.es.net
- Lawrence Berkeley National Laboratory - www.lbl.gov
- NOAA website - www.noaa.gov
- OMAO - www.omao.noaa.gov
- NWS - www.weather.gov
- N-Wave - www.noaa.gov/organization/information-technology/n-wave
- NTIA website - www.ntia.gov
- NTIA Broadband Equity, Access and Deployment Program (BEAD) and Tribal Broadband Connectivity Program - broadbandusa.ntia.doc.gov
- Yukon Kuskokwim Delta Tribal Broadband Consortium website - www.ykdtribalbroadband.org

Appendix: Abbreviations

The following list comprises abbreviation references used in this report.

Term	Abbreviation
American Council for Technology - Industry Advisory Council	ACT-IAC
Automated Surface Observing Systems	ASOS
Amazon Web Service	AWS
Bethel Census Area	BCA
Biological and Environmental Research	BER
Bureau of Indian Affairs	BIA
Carrier-Grade Network Address Translation	CGNAT
Domain Name Service	DNS
Department of Commerce	DOC
Department of Defense	DoD
Department of Energy	DOE
Energy Sciences Network	ESnet
Federal Aviation Administration	FAA
Federal Communications Commission	FCC

Term	Abbreviation
Federal Information Security Modernization Act	FISMA
File Transfer Protocol - Secure	FTP-S
Geosynchronous Earth Orbit	GEO
Gigahertz	GHz
High-Performance Computing	HPC
Indefinite Delivery Indefinite Quantity	IDIQ
Internet of Things	IoT
Internet Protocol Security	IPSEC
Internet Service Provider	ISP
Kusilvak Census Area	KCA
Long Range	LoRa
Megabits per second	Mbps
Message Queuing Telemetry Transport	MQTT
Milliseconds	MS
Networks & Telecommunications Community of Interest	N&T COI
National Centers for Environmental Information	NCEI
National Environmental Policy Act	NEPA
National Oceanic & Atmospheric Administration	NOAA
National Telecommunications & Information Administration	NTIA
Office of Marine & Aviation Operations	OMAO
Plain Old Telephone Service	POTS
Systems Acceptance Testing	SAT
Satellite Communications	SATCOM
Small Business Administration	SBA
Service Level Agreement	SLA

Term	Abbreviation
Service Life Extension Program	SLEP
Surface and Upper-Air Division	SUAD
Trusted Campus Network	TCN
Trusted Internet Connection	TIC
Trusted Internet Connection Access Point	TICAP
Virtual Routing and Forwarding	VRF
Web Operations Center	WOC
Yukon Kuskokwim Delta	YKD
Yukon Kuskokwim Delta Tribal Broadband Consortium	YKDTBC
Zero Trust Network Access	ZTNA