Center for Global Development

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Space and Development: Preparing for Affordable Space-Based Telecommunications

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A new generation of satellites are about to make internet access more inclusive and resilient, but are governments ready to engage?

EXECUTIVE SUMMARY

- Space-based communication technology will make access to "last mile" broadband significantly cheaper, if not yet affordable, for citizens in remote, sparsely populated, dangerous, or otherwise difficult locations.
- Space-based communications provide unique additive value for areas without terrestrial infrastructure. This includes communications at sea and during emergencies related to disasters or conflict.
- Traditional global telecommunications infrastructure will continue to have far more capacity (2,000 terabits per second (Tbps)) than projected space-based infrastructure capacity (estimated at 50 Tbps by 2026). Space-based infrastructure currently complements terrestrial networks by "backhauling" (moving data between "access" networks, to include users' devices, and the "core" or "backbone" network where substantive computing happens) for terrestrial network service providers. Satellite capacity will likely steadily increase as multiple large constellations are launched, and data relay efficiency and satellite-based data processing improves.
- A general lack of "space awareness" obscures pragmatic, space-based options to address the digital divide. Space-based hard infrastructure could expand the baseline connectivity required for digital literacy and accelerate uptake, thereby also helping to address long-standing challenges in multiple sectors in the developing world, including health, disaster management, security, and education.
- Governments and development, advisory, and financing organizations need to consider what investments should be made to maximize the benefits of an increasingly space-based global telecommunications infrastructure, particularly for low- and middle-income countries.

A 1990'S PITCH MADE POSSIBLE WITH 2020'S TECHNOLOGY

According to the recently released Global System for Mobile Communications (GSMA) "State of the Mobile Internet Connectivity Report 2021," hundreds of millions of people in both high- and lower-income countries still have limited access to a fast, reliable, and affordable fixed internet connection, an issue ever more important during the ongoing COVID-19 pandemic and related economic upheaval. Generically, the share of internet users is twice as high in urban areas than in rural areas. The number of people worldwide without access at all to a fixed or mobile broadband signal, estimated to number at 450 million people, remains mostly concentrated in the developing world.[1,2]

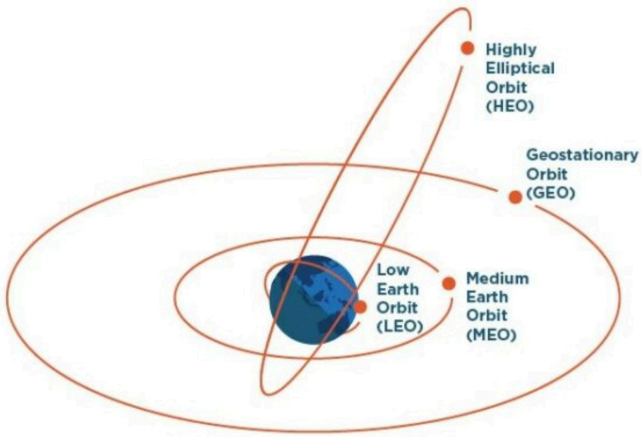
The idea of using satellites to close such coverage gaps has been pursued since the early 1990s, but most space-pioneering companies fell short, despite significant capital investment. In hindsight, these companies, such as Teledesic and early versions of Iridium and Globalstar, had originally designed their systems to appeal to business and government travers willing to pay high fees for global access. Unfortunately, satellite development and deployment took more time than planned, and terrestrial infrastructure deployed more quickly than anticipated to well populated, business-friendly destinations. Equipment costs were too high for the population in mass, thus eroding its potential for profitability.[3] Today, new technology, combined with a more robust and diversified private space sector, lowering launch costs, ever-increasing demand for broadband, strong resurgence of capital investment and government support, and new market strategies that rely on more than subscriptions, have resulted in a stronger baseline business case, setting space-based communications on a course to offer more affordable broadband to those who are currently on the dark side of the digital divide.[4]

Could ground infrastructure again snatch up potential customers? Continued roll-out of terrestrial infrastructure is expensive: the unconnected population is spread out across more than 50 percent of the inhabited land on Earth and often lacks other essential components such as access roads or sufficient power.[5] Fiber optic cable costs about approximately 27,000 per mile to install.[6] Building a cellphone tower costs $50,000 to $200,000 per tower, plus expenses associated with accessing, powering, maintaining, and securing towers in remote or difficult locations.[7] Microwave relay towers are an option that could push the edges of existing networks. For Africa alone, a 2020 OECD report estimated it would cost $100 billion to extend fast internet to the entire population of Africa using traditional means, like fiber and cellphone towers. The African Development Bank recommended annual outlays between $4 billion and $7 billion to address the continent's information and communications technology (ICT) infrastructural backlog. Progress will be made, but not so quickly or so cheaply to meaningly improve access to fast internet in remote or difficult locations in the near term.

A LOOK AT NEW SPACE-BASED INFRASTRUCTURE

New large, or even "mega" constellations (groups of satellites that work together as a system), such as those in development by Telesat, OneWeb, SpaceX, and Amazon, consisting of non-geostationary orbit (NGSO) satellites, will be useful in bridging the digital divide. These companies promise fast internet access in very remote locations for a competitive cost compared to extending standard options like fiber, microwave relay, or older satellite communication systems.[8] The general orbits are depicted in Figure 1.[9]

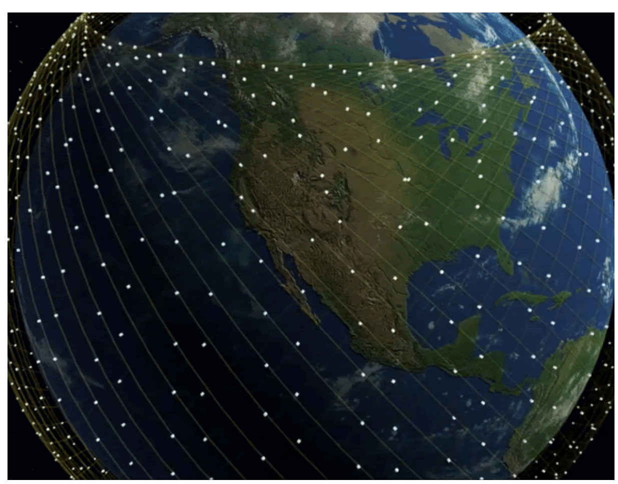
Figure 1. Satellites in geosynchronous and geostationary orbit match the Earth's rotation, thus staying "in synch" or "stationary" over the same point of the planet as the Earth turns



Source: Steven Kosiak, 2019. "Small Satellites in the Emerging Space Environment: Implications for US National Security–Related Space Plans and Programs." Center for New American Security, https://www.cnas.org/publications/reports/small-satellites-in-the-emerging-space-environment

Starlink, the first to enter commercial service, is currently populating thousands of small, table-sized satellites into a matrix rotating only a few hundred miles above the Earth's atmosphere, rather than the 22,000 miles traditional space-based broadband services have been based as shown in Figure 2.[10] Because they are so close to the Earth in low Earth orbit (LEO) compared to bus-sized communication satellites sitting much further away in geostationary orbit (GEO), they don't require as much time or power to push or receive a signal through the atmosphere. Earth-based antennas designed to receive that signal have shrunk to sizes comparable to a pizza box and require far less electricity to run. Starlink's 100-watt power requirement, for example, is capable of being addressed by a typical household outlet or solar generator. Other companies leverage LEO, medium Earth orbit (MEO), or a combination of orbits, to build a constellation that has better coverage of particular areas of the world (such as a constellation specifically designed to service a certain area, like North America or India).

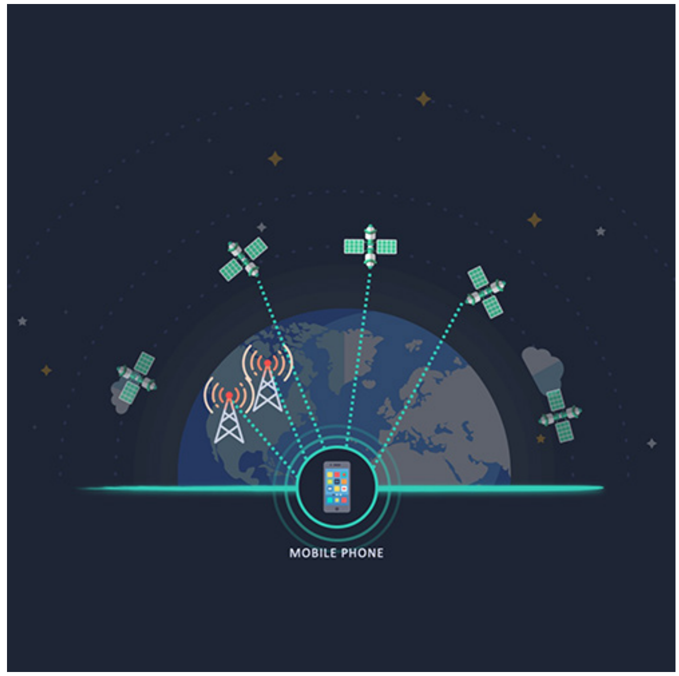
Figure 2. Planned Starlink satellite constellation



Source: Mark Handley, *Using Ground Relays with Starlink*, 2019, https://www.youtube.com/watch?v=m05abdGSOxY

Starlink and OneWeb are both emerging from beta phase and are offering initial commercial service to paying customers in 2021 and 2022, respectively.[11] A growing crowd of competitors, such as Amazon and Verizon's joint venture Kuiper and Telesat's Lightspeed, are quickly developing and testing their own products. China SatNat's GuoWang constellation is in the concept and design phase but is developing quickly with strong government support.[12,13,14] Legacy satellite networks are evolving as well. Inmarsat, for example, is banking on expanding to "hybrid" constellations of high Earth orbit (HEO), GEO, and LEO satellites to expand its customer base and upgrade existing service to longstanding customers like the US military.[15] Other initiatives have continued to use GEO satellites, with government support, to good effect. Australia launched two geostationary Sky Muster satellites in 2016 that are providing service to over 100,000 points in rural and remote areas in Australia.[16]

Figure 3. Satellite-to-cellphone technology



Source: Lynk, https://lynk.world/our-technology

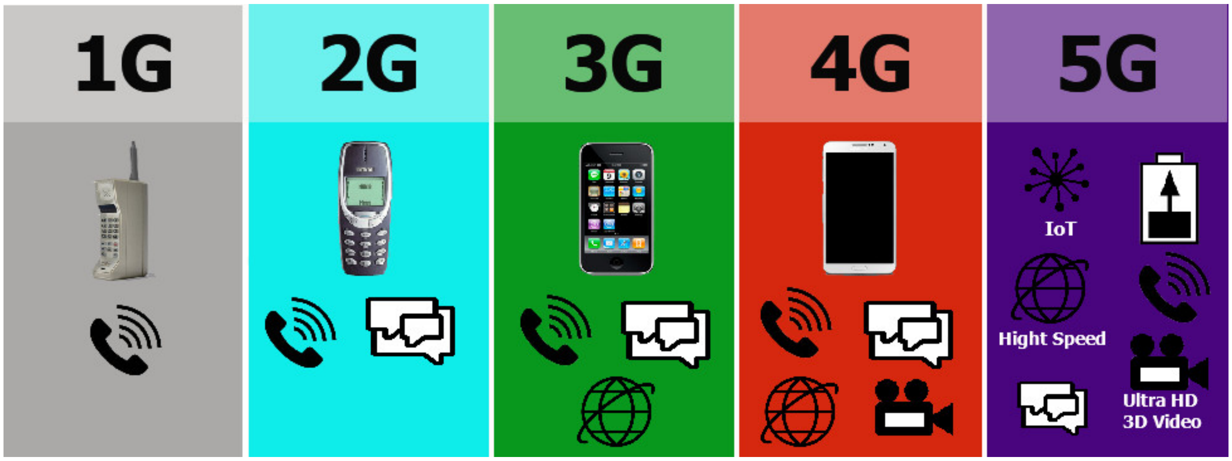
Some companies are moving forward with a design that eliminates the need for a satellite-dedicated receiver owned by users almost completely. Instead, "satellite-to-cellphone" constellations require only a typical, unmodified, hand-held cellphone to enable 2G-4G connectivity. Companies such as Lynk and AST SpaceMoble are racing to establish "satellite-to-smartphone" broadband, described by Lynk as "cellphone towers in the sky."[17,18,19] (see Figure 3[20]). Anyone worldwide could theoretically use a regular cellphone to communicate directly with satellites, using credit bought through a local operator, like Vodacom or MTN. Lynk, thus far, is contracted to provide texting and data store/forward commercial service using its current five satellites for the Bahamas and mobile service operator Aliv starting in June 2022. The company plans to then pursue the market in the Central African Republic and Mongolia as its constellation, and capacity, grows.[21]

AFFORDABILITY IS MOVING IN THE RIGHT DIRECTION

Traditional terrestrial infrastructure will continue to have far more capacity, about 2,000 terabytes per second (Tbps), than space infrastructure, projected to reach 50 Tbps by 2026. Terrestrial infrastructure will likely remain the primary way that information is moved around the world for the foreseeable future. For those that are marooned outside of the terrestrial network, satellites have been one of few commercially available alternatives.

Since the 1970s however, using satellites for broadband has been a stubbornly slow, laggy, and prohibitively expensive solution. If we were to take a snapshot of what's available in Tanzania today, for example, a small organization (like an internet café, a school, a security post), could install a very small aperture terminal (VSAT) dish and hardware kit for about $1,885, with internet subscription plans ranging from $232 per month for mostly-reliable 256 kbps to $13,779 per month for highly-reliable 8 Mbps, which is similar to a basic level ethernet connection.[22] The 256 kbps standard barely meets the 2008 definition of broadband set by the International Telecommunication Union (ITU).[23] As of late 2021, the VSAT option remains extremely expensive, which is why it is limited to organizations

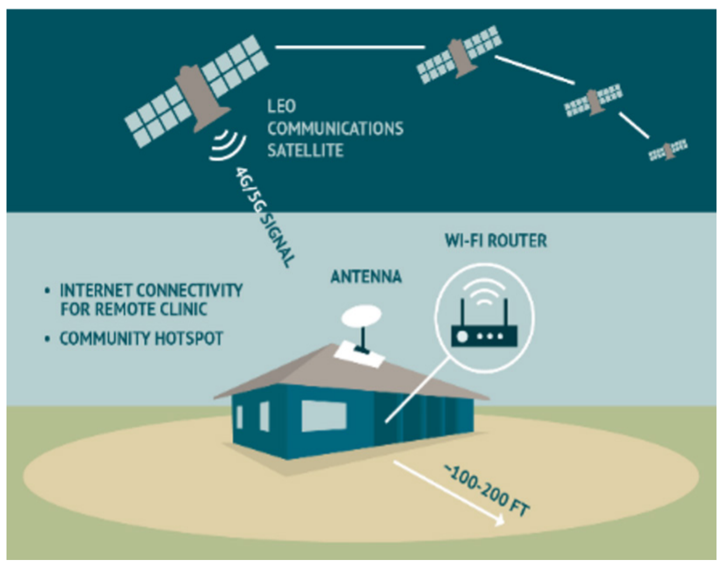
Figure 4. Successive generations of wireless technology



Source: Technospy, "What's the Difference between 3G, 4G, and 5G?," March 1, 2019. https://technospy.home.blog/2019/03/01/what-is-the-difference-between-3g-4g-and-5g/

with an overwhelming requirement for connectivity or the capital necessary to access it. The military and oil industry are examples of organizations that have an operational necessity and the financial resources.

Figure 5. Notional deployment of satellite broadband to remote clinic, extended locally via wifi or mesh network.



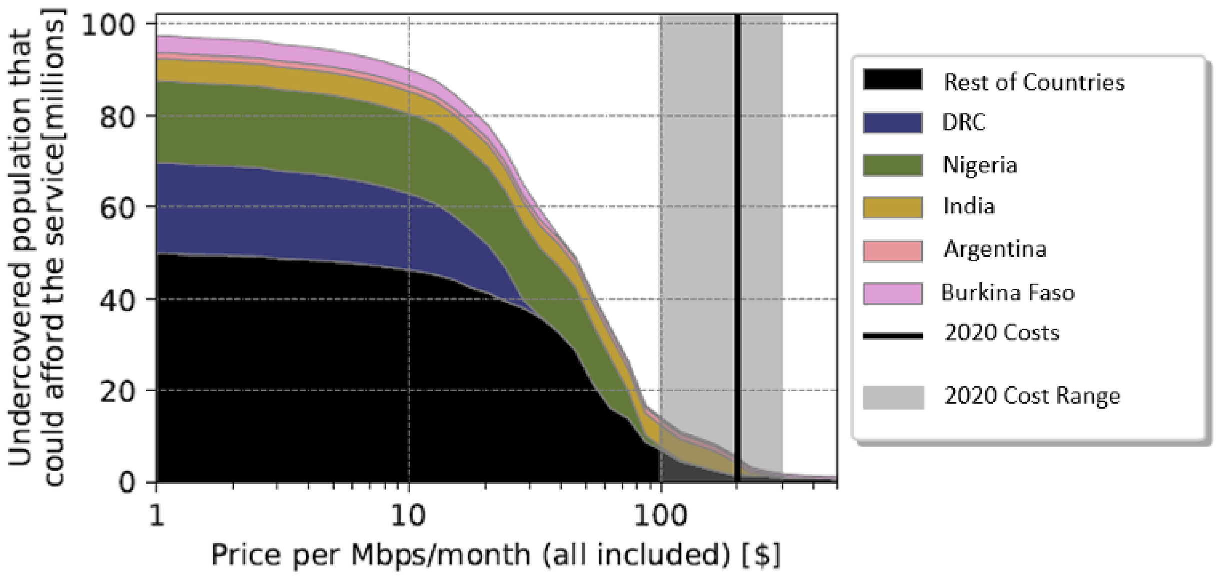
Source: Center for Global Development

The starting block for emerging NGSO constellations providing 4G-5G broadband in the commercial space sector has been set thus far by Starlink, costing approximately $500 for a company-subsidized all-inclusive receiver, wifi router and hardware set and about $100 per month, uncapped, broadband subscription.

A combined "first month" cost of $600 is still not realistic for the majority of the undercovered or underconnected population, as illustrated in Figure 6.[24] Using India as an example, even though a Starlink antenna and broadband subscription is steeply cheaper than traditional VSAT options on the market today, it is still seven to eight times more expensive than what is typically available in India's urban, in-network areas.[25,26] A MIT study examining 37 countries determined that even though Starlink's data is unlimited, the flat fee of $100 per month is affordable for only about 15 percent of the undercovered population. Starlink's greatest potential for early uptake is in rural areas of high-income countries, or undercovered areas of middle-income countries in South America and Southeast Asia.

Figure 6. Cost (per Mbps/month) at which select nations' undercovered population could afford broadband service

The joint International Telecommunications Union/United Nations Broadband Commission for Digital Development defined "affordable broadband," as entry-level broadband services that cost less than 2 percent of monthly gross national income per capita.



Source: Inigo del Portillo et al., "Connecting the Other Half: Exploring Options for the 50% of the Population Unconnected to the Internet," *Telecommunications Policy* 45, no. 3 (April 2021): 102092, https://doi.org/10.1016/j.telpol.2020.102092.

Over the following decade, however, the same study suggested NGSO satellite prices may drop closer to $30 per Mbps per month, opening up affordability to about 60 percent of the population considered. While these costs are more than what many individual households can afford, civil society organizations, government, and nongovernmental organizations can take action to increase sustainability and uptake. Many rural communities, frustrated by the high for-profit cost of rural internet, have successfully established small, cooperative-owned, internet service provider community networks, like the Zenzeleni network in South Africa. These networks have made impressive progress in localizing use and boosting affordability of high-speed broadband.[27,28]

Most promising, satellite-to-cellphone constellations like Lynk provide a shorter-term jump in both accessibility and affordability. Since they are designed to be incorporated into local mobile network operator's ecosystem, then the access problem would be addressed, and the cost at level with the local market for cellphones and mobile credit.

Several other innovative approaches, like utilizing television "white space" (TVWS), or "buffer" space between television channels in the radio frequency spectrum to provide cheap broadband internet access, or using drones and balloons to extend middle and last mile coverage, provide additional alternatives for consideration. TVWS may fade as a viable option as countries become more efficient at reducing unused spectrum. Balloons and drones require significant *in situ* management and maintenance, thus making them less practical for expanding telecommunications infrastructure in developing countries.[29]

IT'S NOT JUST AFFORDABILITY: ADDITIVE SPACE-BASED INFRASTRUCTURE

Satellite-serviced broadband affordability is not the only factor to consider. Space-based infrastructure is additive in the following ways:

1. Improves civilian infrastructure resiliency during conflict

Ground-based telecommunications infrastructure has become a favorite target for armed groups in sub-Sahara Africa. In Mali, for example, armed groups have attacked cellphone towers across northern and central Mali, disrupting internet, voice, and money transfer services across the country. Remote villages are often left with intermittent contact, unable to alert security forces to attacks. Banks become inert, disconnected from their headquarters in Bamako, damaging a struggling economy even further. As reporters Nick Roll and Alhousseini Alhadji wrote, "residents describe themselves as 'cut off from the world.'" Satellite-to-cellphone enabled cell phones or pizza-box-sized NGSO receivers could provide an alternative connection that is easier to protect, hide, or move for vulnerable communities.[30]

2. Enables emergency communications

Satellite-to-cellphone technology could be used to provide communications in situation where the ground infrastructure has been devastated, as seen during the 2010 earthquake in Haiti, the 2011 earthquake in Japan, and the 2015 earthquake in Nepal. Space-based infrastructure would remain intact and available for use, safely in orbit.[31,32]

3. Makes mobile communications accessible on land and at sea

Oceans cover about 70 percent of the Earth, and at-sea communications relies heavily on expensive VSAT-enabled connections to communicate, such as O3B, Inmarsat, Iridium Communications, Thuraya, Hughes Network Systems, and KVH Industries. Starlink plans to make its antenna mobile with other companies to follow, meaning NGSOs could offer a comparatively cheap way to access broadband for trucks, ships and planes.[33] NGSOs could become a global roaming backstop, where even small fishing or transport boat operators will be able afford to call or text from sea, a substantive benefit for the blue economy.

4. Frees data locked countries

Because most data today is moved through undersea cables connected to coastal landing points, landlocked low- and middle-income countries must depend on their neighbors' (potentially imperfect) terrestrial telecommunications networks for access. Emerging satellite communications options present an opportunity for cheaper access and greater infrastructure resilience.[34] As remarked in the ITU 2021 report on regional good practices, building the physical components that permits data communications, particularly for lower income countries, is a prerequisite to meaningfully improving digital literacy and inclusion in the global economy.[35]

TO CONSIDER MOVING FORWARD

- **The space private sector is slowed by the legitimate need to navigate country-by-country regulations and markets.** For example, both Starlink and Lynk are in the process of determining how and where it will deploy. In the United States, Starlink will serve both as a "backhauler," providing the first-mile and middle-mile infrastructure that enables access to a community, and as the last-mile internet service provider to the end user.[36] In other countries, like India, Starlink intends to establish a subsidiary for the last-mile service provider function. Lynk, the satellite-to-cellphone constellation, will serve as first-mile and middle-mile infrastructure, and last-mile access will be available through local mobile network providers. As the technology is implemented, the ITU, governments, and various regulatory bodies will need to update standards, guidelines, and regulations in order to speed up implementation and encourage fair practices.

- **Over time, the ability of satellites in all orbits to relay data amongst each other and to various ground-stations will likely improve.** Futurists predict more computing capacity, data storage, robust and efficient intersatellite communications and networking technology will be loaded onto satellites, creating a space-based internet backbone, amongst other services, further integrating satellites as a critical component of the global terrestrial network.[37,38] The increase in space traffic, due to multiple large satellite constellations, worryingly increases the risk of collisions with existing space debris (some of which is too small to track) and other satellites. Satellites require designated frequency ranges (called "bands") on the electromagnetic spectrum to move data and operate. More satellites mean more competition for this limited natural resource, thus boosting the importance of, and LMIC participation in, international coordinating and arbitration organizations like the UN's International Telecommunications Union and UN Office for Outer Space Affairs.[39]

- **Low- and middle-income countries also have a vital balancing role in international forums like the ITU, where competition for bandwidth and orbits can be moderated by calls for fairness and inclusivity.** The next World Radiocommunication Conference will take place in November 2023, in which it will review, and, if necessary, revise the Radio Regulations, the international treaty governing the use of the spectrum and of global policy for the use of the electromagnetic spectrum and the geostationary-satellite and NGSO satellite orbits. Regional Telecommunication Organizations like the Inter-American Telecommunication Commission (CITEL) and Caribbean Association of National Telecommunications (CANTO) are critical and accessible forums to organize and collaborate.

- **While NGSO satellites are being discussed in the space and telecommunications sectors, the rest of the world, and especially the developing world, also need to be ready to make the most of these emerging commercial capabilities.** In turn, governments, and development, advisory, and financing organizations need to consider what investments should be made to maximize public benefits and mitigate risks of an increasingly space-based global telecommunications infrastructure. Leveraging these options could greatly reduce the cost and difficulty of connecting sparsely populated, dangerous, or geographically difficult places.

INITIAL RECOMMENDATIONS

With all of that in mind, **governments** should consider emerging space-based commercial options to pragmatically close remaining hard infrastructure gaps. Any such program should be approached holistically, with lines of effort also dedicated to maximizing the beneficial use of available networks (i.e. "closing the usage gap"). Resources should also be allocated for last-mile implementation projects that concretely support health, education, and other development goals.[40] New space-based hard infrastructure options should be weighed against other available technologies. Governments should participate in their regional telecommunication organization and be proactive in developing policy and regulations that emphasize the importance of affordable telecom services to encourage a fair balance of motivating profit, necessary cost, and the public good.[41] Public private partnerships, subsidies, tax incentives and mandatory coverage regulations are available tools to expand broadband access.

Bilateral and multilateral aid and development finance agencies should consider new satellite constellations as a viable option when advising partners regarding telecommunications infrastructure. As more NGSO companies become operational, it will be increasingly important to champion transparency from all actors on system capabilities, cost, and best practices—particularly in the establishment of and encouragement to follow, regarding regulations and licensing. Development agencies should increase "space proficiency" in the development sector. Space-related capabilities, be it in telecommunications, remote sensing or geolocation services, have become baseline infrastructure needed to participate in the world economy and an economic driver for developing and developed countries alike.

Private space sector actors should make every effort to avoid technical and jargony language that creates an incomprehensible mystique when explaining services, system capabilities, and pricing, and expect to work closely with governments and aid and development agencies to ensure complimentary infrastructure, like power, is coordinated along with licensing and regulatory compliance. These groups should continue to ruggedize equipment, and drive down power and maintenance requirements, to accelerate access to and use of space-based hard infrastructure in low- and middle-income countries. In addition to doing the usual research to understand a country's priorities, challenges, and aspirations, the private sector should also be aware there has been a rapid expansion of space agencies and general interest in the use of space worldwide, to include lower-income countries. Multiple countries and regions have established space strategies and policies relevant to telecommunications. The African Union, for example, published both a Space Strategy and Policy in 2016 to "facilitate growth and development across the continent," and it details many ways in which space related technology can be practically applied in support of their goal.

SPACE-BASED INFRASTRUCTURE IS RELEVANT TO ALL

Although traditional global telecommunications infrastructure will continue to have far more capacity, space-based technology provides a path toward easier, more affordable, and more reliable broadband for remote, sparsely populated, dangerous or otherwise difficult locations. Space-based hard infrastructure could be a significant tool in the global effort to establish the baseline connectivity required for digital literacy and accelerate uptake, thereby also addressing long-standing challenges in multiple sectors in the developing world, such as health, disaster management, security, education, etc. Governments, and development, advisory, and financing organizations need to consider how best to maximize the benefits of an increasingly space-based global telecommunications infrastructure.

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