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SpaceX: Starlink’s UNCERTAIN DEMAND TRAJECTORY[[1]](#endnote-1)

Arpita Agnihotri and Saurabh Bhattacharya wrote this case solely to provide material for class discussion. The authors do not intend to illustrate either effective or ineffective handling of a managerial situation. The authors may have disguised certain names and other identifying information to protect confidentiality.

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Elon R. Musk, founder and chief executive officer (CEO) of California-based Space Exploration Technologies Corp. (SpaceX), was developing Starlink, a high-speed, low-latency, affordable, low Earth orbit (LEO) satellite-based Internet system for consumers (see Exhibit 1).[[2]](#endnote-2) The system’s satellites were especially meant to service rural and remote areas where terrestrial broadband service could not be established.[[3]](#endnote-3) If the revenue projections were accurate, the project could be lucrative, which for Musk meant that he could use the business of satellite Internet to fund SpaceX’s ultimate and expensive mission of sending humans to Mars.[[4]](#endnote-4)

Competition in the satellite Internet field was increasing, with players such as Telesat Corp., OneWeb, and Kuiper Systems LLC (Amazon.com Inc.’s Project Kuiper) also intending to offer LEO satellite Internet.[[5]](#endnote-5) However, the demand for LEO satellite Internet was uncertain,[[6]](#endnote-6) especially after the fifth-generation mobile network (5G) had been introduced, and players such as T-Mobile promised to offer that service in both rural and urban areas of the United States.[[7]](#endnote-7)

SpaceX’s biggest challenge would be differentiating itself from other broadband constellations operating in LEO.[[8]](#endnote-8) In the 1990s, LEO satellites launched by companies such as Iridium Communications Inc. (Iridium) did not succeed.[[9]](#endnote-9) Acknowledging past failures of the satellite Internet system, Musk said, “No one has ever succeeded in making a viable low Earth orbit communication constellation right off the bat.” He added, “I do believe we’ll be successful, but it is far from a sure thing.”[[10]](#endnote-10) Yet by July 2020, SpaceX had launched more than 500 Starlink satellites and was beginning the beta testing of these satellites.[[11]](#endnote-11)

Still, 500 satellites barely represented a start. Complete coverage of Earth with “moderate” Internet service would require 12,000 LEO Starlink satellites, which created another challenge: overcoming the worsening problem of space debris and obstacles for astronomers. On July 26, 2020, Starlink satellites had already ruined images of the NEOWISE comet,[[12]](#endnote-12) which astronomers were keenly observing.[[13]](#endnote-13)

Musk had some analysis and planning to do. How should he organize and prioritize known information about the various issues Starlink was facing? Who, exactly, were Starlink’s competitors, and how should SpaceX compete against them? Should Musk proceed with the project when demand was uncertain, or should he first fix the challenges of space debris and obstacles for astronomers?

BACKGROUND

In 2019, SpaceX raised US$1.33 billion[[14]](#endnote-14) over three rounds of funding. It was working on three ambitious programs: Crew Dragon, Starship, and Starlink. Crew Dragon and Starship represented SpaceX’s efforts to fly people into space. Starlink was intended to create a global network of small satellites to provide high-speed Internet. The network was known as a “megaconstellation,” with each megaconstellation having an interconnected system of approximately 12,000 satellites.[[15]](#endnote-15)

According to SpaceX, developing the Starlink network could cost about $10 billion in total, but the company was managing the funds through internal sources only.[[16]](#endnote-16) Jonathan Hofeller, SpaceX’s vice-president of Starlink and commercial sales, said, “We’ve been able to fund the development of Starlink primarily from our internal businesses.”[[17]](#endnote-17)

Starlink’s satellites were 227-kilogram “flat panel” satellites, expected to orbit the earth at an altitude of approximately 550 kilometres.[[18]](#endnote-18) Although Starlink’s first-generation satellites did not have the facility of inter-satellite communication, its second-generation satellites had this facility.[[19]](#endnote-19)

On May 26, 2020, SpaceX filed an application with the US Federal Communications Commission (FCC) to launch a total of 30,000 Starlink second-generation satellites in addition to the first-generation satellites already approved.[[20]](#endnote-20) By 2027, SpaceX intended to have 12,000 Starlink satellites in Earth’s orbit,[[21]](#endnote-21) providing high-speed Internet to millions of customers globally, with advantage of economies of scale for satellite manufacturing.[[22]](#endnote-22)

In 2020, SpaceX’s revenue was $1.2 billion, which was an increase of 20 per cent over 2019. The company employed 8,000 people.[[23]](#endnote-23) SpaceX’s valuation increased from $12 billion in 2014 to $36 billion in June 2020.[[24]](#endnote-24) Trefis*,* an interactive financial community, expected Starlink to achieve a valuation of $30 billion by 2025 if it could generate $10.4 billion in revenue by then.[[25]](#endnote-25)

GEOSTATIONARY SATELLITE INTERNET PROVIDERS

In the United States, satellite Internet was primarily targeted to rural households that could not be connected by fibre-optic or coaxial cable due to problems with infrastructure or the cost to overcome those infrastructure challenges.[[26]](#endnote-26) In those areas, Internet service was offered through geosynchronous satellites; however, the system had problems with latency, or lag. The need for the signal to fly thousands of kilometres through space back and forth resulted in a delay of half a second—a significant problem for anything but basic data transmission over the Internet.[[27]](#endnote-27)

Geostationary satellite Internet providers earned most of their revenues from governments and businesses and not from household customers.[[28]](#endnote-28) The market in the United States was dominated by two companies: Hughes Network Systems LLC (HughesNet) and Viasat Inc. (Viasat). In 2019, HughesNet and Viasat had a combined total of 2.5 million satellite Internet customers.[[29]](#endnote-29)

In the United States, where the average American family used more than 300 gigabytes (GB) of data per month,[[30]](#endnote-30) 19 million people (from an estimated 7.6 million households) still lacked access to fixed broadband Internet.[[31]](#endnote-31) For those people, the options were dial-up service (digital subscriber line, or DSL; originally digital subscriber loop), which was a very slow Internet connection, or satellite Internet. The average cost of a geostationary satellite Internet plan in the United States was approximately $100 per month, while a coaxial cable or fibre-optic cable plan averaged $50 per month.[[32]](#endnote-32)

In addition to the monthly service fee, Viasat charged $10 per month for equipment rentals (a satellite antenna and modem), with the option of paying a lifetime prepaid equipment lease for $300.[[33]](#endnote-33) Viasat charged a one-time installation fee of $100, but new customers were often successful in requesting a rebate.[[34]](#endnote-34) HughesNet charged $15 per month plus a one-time $100 activation fee with an option to purchase the equipment for $450 (with the activation fee waived). Both companies held clients to a two-year contract.[[35]](#endnote-35) HughesNet based its satellite Internet prices on a data cap. All of its packages offered the same speed—25 megabits per second (Mbps)—with the packages offering a range of 10–50 GB data per month before paying overage costs.[[36]](#endnote-36) In contrast, Viasat offered packages based on both speed and data, with data caps for Internet satellite ranging from 25-150 GB per month and speed ranging from 12–100 Mbps (see Exhibit 2).[[37]](#endnote-37)

LOW EARTH ORBIT (LEO) SATELLITE INTERNET SERVICE

Until 2020, people in rural and remote areas of the United States primarily relied on geostationary satellite Internet, which was expensive compared with terrestrial Internet.[[38]](#endnote-38) The pricing of LEO satellite Internet was not known (see Exhibit 2).

Starlink and its competitors, such as OneWeb, Telesat, and Project Kuiper, planned to place thousands of broadband satellites into LEO instead of a geostationary orbit. Using LEO could help the companies solve the half-second latency problems of geostationary satellites, as LEO satellites had a delay of approximately 20 milliseconds—barely noticeable to the average user.[[39]](#endnote-39) In February 2019, OneWeb launched its first batch of six satellites and by March 2020, it had launched a further 68 satellites.[[40]](#endnote-40) In 2019, Amazon announced Project Kuiper and its intention to place more than 3,200 broadband satellites into LEO.[[41]](#endnote-41) Telesat intended to place 78 satellites into LEO by 2022 and another 220 satellites by the end of 2023 (see Exhibit 3).[[42]](#endnote-42)

By March 2020, SpaceX had received FCC approval for one million ground antennas[[43]](#endnote-43) (approximately the size of a pizza box[[44]](#endnote-44)) used by customers to connect with the satellites passing overhead.[[45]](#endnote-45) However, during Starlink’s first broadcasting test in early 2019, which began with the launch of 60 satellites, three satellites failed in their orbit.[[46]](#endnote-46) Starlink was hoping to begin its commercial services by the end of 2020.[[47]](#endnote-47)

Demand for LEO Satellite Internet

Starlink intended to serve customers in the US rural areas, where “5G is really not well-suited” (see Exhibit 4).[[48]](#endnote-48) More than a quarter of the 29 million rural Americans did not have access to high-speed Internet, which became even more challenging during the COVID-19 pandemic.[[49]](#endnote-49)

Although the price of LEO satellites was unknown, ground antennas were expected to be expensive for customers, raising affordability issues, especially for rural households.[[50]](#endnote-50) Musk indicated that SpaceX would try to sign deals with global telecommunication service providers and governments that wanted to reach interior parts of their countries.[[51]](#endnote-51) LEO satellite Internet providers also found aviation and maritime markets to be lucrative.[[52]](#endnote-52) Starlink and OneWeb also promised to make connectivity better in the Arctic—a region of about four million people and an area where the US military usually struggled with its current communication satellite technology.[[53]](#endnote-53)

Carissa Christensen, CEO of the analytics firm Bryce Space and Technology, raised concerns about the affordability of satellite Internet. She cited the example of O3b Networks Ltd., a satellite-based Internet company founded in 2007 by Greg Wyler, the CEO of OneWeb. Its goal was to bring online the estimated three billion people globally without Internet access. However, the market for satellite mega-constellations did not exist; therefore, to survive, O3b switched to providing data services for maritime operations, which, according to Christensen, implied “transformational visions are not necessarily going to translate into a realistic business model.”[[54]](#endnote-54) Matt Desch, CEO of Iridium, also had concerns about whether there was sufficient demand for LEO satellite Internet, observing, “The investment markets are clearly concerned, which is why these new markets are being slow to be funded, at least by the public equity and debt markets.”[[55]](#endnote-55)

Starlink versus 5G

SpaceX’s Starlink project also faced competition from the 5G system. Experts believed 5G posed a threat to the satellite Internet business, especially with regard to latency.[[56]](#endnote-56) Starlink’s latency was estimated to be less than 20 milliseconds,[[57]](#endnote-57) which was an improvement over 4G’s latency of 50 milliseconds, but still slower than 5G’s latency of 5 milliseconds.[[58]](#endnote-58) Starlink’s speed was faster than 5G, which offered a speed of 330 Mbps in urban areas, while Starlink’s Internet service was forecast to offer speeds that were three times faster—up to 1 gigabits per second (Gbps).[[59]](#endnote-59)

Because 5G was expected to be deployed more in urban areas of the United States,[[60]](#endnote-60) the FCC announced in 2019 the launch of a $9 billion fund to accelerate the deployment of advanced 5G wireless networks in rural areas across the United States.[[61]](#endnote-61) In June 2020, T-Mobile, the third-largest wireless carrier in the United States by the number of subscribers,[[62]](#endnote-62) also began offering 5G services in rural areas.[[63]](#endnote-63) Its Magenta 5G plan was available for $70 per month.[[64]](#endnote-64) T-Mobile also claimed that by 2026, it would cover 90 per cent of rural United States with 5G, offering a minimum speed of 50 Mbps.[[65]](#endnote-65) T-Mobile’s operating profit margin had been around 13 per cent.[[66]](#endnote-66)

Musk maintained that LEO satellite Internet was still superior, especially with its potential, commenting, “That same system, we could leverage to put into a constellation on Mars.”[[67]](#endnote-67) He further added, “Mars is going to need a global communication system too, and there’s no fiber optics or wires or anything.”[[68]](#endnote-68) Moreover, once built, maintaining satellites was less expensive than maintaining fibre-optic and co-axial cables. Comcast Corp., for example, which provided fibre optic–based broadband in the United States, spent $10 billion–$11 billion every year on capital maintenance and investment.[[69]](#endnote-69)

According to media reports, 5G and Starlink were not comparable and each had its own function. Comparing them was equivalent to comparing Uber Eats with Uber Freight services.[[70]](#endnote-70) Uber Eats was a food ordering and delivery platform, while Uber Freight allowed independent truckers to connect via a mobile application (app) with shippers and freight forwarders.[[71]](#endnote-71) 5G was fast and efficient, but depended on transmitters mounted on towers about half a kilometre apart, which was ideal in densely populated areas where the infrastructure was easy to establish and the density of users was high. Starlink, on the other hand, while slower and less convenient than 5G, could efficiently service sparsely populated rural areas. The only ground equipment needed was one receiver per household. Although the technologies were unrelated, they could be complementary.[[72]](#endnote-72) LEO satellites could extend cellular 5G networks from their dense web of transmitters to air, sea, and other remote areas that could not be covered by small cell networks, thus offering a seamless experience for end-users.[[73]](#endnote-73) Moreover, during catastrophic events, when cellular and Internet networks had higher chances of failure, LEO satellite Internet providers could take over to provide services in critical industries, such as health care.[[74]](#endnote-74)

Another limitation to 5G networks was its unknown effects on people and the environment. Scientists and physicians in the European Union appealed to governments to halt the expansion of 5G until the effect of radiation caused by radio-frequency electromagnetic fields (RF-EMF) could be investigated. Most wireless networks and wireless devices depended on RF-EMF, and while the second, third, and fourth generations of cellular technology (2G, 3G, 4G) and Wi-Fi all created electromagnetic fields, 5G escalated the potential risk because of the sheer number of base stations required to generate the network and the nature of the waves generated by the network.[[75]](#endnote-75) Installation of 5G in the United States would require more than 800,000 cell antenna sites in populated areas, replete with homes, parks, shopping, and offices.[[76]](#endnote-76) And, unlike other cellular technologies, which relied primarily on microwaves, 5G employed millimetre waves. The shorter wave length was the reason antennas were needed every few hundred metres (thus the high number of transmitters), but the shorter wave length also raised concerns about millimetre-wave radiation. According to scientists, millimetre waves were mostly absorbed in the top few millimetres of human skin and in the surface layers of the cornea. Short-term exposures to millimetre waves were expected to adversely affect the peripheral nervous system, immune system, and cardiovascular system.[[77]](#endnote-77)

Economic Feasibility of LEO Satellites

LEO satellites had not been successful in the past. When Iridium launched a constellation of 95 LEO satellites into Earth’s orbit in the 1990s, 30 per cent of the satellites failed.[[78]](#endnote-78) The company’s satellite-based phones were priced at $3,000 each and calls were charged at $4–$7 per minute in 1997 (a function of the cost of building the satellites and launching them into orbit).[[79]](#endnote-79)

According to Blaine Curcio, founder of Orbital Gateway Consulting, that cost had been much reduced by 2020. He claimed, “The cost to launch 1 Gbps of capacity is literally 100 times less than it was 15 to 20 years ago.”[[80]](#endnote-80) However, according to McKinsey, the cost of satellite launches was just one part of the equation; reducing the cost of manufacturing spacecraft, ground equipment, and user equipment was equally important to unlock the potential of LEO satellite Internet.[[81]](#endnote-81) The price of consumer equipment had fallen; for example, antennas that had cost $100,000 in the 1990s had fallen to $300–$500 by 2020.[[82]](#endnote-82)

Bulent Altan, head of space at Mynaric, a laser communication technology manufacturer, suggested that for satellite Internet to be economically viable, user equipment must be sold at three to four times the operator’s monthly service charge so that investments could be made in equipment maintenance.[[83]](#endnote-83) In 2019, OneWeb indicated that it was planning to price a user terminal at $200–$300, but SpaceX had not revealed its price plans.[[84]](#endnote-84)

For Starlink to be economically viable, Musk maintained that the company needed to deploy 1,000 satellites. He added, “If we are putting a lot more satellites than that in orbit, that’s a very good thing—it means there is a lot of demand for the system.”[[85]](#endnote-85) Starlink’s goal was “targeting service in the Northern US and Canada in 2020, rapidly expanding to near-global coverage of the populated world by 2021.”[[86]](#endnote-86) Musk’s financial goal for Starlink was an operating profit margin of 40 per cent in 2021, 50 per cent in 2022, and 60 per cent in 2025.[[87]](#endnote-87) With expected operating profits of $10 billion per year and a cost of $10 billion to build Starlink, a year’s profit was expected to offset SpaceX’s cost in launching Starlink.[[88]](#endnote-88)

OTHER ISSUES

Scientists were concerned that the numerous satellites launched by SpaceX and other companies were increasing the amount of debris in space. In 2018, there were more than 14,000 particles of space junk that were uncontrolled.[[89]](#endnote-89) Space debris could cause collisions, damaging satellites, telescopes, and other objects orbiting the earth. Because of the speed of travel and the lack of countervailing gravitational forces, any debris larger than 10 centimetres could shatter a satellite or spacecraft into pieces, consequently creating more space debris.[[90]](#endnote-90)

In its FCC filing in October 2019, SpaceX claimed that if any Starlink satellite failed immediately after being launched into its initial orbit—an altitude of about 350 kilometres—the risk of the failed satellite colliding with any objects larger than 10 centimetres was just 0.000000303 per cent. SpaceX did not provide a risk analysis for satellites that failed at their operational height of 550 kilometres.[[91]](#endnote-91)

Astronomers also raised concerns about how Starlink’s mega-constellation affected observations of the universe.[[92]](#endnote-92) The initial batch of SpaceX’s Starlink satellites shone brightly in astronomical observations of the night sky. Cees Bassa, an astronomer from the Netherlands Institute for Radio Astronomy, said, “Astronomy will [still] be possible, we will just have to learn to deal with many satellites passing through our observations, and they may ruin some observations.”[[93]](#endnote-93)

The ROAD AHEAD

Musk’s ultimate mission for SpaceX was to send humans to Mars—a project that could cost up to $220 billion.[[94]](#endnote-94) SpaceX’s revenue from rocket launch contracts was about $3 billion annually, with the potential of reaching $5 billion by 2025. Revenue from Starlink’s Internet services was projected to be around $30 billion,[[95]](#endnote-95) which Musk intended to use for SpaceX’s Mars project. However, Roger Rusch, president of TelAstra, an investment consulting firm in the satellite industry, was not optimistic, commenting, “My view is that these LEO constellations are totally uneconomic.”[[96]](#endnote-96)

Musk was also known to overpromise and underdeliver, as had been the case with Tesla.[[97]](#endnote-97) But he was known, as well, for taking on big challenges, and in the past, Musk had proven wrong those market analysts who believed that industries such as conventional automobiles, aerospace, or banking could not be disrupted.[[98]](#endnote-98) Could Musk do it again with Starlink? He wanted Starlink as a trial run of satellite Internet services for Mars.[[99]](#endnote-99) Given the competition and low prices of other Internet service providers, how could Musk ensure that Starlink remained an economically feasible project?

EXHIBIT 1: KEY TERMS

|  |  |
| --- | --- |
| **Key Term** | **Definition** |
| LEO satellites | Low Earth orbit (LEO) satellites operated between 500 and 2,000 kilometres above Earth’s surface. |
| Need for multiple LEO satellites | LEO satellites revolved around Earth at approximately 8 kilometres per second, completing a full orbit in 90–120 minutes. The rapid orbit made satellites visible to receivers on the ground for a short period of time. Multiple satellites, however, could establish a permanent Internet connection because as one satellite approached the horizon, it passed the signal to the next. |
| Geostationary satellites | Satellites that operated at an altitude of 36,000 kilometres above Earth’s surface. At that altitude, the satellite’s orbital period was the same as Earth’s rotation period; thus, the satellite was in a fixed (stationary) position relative to the Earth. |
| Latency | The time delay between cause and effect of physical change. In communications, latency referred to the time needed to send and receive a packet of data on a network, usually measured in milliseconds. |
| Ground station | A radio station on or near Earth that communicated with a space station (satellite) above Earth’s surface. Satellite ground stations were typically used to provide voice, data, broadcast, and two-way broadband communications. |
| 5G | Fifth generation of cellular technology, designed to increase speed, reduce latency, and improve flexibility of wireless services. |
| Satellite versus terrestrial | “Satellite is the only broadband wide-area network technology that is available everywhere—in urban and rural areas around the world. All that is required for a location to receive connectivity from the satellite is a clear view of the sky unobstructed by trees, tall buildings or other objects. In contrast, terrestrial technologies are limited in their coverage area.” |
| Broadband Internet | “An Internet connection with a high data transfer rate.” |
| Terrestrial Networks | “Terrestrial networks are suitable for high speed wired communications, using cheap devices and fixed points of access, and for medium-to-high speed wireless connectivity, resulting in a more flexible infrastructure.” |
| Space debris | **Space debris** refers to artificial dysfunctional materials in the space orbiting Earth. They could be as small as a microscopic chip or as large as a discarded rocket stage. |
| Satellite gateway | **“A ground station that transmits data to/from the satellite to the local area network.”** |

Source: Greg Ritchie and Thomas Seal, “Why Low-Earth Orbit Satellites Are the New Space Race,” Bloomberg Businessweek, July 10, 2020, accessed August 17, 2020, www.bloomberg.com/news/articles/2019-08-09/why-low-earth-orbit-satellites-are-the-new-space-race-quicktake; Elizabeth Howell, “Space Companies Are Investing Big in 5G Technology,” Space, October 20, 2019, accessed August 17, 2020, www.space.com/5g-in-space-Internet-satellites.html; “Satellite Earth Stations,” Ofcom, December 18, 2019, accessed August 17, 2020, www.ofcom.org.uk/manage-your-licence/radiocommunication-licences/satellite-earth; “What Is 5G?,” Cisco, accessed August 17, 2020, www.cisco.com/c/en/us/solutions/what-is-5g.html. Erik Gregersen, “Space Debris,” Britannica, June 15, 2020, accessed January 11, 2021, www.britannica.com/technology/space-debris; “Broadband Internet Connection,” NFON, accessed January 11, 2020, www.nfon.com/gb/service/knowledge-base/knowledge-base-detail/broadband-internet-connection; Francesco Zampognaro, “Satellite and Terrestrial Network Integration,” 3, University of Rome Tor Vergata, 2008/2009, accessed January 11, 2021, https://core.ac.uk/download/pdf/53822257.pdf; “What Is a Satellite Gateway?,” X2nSat, accessed January 11, 2020, https://x2n.com/faq/what-is-a-satellite-gateway/; Michel Verbist, “Satellite vs. Terrestrial: Which Network Is Right for You?,” Orange Business Services, October 1, 2020, accessed January 11, 2021, www.orange-business.com/sites/default/files/media/library/0215\_satellite\_vs\_terrestrial\_wpr-sat-0094.pdf.

EXHIBIT 2: INTERNET SERVICE PROVIDERS IN THE United States

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type** | **Company** | **Monthly Price**  **(in US$)** | **Download Speed** | **Data Cap** |
| Terrestrial (broadband) | Xfinity (Comcast Cable Communications LLC) | $20–$299.95 | 25–2,000 Mbps | 1 TB–unlimited |
| Terrestrial (broadband) | Lumen Technologies Inc. (previously CenturyLink) | $49–$65 | 15–940 Mbps | 1 TB |
| Terrestrial  (Broadband and 5G) | AT&T Inc. | $49.99 | 940 Mbps | Unlimited |
| Terrestrial  (Broadband and 5G) | Verizon Communications Inc. | $39.99–$79.99 | 200–940 Mbps | Not Available |
| Terrestrial (5G) | T-Mobile US Inc. | $40–$70 | 330 Mbps (urban)  50 Mbps (rural) | 10 GB–unlimited  Hotspot: 5–15 GB |
| Geostationary | Viasat Inc. | $30–$150 | 12–100 Mbps | 25–150 GB |
| Geostationary | Hughes Network Systems LLC (HughesNet) | $59.99–$149.99 | Up to 25 Mbps | 10–50 GB |

Note: LLC = limited liability company; Mbps = megabits per second; TB = terabytes; 5G = fifth-generation mobile network; Gbps = gigabits per second; GB – gigabytes.

Source: Catherine McNally, “Best Internet Service Providers 2020,” Reviews, June 30, 2020, accessed August 17, 2020, www.reviews.org/Internet-service/best-Internet-service-providers; Dave Schafer, “How Much Does Satellite Internet Cost?,” Satellite Internet, December 2, 2019, accessed August 17, 2020, www.satelliteInternet.com/resources/how-much-does-satellite-Internet-cost; “Metro: Phone Plans,” Metro by T-Mobile, accessed August 17, 2020, www.metrobyt-mobile.com/shop/plans; Philip Michaels, “T-Mobile 5G Rollout: Locations, Phones, Price and More,” Tom’s Guide, May 6, 2020, accessed August 17, 2020, www.tomsguide.com/uk/us/t-mobile-5g-network,news-29965.html.

EXHIBIT 3: EFFICIENCY OF LEO SATELLITE CONSTELLATION SYSTEMS, by COMPANY

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Telesat** | **OneWeb** | **SpaceX** |
| Required number of gateways per ground station | 5–6 | 11 | 30 |
| Average data rate per satellite (Gbps) | 22.74 | 2.17 | 5.36 |
| Maximum data rate per satellite (Gbps) | 38.68 | 9.97 | 21.36 |
| Satellite efficiency (%) (average Gbps/satellite) | 58.8 | 21.7 | 25.1 |

Note: Gbps = gigabits per second.

Source: Inigo del Portillo, Bruce G. Cameron, and Edward F. Crawley, “A Technical Comparison of Three Low Earth Orbit Satellite Constellation Systems to Provide Global Broadband,” (presentation to 69th International Astronautical Congress 2018, Bremen, Germany, October 1, 2018), accessed August 17, 2020, www.mit.edu/~portillo/files/Comparison-LEO-IAC-2018-slides.pdf.

EXHIBIT 4: United States—KEY DEMOGRPAHICS, 2017–2019

|  |  |  |  |
| --- | --- | --- | --- |
|  | **2017** | **2018** | **2019** |
| Rural population (millions) | 58.34 | 58.05 | 57.8 |
| Urban population (millions) | 266.81 | 269.11 | 271.73 |
| Average family size | 3.14 | 3.14 | 3.14 |
| Disposable personal income (US$) | 14,000 | 14,560 | 14,975 |

|  |  |
| --- | --- |
| **Median Household Income (2011–2015)** | **(US$)** |
| Rural | 52,386 |
| Urban | 54,296 |

Source: Erin Duffin, “Size of Urban and Rural Population of the U.S. 1960-2019,” Statista, November 28, 2019, accessed August 17, 2020, www.statista.com/statistics/985183/size-urban-rural-population-us; Erin Duffin, “Disposable Personal Income in the U.S. 2000–2019,” Statista, March 31, 2020, accessed August 17, 2020, www.statista.com/statistics/710209/us-disposable-income; “Families in the U.S.,” Statista, 2019, accessed August 17, 2020, www.statista.com/study/9824/families-in-the-us-statista-dossier; Alemayehu Bishaw and Kirby G. Posey, “A Comparison of Rural and Urban America: Household Income and Poverty,” United States Census Bureau, December 8, 2016, accessed August 17, 2020, www.census.gov/newsroom/blogs/random-samplings/2016/12/a\_comparison\_of\_rura.html.

ENDNOTES

1. This case has been written on the basis of published sources only. Consequently, the interpretation and perspectives presented in this case are not necessarily those of Space Exploration Technologies Corp. or any of its employees. [↑](#endnote-ref-1)
2. Dave Mosher, “Elon Musk Just Revealed New Details about Starlink, a Plan to Surround Earth with 12,000 High-Speed Internet Satellites. Here’s How it Might Work,” *Business Insider,* May 16, 2019, accessed August 17, 2020, www.businessinsider.com/spacex-starlink-satellite-internet-how-it-works-2019-5. [↑](#endnote-ref-2)
3. Daniel Oberhaus, “SpaceX Is Banking on Satellite Internet. Maybe It Shouldn’t,” *Wired,* May 15, 2019, accessed August 17, 2020, www.wired.com/story/spacex-starlink-satellite-internet. Broadband Internet referred to a high-speed signal that was always on and delivered by radio, phone, optical fibre, or cable lines. [↑](#endnote-ref-3)
4. Ibid. [↑](#endnote-ref-4)
5. Michael Sheetz, “Here’s Why Amazon Is Trying to Reach Every Inch of the World with Satellites Providing Internet,” CNBC*,* April 7, 2019, accessed August 17, 2020,www.cnbc.com/2019/04/05/jeff-bezos-amazon-Internet-satellites-4-billion-new-customers.html. [↑](#endnote-ref-5)
6. Oberhaus, op. cit. [↑](#endnote-ref-6)
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