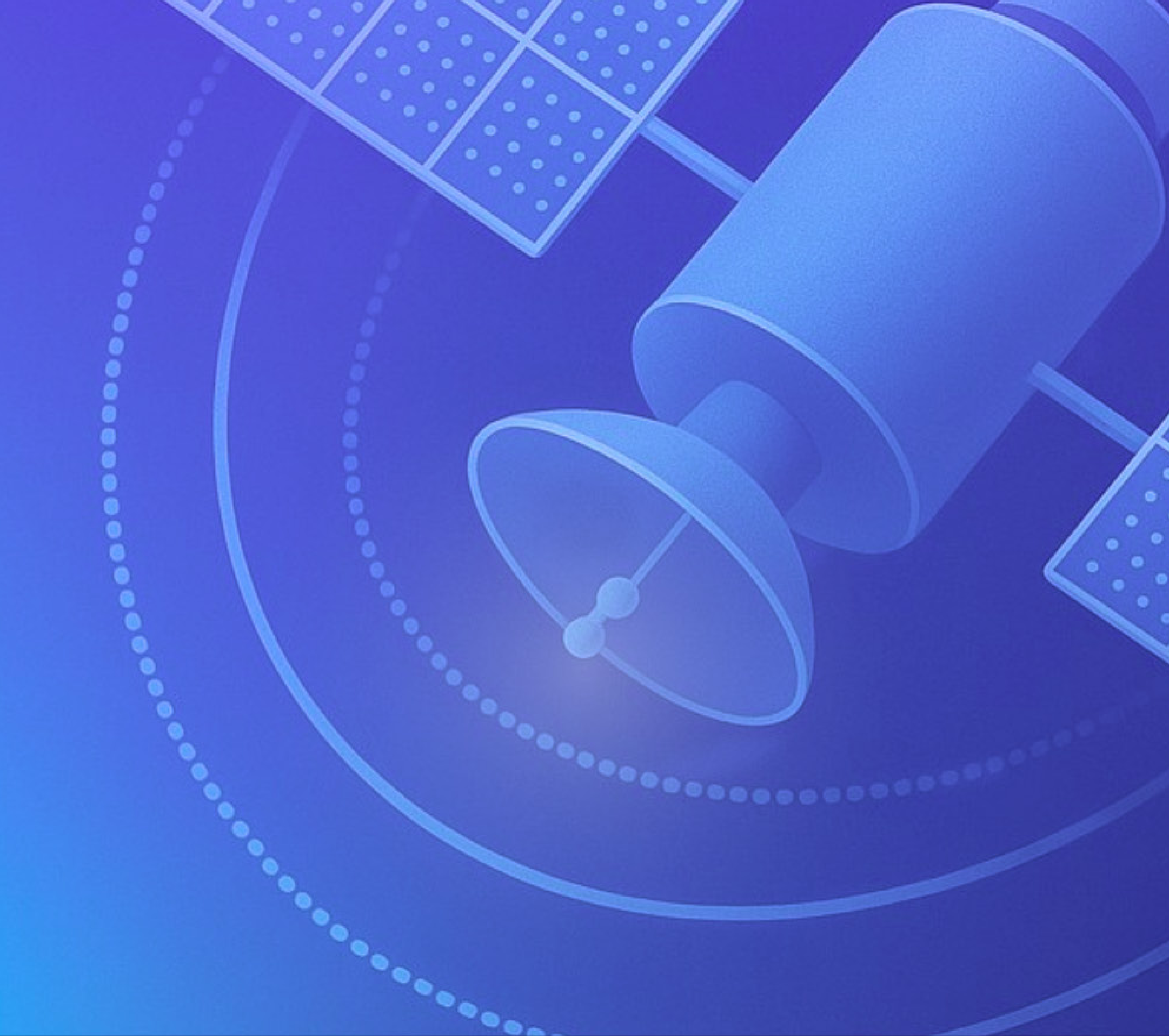

The State of Satellite Broadband

August 2025

BROADBAND COMMISSION FOR SUSTAINABLE DEVELOPMENT 15 YEARS
ITU unesco

ITU and UNESCO. 2025. The State of Satellite Broadband 2025

ISBN:

978-92-61-40581-6 (PDF version)
978-92-61-40591-5 (ePUB version)

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Acknowledgements

This report has been written collaboratively, drawing on insights and contributions from Commissioners and their organizations, as listed below. As such, the views expressed here are not attributed to any one organization or individual. The report has been written by Phillippa Biggs. From the International Telecommunication Union (ITU), Nur Sulyna Abdullah provided direction and Julia Gorlovetskaya provided editorial review and creative direction. Sergio Buonomo, Karina Cessy, Jorge Ciccorossi, Véronique Glaude, Nick Sinanis and Alexandre Vallet also reviewed the report. We wish to thank all members of the Broadband Commission and their Focal Points who contributed to this report and took the time to review and revise the text.

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1

Introduction

The story of space-based broadband technologies is an exciting one, combining major technological innovations with exponential growth and entrepreneurial spirit. The year 2025 is proving a pivotal year for the global space industry, in terms of innovation, regulatory developments and global engagement. The World Economic Forum's Space Economy 2024 report predicted that the space industry is currently growing at 9% per year and will reach US$1.8 trillion by 2035, contributing a growing share to the global economy through communications, positioning, navigation and timing, and Earth observation.

Space is viewed as having features of a public good belonging to all humanity, despite the limitation that, historically, relatively few countries could afford to master the advanced science, expertise and resources needed to access space.

Today, more and more countries are engaging in space and space activities, as reflected in the long and growing list of space agencies[1]. Some 104 countries have joined as members of the Committee on Peaceful Uses of Outer Space (with Djibouti and Latvia among the more recent members of the Committee)[2], while over 80 nations have initiated space programmes. For example, in 2024, the Rep. of Korea established its national space agency, the Korea Aerospace Administration.

Major technological developments are underway, driven in part by new and innovative players from the private sector. Satellite and space-based broadband technologies can either connect users directly, or in combination with other technologies. Exciting new space-based technologies and Non-Terrestrial Networks (NTN) are on the horizon, as well as Direct-to-Cell (D2C) or Direct-to-Device (D2D) services and quantum sensing. Rapid innovation and massive investments mean that satellite connectivity can work effectively

1 https://www.unoosa.org/oosa/en/ourwork/space-agencies.html
2 https://www.unoosa.org/oosa/en/ourwork/copuos/members/evolution.html

in combination with terrestrial broadband technologies to connect unserved and underserved areas.

The applications of space-based and satellite technologies are far-reaching and immense. They can provide critical information and connectivity in support of the Sustainable Development Goals (SDGs), underpinning disaster relief, climate change assessments, humanitarian missions or enabling better access to education, health and financial services and others. Satellite communications can reach people in remote, rural or unserved areas difficult to reach through terrestrial connectivity, opening up new economic opportunities.

The Broadband Commission last examined space technologies in 2017, with its report on 'Technologies in Space and the Upper Atmosphere: Identifying the Potential of New Communications Technologies for Sustainable Development'. Since then, the satellite market has expanded significantly – in terms of investments, satellite numbers and launches, as well as the shift towards entire constellations of smaller and cheaper satellites. This 'State of Satellite Broadband 2025' report reviews some of the latest innovations and offers insights from several Broadband Commissioners about the burgeoning space-based economy – its advances, risks and challenges.

2

Strong Growth and regulatory challenges

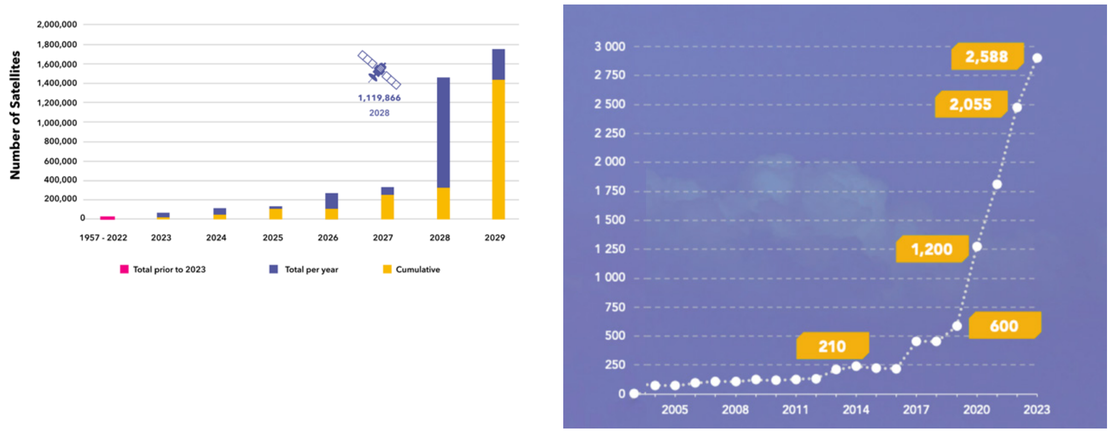
The evolution and rapid growth of satellite communications can contribute to transforming global connectivity. After decades of relatively steady launch rates, the number of satellite launches is increasing rapidly (Figure 1). From 1957 to 2012, the number of satellites launched into outer space remained remarkably consistent, at approximately 150 each year. However, a decade ago, the number of satellites launched into orbit began to increase at an exponential rate, from 210 (2013), to 600 (2019), to 1,200 (2020) and, most recently, to 2,588 in 2023 (Figure 1, right graph).

The number of satellite launches continues to increase. Communication satellites and in particular Low Earth Orbit (LEO) satellites account for the majority of this increase (Figure 2). Key to the increase in launches is the reduction in launch costs, which may have fallen as much as tenfold over the last twenty years[3] (estimates vary, depending on whether they consider discrete costs or cost per mass). The miniaturization of space systems, deployment of large constellations and growing number of commercial operators, all contributed to the highest launch rate ever to date, in 2023. Improved power generation and storage, combined with efficiencies in propulsion and control systems mean greater power is available for satellite payload operations, boosting payloads.

[3] WEF Space Economy Report 2024, https://www3.weforum.org/docs/WEF_Space_2024.pdf

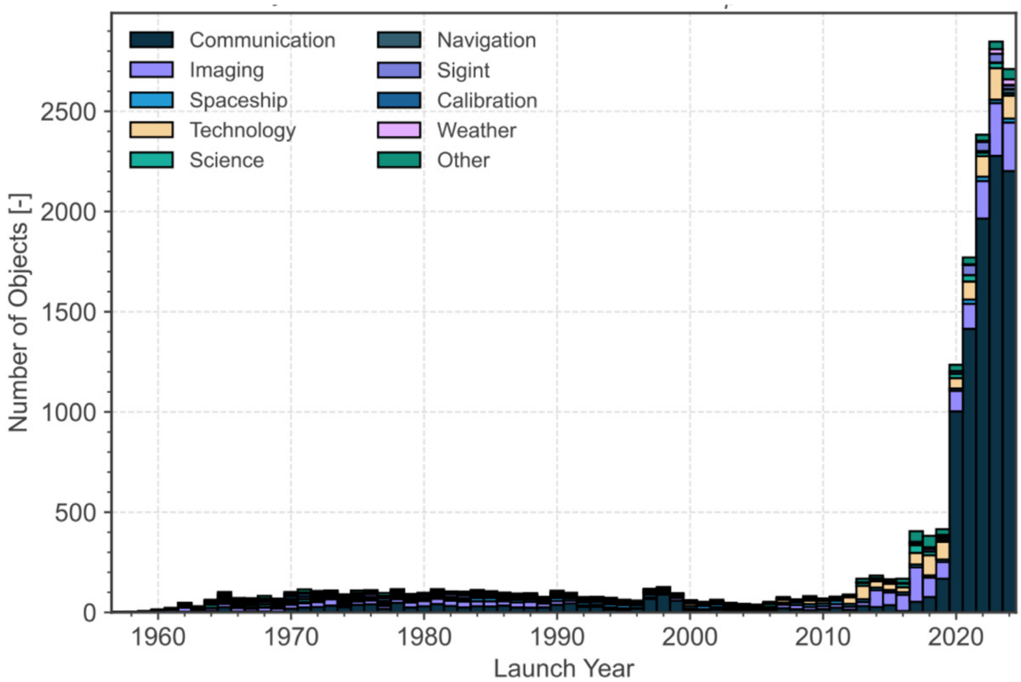
Figure 1: Number of Satellite Launches since 1957

Number of non-geostationary satellites for which Member States have registered radio frequencies with ITU (by year and cumulatively, left graph); Number of launched space objects until 2023 (right graph)



Source: ITU, quoted in 'Our Common Agenda Policy Brief 7: For All Humanity – the Future of Outer Space Governance', at: www.un.org/sites/un2.un.org/files/our-common-agenda-policy-brief-outer-space-en.pdf and UNOOSA, Page 23, www.unoosa.org/documents/pdf/annualreport/UNOOSA_Annual_Report_2023.pdf

Figure 2: Payload Launch Traffic into 200-1750 km altitude, 1957-2023

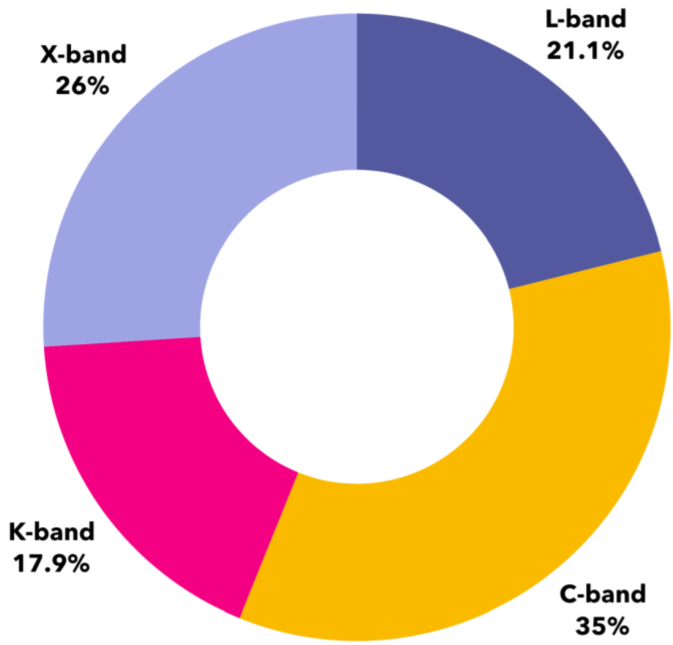


Source: European Space Agency (ESA), Space Environment Report 2024, available at: www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf

McKinsey estimates that there were 5,000 satellites providing communications in March 2023, with satellite launches having grown by 15% a year since 2017 (compared with around 1,000 active communication or Earth observation satellites and 1,500 satellites for R&D and other missions)[4]. Looking ahead, McKinsey identifies plans for growth of up to 65,000 new communication satellites and 3,000 non-communication satellites (for applications such as Earth observation). McKinsey's baseline scenario foresees 27,000 active satellites in orbit by 2030. According to Fortune Business Insights, satellites in the C-band account for the largest share of market revenue (Figure 3).

However, forecasts vary significantly – for example, Satellite Today suggests that by 2030, the number of active satellites could reach as many as 50,000, most in Low-Earth Orbit (LEO)[5]. The year 2025 is slated to see the launch of Amazon's Project Kuiper, BAE Systems' Azalea and AST SpaceMobile's BlueBird Block 2 satellites and China's Thousands Sails 648 satellite Constellation. SpaceX will continue to add to its 7,000 Starlink satellites already in orbit. (These statistics exclude communication satellite launches by Viasat, Eutelsat, Optus, JSAT, Telesat, OneWeb and O3b).

Figure 3: Global Satellite Internet Market Share, by Frequency Band Type, 2023



Source: www.fortunebusinessinsights.com/satellite-internet-market-109242

The rapid growth in satellite launches, numbers, and mass reflects remarkable progress in space technology and global connectivity. Such growth brings new opportunities for innovation, collaboration, and expanded access to the benefits of space to contribute to close the digital divide. Conversely, this growth in satellite launches, numbers and mass also presents challenges for operation, safety and security. The current 'race to space' may put existing regulatory systems under pressure as regulators seek to ensure equitable access to space orbital/spectrum resources by all nations, including those just beginning their space journeys. There is associated growth in the risks of collision (including with orbital debris), light pollution, harm from unwanted

4 https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/space-launch-are-we-heading-for-oversupply-or-a-shortfall
5 https://interactive.satellitetoday.com/via/december-2024/10-tech-trends-that-will-impact-the-satellite-industry-in-2025

emissions and environmental harm to the atmosphere and Earth itself from the constant disposal of spacecraft at end-of-life, and their continued replacement.

In terms of standards, satellite and cellular industries have historically been regulated relatively separately in terms of hardware, connectivity protocols and regulation, although both use valuable radiofrequency as a common resource with harmonized management and access. According to some commentators, the rush towards large constellations could fuel a race to launch Direct-to-Cell or Direct-to-Device (D2D) services. However, the consultancy firm Analysys Mason (2024) suggests that no single firm is likely to become a 'winner-take-all' in the D2D market, due to the complexities and dependencies surrounding regulation, mobile value chains and spectrum uses[6]. Further, there is a growing risk of harmful radio spectrum interference between different systems and the potential for spectrum warehousing and inefficient use of resources.

The ITU Radiocommunication Sector (ITU-R) is responsible for ensuring the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including those using the geostationary-satellite or other satellite orbits. ITU's activities are aimed at preserving access to space for all, and the harmonized use of radio-frequency spectrum resources.

The Radio Regulations is the international treaty that governs the global use of radio-frequency spectrum and satellite orbits and contains the provisions for the coordination and recording of frequency assignments in the Master International Frequency Register (MIFR). To highlight the importance of growing the space economy and keeping it available for all nations, the upcoming ITU World Radiocommunication Conference 2027 (WRC-27) agenda has some 14+ agenda items that cover regulation of the activities of space services[7].

To facilitate the harmonized use of radio-frequency spectrum in space, detailed information on the deployment and operational information has to be provided for satellite systems. For satellites to be launched successfully and made operational, it is increasingly important to manage the entire lifecycle – including what is launched into space in the first instance, as well as planning for fleet maintenance, employing suitable deorbiting strategies and mitigating the risks of collisions to ensure space sustainability. Indeed, the broader vision of 'space sustainability' now also encompasses the environmental impact of space activities, as well as their impact on other fields, including radio and optical astronomy stations and the protection of dark and quiet skies.

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[6] Geostationary (GEO) satellites orbit 35,786 km above the equator, each covering a large area from a fixed position relative to Earth. LEO satellites operate within 500-2000 km of Earth. Medium Earth Orbit (MEO) satellites cover a wide range of altitudes between LEO and GEO. For more information, see www.itu.int/hub/2025/03/space-connect-updating-regulations-for-leo-satellite-services/ and www.analysysmason.com/contentassets/0ad19588e9de4c1eb69f65e8fa3c97e9/analysys_mason_d2d_constellations_spacex_jul2024_nsi039.pdf.

[7] The full WRC-27 agenda can be found in ITU-R Resolution 813 (WRC-23), with the complete description of agenda items in the associated Resolution.

3

Technological Developments

Next-generation satellites have been deployed to provide fixed high-speed broadband services over entire continents (e.g. Africa, Asia and Oceania) as a cost-effective communication solution. Historically, some telcos have leveraged satellite services for cellular backhaul services where it was cost-effective to do so, expanding mobile coverage into rural and hard-to-reach places. Now, advanced satellites offer broadband speeds and bandwidths that are beginning to approach those of 4G (and soon 5G) at more reasonable prices, enabling individuals, businesses, schools, and medical centres to connect to the Internet.

Meanwhile, satellites are evolving rapidly, with multi-orbit satellite networks, inter-satellite links, and the integration of non-terrestrial networks, and enhancing connectivity solutions (Box 1). Software-defined satellites and in-orbit satellite servicing can help to meet the growing needs of firms, governments and other users for faster, more reliable and more secure satellite communications. The World Economic Forum estimates that the price of data is expected to drop by at least 10% by 2035, with demand increasing by at least 60%[8]. As data prices fall, telcos serving markets with large unconnected areas may consider integrating space-based or stratospheric capacity more fully into their core networks.

The Low Earth Orbit (LEO) environment has become increasingly attractive and therefore increasingly crowded, and the space industry has been exploring the possibility of using lower orbits, including the Very Low Earth Orbit (VLEO), operating between altitudes of 250-350 km. While this is effectively a 'self-cleaning orbit' (as equipment in VLEO deorbits and burns up quickly in the Earth's atmosphere), such practices raise potential environmental concerns linked to the amount of metallic alloy particles and other chemicals left from equipment and parts on reentry, with unknown possible side-effects in the Earth's atmosphere. Collision risks also still persist, with oversaturation of those orbits.

8 https://www3.weforum.org/docs/WEF_Space_2024.pdf

Another important development is the integration of terrestrial and non-terrestrial networks (NTN), which can enable roaming between terrestrial and non-terrestrial networks to enable seamless connectivity for end-users. On the consumer side, Direct-to-Device (D2D), including Direct-to-Cell (D2C) and Internet of Things (IoT) solutions are being brought to market, which offer opportunities to connect consumer smartphones with communication satellites[9].

These concepts enable satellite operators to connect to mobile terrestrial devices, offering the potential to provide more ubiquitous connectivity (commercial deployments currently include early emergency, SMS and voice services) and to enable more extensive digital inclusion. Due to the quasi "omni-presence" of satellite mobile coverage, additional connectivity can be provided to rural and remote areas, where building terrestrial networks is very costly and/or is not possible at all. Such mutual benefits explain why more cooperation projects between satellite and terrestrial operators are being observed in the market. Growing innovation and investment has led to devices (including smartphones, IoT sensors, and dongles) that can work in both satellite and cellular modes.

D2D/D2C will be discussed by ITU Member States at the next World Radiocommunication Conference 2027 (WRC-27) under agenda item 1.13, which considers studies on possible new allocations to the mobile-satellite service for direct connectivity between space stations and International Mobile Telecommunication (IMT) user equipment to complement terrestrial IMT network coverage.

Besides its WRC-27 related work, ITU is also addressing regular updates on the various generations of IMT (4G, 5G) specifications and started work on IMT-2030 (6G) already back in 2020[10]. IMT-2030 (6G) is expected to become commercially available sometime around 2030. Since the start of the deployment of the terrestrial component of IMT, the satellite component has been part of ITU-R's work and a series of ITU-R Recommendations has been developed for the satellite component of the relevant IMT generation. Recommendation ITU-R M.2160, the "Framework and overall objectives of the future development of IMT for 2030 and beyond", published in November 2023, explicitly states:

> *"The interworking of IMT-2030 terrestrial network with its non-terrestrial networks (NTN), including satellite communications, high altitude platform stations as IMT base stations (HIBS), is expected to enhance required connectivity objectives*".

ITU-R recently finalized the Recommendation identifying the detailed specifications of the satellite component of IMT-2020(5G) and it will be submitted in November 2025 for approval by the ITU Member States. At the same time, ITU-R has started initial discussions on the satellite component of IMT-2030 (6G).

In terms of the commercial prospects of D2C, in September 2024, Juniper Research considered that commercial D2C services would begin in 2025 and will generate a modest US$30 million

[9] Although similar in concept, satellite "Direct-to-Cellular" (D2C) technology allows standard mobile phones / smartphones to directly connect to satellites in space, while "Direct-to-Device" (D2D) technology is designed specifically for IoT (Internet of Things) devices, rather than smartphones. Both terms are often used interchangeably in press and public media, although this is not technically the case.

[10] https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/Pages/IMT.aspx

in global revenue in its first year[11]. By 2029, D2C revenues are expected to skyrocket to almost US$1.7 billion. Nevertheless, Juniper notes that operators will need to contend with issues like regulatory barriers and device compatibility (the smartphone must include a radio capable of receiving wireless coverage across various bands in the satellite spectrum). Juniper suggests that monetization may prove difficult, and operators may struggle to convince mobile subscribers to adopt an additional subscription for direct-to-cell services on top of existing cellular plans. Monetization will ultimately depend on the specific contractual arrangements between satellite and mobile operators.

China Telecom was among the first companies to connect a 5G phone directly to a satellite through its proprietary technologies (with Tiantong) and low-altitude plans, focused on drones, and non-terrestrial networks[12]. In the United States, T-Mobile US and SpaceX launched a public beta test of their D2C satellite service using Starlink satellites and also made it available to customers of rivals AT&T and Verizon. The beta test covers 500,000 square miles across the US in remote or rural areas which lack coverage. It will initially offer only SMS, with data, voice and picture messaging to follow. The beta service is currently free, but monthly charges were scheduled to start in July 2025[13].

AST SpaceMobile has launched five operational satellites to deliver 4G and 5G services worldwide and plans to expand its network to as many as 243 satellites. AST SpaceMobile's advanced phased-array antenna, BlueWalker 3, is one of the most powerful in the industry and will deliver high-quality services to unmodified cellular consumer devices. Similarly, Lynk Global has deployed satellites to provide coverage in remote areas, emphasizing partnerships with telecom operators and regulatory approvals. The European Space Agency has established a new collaboration with Viasat, extend and promote European participation in a standards-based, open architecture LEO constellation that can augment existing GEO & LEO D2D satellite services.

11 https://www.juniperresearch.com/press/direct-to-cell-market-revenue-to-reach-28bn-globally-over-next-five-years/
12 MWC SHANGHAI DIARY: China operator ch... - Mobile World Live
13 T-Mobile US launches Starlink D2D pub... - Mobile World Live

Insight 1: Enhancing Connectivity through Emerging Satellite Technologies

Satellite communications provide critical Internet, broadcast television and communication services to users worldwide. Satellite services are crucial in remote, unserved, and underserved areas, and in times of natural disasters. Satellite technologies contribute to bridging the digital divide and accelerating a more inclusive digital transformation. However, the future of connectivity will rely on combining the strengths of different technologies to increase economies of scale, cost efficiency and coverage, while delivering exceptional resilience and more advanced services.

A range of new innovative solutions in satellite communications, such as Direct-to-Device (D2D), multi-orbit satellite networks, inter-satellite links, software-defined satellites, and in-orbit satellite servicing, are making satellite communications more versatile and cost-effective, meeting the increasing demand for seamless, reliable, and resilient connectivity. These innovations are driving a new era for the connectivity ecosystem, contributing to bridging the digital divide.

AI is also revolutionizing satellite communications, offering unparalleled opportunities to enhance connectivity. AI's transformative applications in satellite communications include network optimization. It can analyze vast amounts of real-time data to predict usage patterns and traffic demands, making dynamic adjustments to optimize network performance. For example, during natural disasters, AI can prioritize connectivity for emergency response teams and affected communities, ensuring vital communication channels remain open, where and when most needed.

AI can use weather data to predict signal attenuation, allowing for proactive measures to maintain service quality as well as interference detection and mitigation, ensuring clearer communication channels, reduced latency and greater throughput. AI enhances maintenance by analyzing onboard sensors' data to forecast potential failures before they occur. It improves autonomous satellite operations, including orbital manoeuvring and collision avoidance, reducing the need for human interventions.

The integration of AI into satellite communications can help enhance connectivity and bridge digital divides. However, success requires significant investment in technology and training, as well as a robust regulatory framework which can foster innovation and bring benefits to consumers, while protecting human and user rights. As these technologies continue to evolve, satellite communications are playing a pivotal role in achieving universal, meaningful connectivity.

GSOA and its members remain committed to leverage innovation and harness the potential of AI to help reach the Broadband Commission's Advocacy Targets and deliver global digital inclusion.

Source: Isabelle Mauro, Director General of the Global Satellite Operators Association (GSOA).

However, D2C and D2D are still in their infancy, and still have significant technical challenges to overcome, including the problem of indoor access[14]. An indoor repeater system could be used to bring the signal in and out of the indoor environment using an outdoor ground-based satellite antenna to bridge both signal paths (uplink and downlink) to the LEO satellite. Box 1 explores new satellite technologies for connectivity.

[14] LEO Satellites: Revolutionary Connectivity or a Supporting Act? - Strand Consult

Box 1: New Satellite Technologies for Transformative Connectivity

Today, new innovative solutions in satellite communications, such as multi-orbit satellite networks, inter-satellite links, software-defined satellites and in-orbit satellite servicing, are helping meet the growing needs of enterprises, governments and other users for increased capacity and connectivity.

The evolution of standards and the introduction of non-terrestrial networks (NTN) into the 3rd Generation Partnership Project (3GPP) will play a major role in the integration of satellites into 5G and 6G ecosystems. The ability to provide connectivity to small antennas, whether in smartphones or fixed terminals at homes and businesses, and antennas integrated into vehicles will extend connectivity capabilities even further in the near term.

A non-terrestrial network (NTN) refers to a 3GPP-defined concept involving the integration of satellite and some terrestrial networks for the support of seamless service continuity in diverse environments. NTNs encompass satellite-based networks operating in frequency bands allocated to mobile satellite services (MSS) or fixed satellite services (FSS). The integration of NTN and terrestrial networks can provide seamless connectivity and roaming capabilities for IoT devices transitioning between ground-based and satellite coverage areas.

Satellite technologies are well-suited for large-scale, global IoT deployments, providing coverage across wide geographies. Satellite IoT opens the door to transformative applications in a range of sectors, such as smart cities, precision agriculture and environmental monitoring, by overcoming existing connectivity challenges. Satellite NB-IoT (Narrowband IoT) solutions employ small, low-power and low-cost IoT modules designed for efficient operation with satellite networks, making applications more affordable and sustainable.

Another category of non-terrestrial network NTN is direct-to-device (D2D) connectivity, which involves connecting satellites directly to smartphones. One approach utilizes spectrum already allocated to mobile satellite services (MSS) and leverages the 3GPP NTN specifications. This ensures compatibility and interoperability across platforms by aligning with standardized protocols and frameworks. It offers a seamless transition between terrestrial and satellite networks for voice, data and messaging services, allowing users to benefit from connectivity regardless of their location. It requires mobile chipset vendors to support relevant MSS frequencies and 3GPP NTN air interfaces. This approach has been authorized in various countries without the need for additional regulatory frameworks to protect terrestrial carriers.

An alternative approach is for D2D to operate in the same frequency bands as those used by mobile operators, as a complementary solution to terrestrial mobile coverage. While this approach can leverage the installed base of smartphones and eliminates the need for specialized NTN-compatible chipsets, there are still significant technical challenges. It requires modifications to the radio access network (RAN) and core infrastructure of satellite-based systems, as well as enhancements to increase range and Doppler tolerance, manage interference and potentially establish exclusion zones or transmit power limitations. As stakeholders navigate these challenges and opportunities, collaboration between satellite operators, mobile network operators and regulatory bodies is required to realize the full potential of satellite D2D connectivity to usher in a new era of ubiquitous and seamless communication.

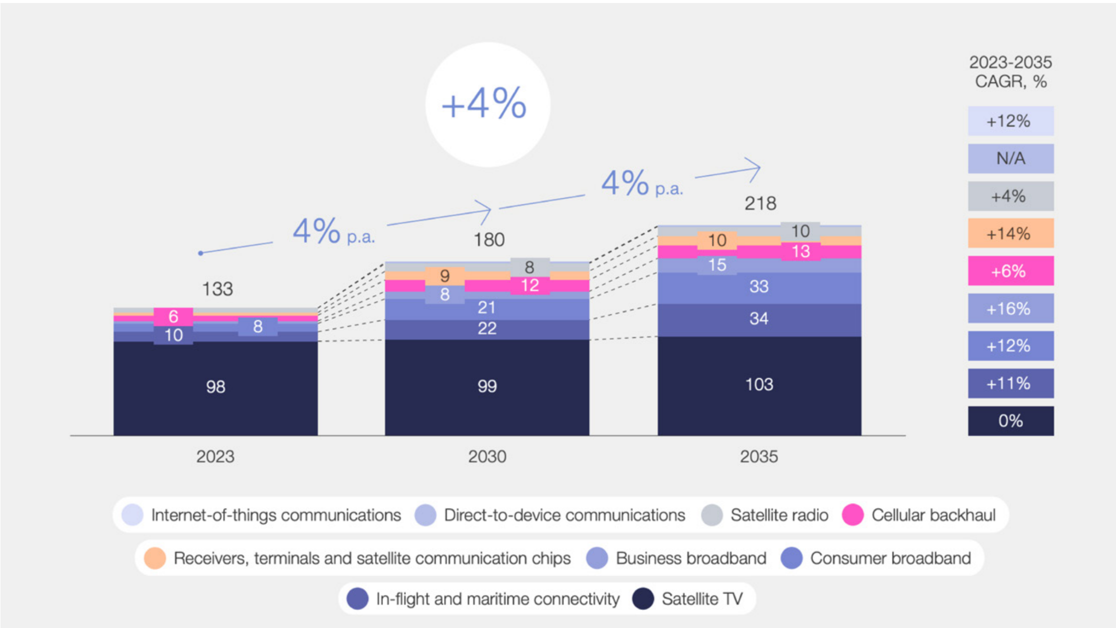
The industry is moving towards the creation of a global network ecosystem for software-defined satellites (SDS), modems, antennas, wave forms and the interoperability required to realize the full potential of future applications and connectivity needs. Software-defined satellites introduce flexibility and programmability into traditional telecom networks, which simplifies management, uses network resources more efficiently and reduces operating costs.

Source: GSOA report, 'New Satellite Technologies for Transformative Connectivity', GSOA: https://gsoasatellite.com/wp-content/uploads/GSOA-New-Satellite-Tech-Paper_July-2024.pdf and GSOA report, The Future of Satellite Connectivity: Various Approaches to Direct-to-Device Services https://gsoasatellite.com/reports_and_studies/the-future-of-satellite-connectivity-various-approaches-to-direct-to-device-services/

Another approach to D2C or Direct-to-Device (D2D) explores the development of separate direct-to-phone constellations running on mobile satellite spectrum[15]. Companies such as Iridium, GlobalStar, Ligado, Omnispace and Viasat are pursuing this approach. The use of spectrum already authorized for mobile satellite use reduces the time to launch, as regulatory permissions may already have been achieved and few extra authorizations may be needed. This approach relies on consumers using modern mobile phones, equipped with next-generation chips.

These new technological developments are enabling more communication capabilities. According to the World Economic Forum, commercial communications are projected to grow from USD$196 billion in 2023 to USD$218 billion in 2035 and will remain the largest source of revenue for backbone players. The market will benefit from the acceleration of broadband and connectivity applications, as well as large constellations progressively reaching full deployment (Figure 4).

Figure 4: Revenue growth from commercial communications ($ billion), 2023-2035



Source: World Economic Forum's Space Economy Report 2024, https://www3.weforum.org/docs/WEF_Space_2024.pdf

15 https://satcube.com/news/current-satcom-trends-shaping-the-future-of-connectivity

4

Space is becoming more accessible

Another major shift in space operations has been the rise of the private sector in launch services and operations. Major players in launch services include SpaceX, United Launch Alliance (ULA) Centaur, Rocket Lab, Blue Origin and the nascent Firefly. SpaceX has also developed reusable launch vehicles. Innovations in launch are significant because private firms are now launching more frequently than government space programmes. For example, SpaceX launched nearly 140 rockets in 2024 alone – more than NASA launched during the entire 30-year Space Shuttle program[16].

Space organizations are increasingly leveraging Artificial Intelligence (AI) to process the large volume of data being collected about space or from space. Currently, AI is used most often in support of data processing and management. However, the industry is moving towards using AI for autonomous operations as well as in edge-compute applications, being able to compute in space and sending only relevant insights down to the ground. Future developments may include quantum sensing and the emergence of Ground Station as a Service (GSaaS)[17].

16 https://edition.cnn.com/2025/02/07/science/spacex-elon-musk-tesla-roadster-asteroid-astronomers/index.html

17 https://eos.com/blog/eosda-reflects-on-satellite-industry-trends-for-2025/

Insight 2: The intersection of space and satellite telecommunications

Emerging technologies such as AI, high-speed data transmission or quantum computing offer both opportunities and challenges. The space sector has embraced quantum technology and AI to improve its accuracy and efficiency. Satcom with 5G data transmission has seen an advent of LEO capabilities which, in cooperation with GEO and terrestrial networks, can offer low-latency services and connectivity all around the world, including in the polar regions. Today, space traffic management, debris mitigation and satellite interference resolution systems all look up to emerging technologies' solutions to help humans cope with an increasing array of issues and risks on a daily basis.

For every mission or any satellite process, huge quantities of data are handled and transmitted. AI can process them rapidly, offering solutions to make fast or immediate learned decisions. This can reduce risks and make missions and services more secure, economically efficient and environmentally sound. For satellite communication operators, AI can secure high quality communications by optimally and automatically fine-tuning frequencies and power signals and by analyzing and predicting external interferences such as space weather or those derived by man-made objects. Humans handling control on the ground and astronauts in space can benefit from AI's capabilities to solve ongoing operational, scientific or crew management problems. These emerging technologies share the automatization of processes. AI can reach decisions quickly and trigger immediate reactions, which can be applied to space traffic management and collision avoidance systems to improve the safety and efficiency of space operations.

With the greater use of these technologies, the challenges for the future are also amplified. How to ensure the accountability of human decision makers when control is taken off human hands and brains? How to create a complete and fair legal environment to regulate automated processes? To maintain sustainability in outer space and on Earth, we must reach solutions to numerous value-based issues incorporating ethic, the rule of law, international relations and others. Humanity must harness technology for the better, and not for worse.

Source: Mr. Piotr Dmochowski-Lipski, Executive Secretary, European Organisation of Telecommunication Satellites (EUTELSAT) IGO.

Space has become more accessible – to more countries, more firms and more entrepreneurs. For example, since 2018, the KiboCube programme between UNOOSA and JAXA, the Japanese Space Agency, has supported the development of satellites from Kenya, Guatemala, Mauritius and the Republic of Moldova. Such activities are among the catalysts for the creation of more space agencies around the world [18].

There is a larger number of countries accessing space. The unprecedented expansion in the number of space objects has also raised broader concerns about space sustainability (Insight 3) and has highlighted the need to evolve and strengthen the policy and regulatory mechanisms at the national and international levels to accommodate the growth in space activities and potential congestion and to mitigate the resulting risks, including collisions. These mechanisms are the subject of intense discussions in various national and international forums. Greater, and better, coordination and harmonization are needed between and across multiple agencies, while simplifying and aligning space-related policies and regulatory mechanisms, in both regional and global forums.

18 P.26, https://www.unoosa.org/documents/pdf/annualreport/UNOOSA_Annual_Report_2023.pdf

Insight 3: Space Sustainability is Vital

Space-based communications offer significant opportunities for economic prosperity, universal connectivity, and security in all nations. Sovereign access to space seemed an impossible aspiration for most nations at the start of this decade. Now, technology makes space an attainable, and viable, means to drive connectivity, and deliver the associated benefits for all nations. Indeed, all nations have a vested interest in space to improve prosperity, even in their most remote regions.

To realize this potential, we must remain vigilant in actively managing our shared and scarce orbital resources to ensure a sustainable and inclusive future. One of the most promising new technologies is satellite direct-to-device (D2D) connectivity enabling anyone, anywhere to be connected to the Internet with a 5G connection via space using an ordinary mobile phone.

Regional and national satellite systems have long served vital roles in ensuring physical security, supporting food production, and also facilitating management of climate and weather-related challenges. New space-based technologies provide valuable ways to augment these capabilities.

Recent advances that make access to space more affordable create opportunities for all nations to participate in the space economy---even nations that were not historically space-faring. These new opportunities extend beyond satellites, and enable improved education, access to health care, participation in government, e-commerce, precision agriculture, emergency response, and many other essential services.

Our shared spectrum and orbits are finite natural resources that fuel tremendous opportunities. Equitable access ensures that all nations can do so in ways that best meet their individual needs. The ability to create these new opportunities at the national level may be the best way to facilitate enduring progress and prosperity in all nations. But we now face a self-created crisis both in space and here on Earth. A crisis that is being caused by a few commercial interests that seek to secure these opportunities for themselves, consuming shared, scarce and finite spectrum and orbits to the exclusion of others, and operating in ways that threaten to:

- foreclose equitable access to space;
- undermine that critical foundation of many development activities by IGOs;
- bypass sovereign management of telecom, computing, and cloud infrastructure;
- leave many developing nations behind; and
- create yet-unquantified damage to our environment.

Fortunately, our leaders within the UN family have joined with other leaders around the world in raising awareness of these threats. And over 160 nations joined together in Dubai, UAE, at WRC-2023 to set a path for a sustainable and more inclusive future in space. We cannot rely on the market forces that enabled this crisis to solve it. Implementation of solutions rests with individual nations, who must now act to protect these critical global opportunities, and their sovereign interests, before it is too late.

Source: Mark Dankberg, ViaSat.

5

Regional Trends

The rise of the private sector in space activities has also helped expand greater access to space in many different regions. SpaceX has become a major player in a relatively short period. By mid-2024, Starlink had already launched services in fourteen countries throughout Africa (Benin, Botswana, Eswatini, Ghana, Kenya, Madagascar, Malawi, Mozambique, Nigeria, Rwanda, Sierra Leone, South Sudan, Zambia and Zimbabwe). Starlink planned to launch services in Angola, Lesotho and Namibia in the remainder of 2024, and in Comoros and Mauritius in 2025. South Africa does not have a confirmed launch date at present[19].

Partnerships are proving vital. Intelsat and Africa Mobile Networks (AMN) have deployed over 3,000 rural base satellite antennas across several countries in Africa since 2018, providing new telecommunication services to more than 8 million people[20]. AMN's largest network is in Nigeria, with over 1,350 sites. With over 450 sites added just since June 2023, this collaboration provides phone and Internet services to some 3.5 million people in previously unconnected Nigerian communities. In October 2024, Intelsat unveiled a new satellite cellular backhaul service platform, located at a datacenter in Nigeria[21].

Amazon's Project Kuiper is planning to launch operational satellites, including some with Direct-to-Cell (D2C) capabilities. The project plans to deploy a constellation of 3,236 LEO satellites to provide global broadband coverage. Amazon plans to launch half or 50% of this constellation by 30 July 2026, according to its Federal Communications Commission (FCC) filings.

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19 https://mybroadband.co.za/news/telecoms/542211-south-africa-becomes-only-southern-african-country-without-starlink-launch-date.html
20 www.intelsat.com/newsroom/intelsat-and-africa-mobile-networks-expand-cellular-coverage-across-africa/#:~:text=%E2%80%93%20Intelsat%2C%20operator%20of%20one%20of,more%20than%208%20million%20people.
21 https://www.intelsat.com/newsroom/intelsat-expands-cellular-opportunities-to-nigeria-and-neighbors/

Geespace (part of Geely Technology Group) has launched 30 satellites in China and plans to expand to 72 by 2025, targeting global broadband and D2C capabilities. The Qianfan ("Thousand Sails") constellation is a Chinese initiative that has already deployed 54 satellites and aims for over 15,000 by 2030.

Very High Throughput Satellites use multibeam antennas and adaptive modulation to efficiently deliver vast amounts of data and provide Internet speeds approaching those of terrestrial broadband. VHTS include satellites like Eutelsat KONNECT and ViaSat-3, which are already operational and demonstrating their potential to connect remote regions with high-speed Internet.

By December 2023, Eutelsat had successfully reached the 500,000-user mark with Eutelsat Konnect Wi-Fi, and the Eutelsat Group has pledged to connect 1 million people in Sub-Saharan Africa by 2027. Eutelsat's satellite broadband initiative, powered by the new-generation EUTELSAT's KONNECT satellite delivers broadband Internet access to rural areas beyond reach of terrestrial networks. Dimension Data Mozambique has extended its satellite service to Mozambique using OneWeb's constellation of 648 LEO satellites[22].

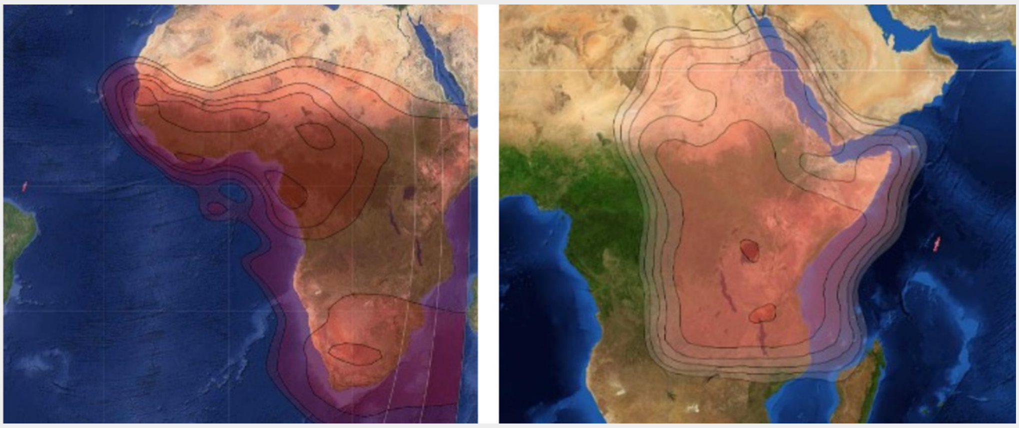
The "First Kenyan University Nano Satellite-Precursor Flight" (1KUNS-PF) was the first satellite deployed by Kenya[23]. It was developed by the University of Nairobi through KiboCUBE (the cooperation between UNOOSA and the Japan Aerospace Exploration Agency (JAXA) mentioned previously), offering developing countries the opportunity to develop and deploy their own cube satellite – CubeSat – from the Japanese Experiment Module on the International Space Station. 1KUNS-PF was deployed on 11 May 2018 and has helped Kenya acquire data to monitor agriculture and coastal areas. It has also proved a driver for the establishment of the Kenya Space Agency. Rwanda's first satellite, RWASAT-1, was launched in 2019 to monitor agriculture, coastal areas, forests, and biodiversity. Rwanda Space Agency was established in 2020 with a mission to help "create a world-class space ecosystem" and "enable the space value chain" across Africa[24].

SES and Telstar offer satellite coverage of Western and Eastern Africa, respectively, using the Ku Band (see Image 1). Globalstar now connects many millions of people across Africa, with 28 ground stations.

22 www.budde.com.au/Research/Mozambique-Telecoms-Mobile-and-Broadband-Statistics-and-Analyses
23 https://www.unoosa.org/documents/pdf/annualreport/UNOOSA_Annual_Report_2023.pdf
24 https://www.itu.int/hub/2025/03/space-connect-updating-regulations-for-leo-satellite-services/

Image 1: Ku-Band Coverage of Western and Eastern Africa

SES and Telstar offer satellite coverage of Western and Eastern Africa, respectively, using the Ku Band.



Source: https://www.bcsatellite.net/satellite-coverage-maps/

Arab States have historically enjoyed considerable levels of access to satellite communications, given their large remote areas with low population density and mountainous regions. Arabsat is the leading satellite service provider in the Arab region and is headquartered in Riyadh, Kingdom of Saudi Arabia, with an additional control ground stations in Tunisia. Its fleet carries over 650 television channels, 245 radio stations, paid TV networks, and a wide range of HD channels and provides a full spectrum of radio, television, telecommunications, and broadband services. It reaches tens of millions of homes in over 100 countries in the Middle East, Africa, Europe, and Central Asia. Insight 4 explores how the Kingdom of Saudi Arabia is harnessing Space technologies, including satellite, to achieve the SDGs.

Insight 4: How the Kingdom of Saudi Arabia is harnessing Space technologies

The Kingdom of Saudi Arabia has long been a pioneer in harnessing technology and innovation to further advance the digital ecosystem, drive the widespread adoption of emerging technologies, such as Space and satellite technologies, and catalyze advancements towards achieving the SDGs and the 2025 Advocacy Targets, to shape new frontiers for all.

Driven by the Kingdom's developmental plans and Saudi Vision 2030, the Communications, Space, and Technology Commission (CST) is contributing to bridging the digital divide by advocating a new generation of wireless networks to break the boundaries of the current terrestrial-based systems and fully adopt Non-Terrestrial Networks (NTNs). NTN consists of variants of space-borne and air-borne communication networks including GEO, MEO, LEO satellite constellations, High Altitude Platform Systems (HAPS), Low Altitude Platform Systems (LAPS) and air-to-ground (A2G) networks. These elements and components are evolving to connect the unconnected and are positioned to become an integral part of the future 6th Generation (6G) wireless network.

Building on this, CST has launched the "NTN Program" to enable the NTN technologies and to facilitate the roadmap to the 6G communications. Saudi Arabia has also conducted pioneering trials and investments to accelerate NTN deployment, emphasizing its role in not just digital inclusion but also sustainable development, emergency response, and precision agriculture.

However, harnessing Space technologies requires collaborative efforts from multiple stakeholders to ensure equitable access to digital resources. As such, in cooperation with ITU, we organize the "Connecting the World from the Skies" global forum every two years, which extensively addresses NTN advancements from technological, policy, and scientific perspectives through discussions, keynotes, and technology demonstrations. The 2024 edition showcased ground-breaking achievements, such as the first Direct-to-Device (D2D) technology demonstration in the MENA region. To accommodate the rapidly evolving NTN technologies, including HAPS and NGSO constellations, we partnered with ITU to develop innovative solutions that integrate both traditional and satellite communication services to address the global digital divide.

While the rapid growth of Space activities brings substantial benefits, it also poses significant challenges to Space sustainability, our vision is to ensure that space remains safe and accessible for everyone. As the global community embarks on Space exploration, we have hosted the first Space Debris Conference with the ITU as a partner, and the United Nations Office for Outer Space Affairs (UNOOSA) as a content partner. Aiming to secure the future growth of the global Space economy by bringing nations together to create and raise awareness about Space challenges, discuss regulatory and policy elements, and promote the creation of multi-prong research for Space debris. Additionally, we have launched the global SpaceUp Competition, aimed at encouraging global Space entrepreneurship, start-ups and SMEs to adoption of Space-based solutions by organizations across various key sectors.

The Kingdom is actively participating in global initiatives to promote Space technology and investing in research and development to innovation within this vital field. Along with the World Economic Forum (WEF), we unveiled the "Center for Space Future" to contribute to space technological innovation and maximize the economic and environmental value of the space sector.

Together, through these transformative initiatives, the Kingdom is contributing to the global advancement of space technologies and capabilities, fostering a more interconnected, inclusive, and sustainable world for all.

Source: H.E. Dr. Mohammed Saud M. Altamaimi, Communications, Space & Technology Commission (CST).

Asia-Pacific's satellite communications market consisted of 39 active satellite operators by 2024, according to Kratos market research, with at least 4.6 Tbps of capacity supply, approximately 27,000 satellite backhaul sites (by 2023) and around 740,000 connected satellite IoT terminals in 2022, with more coming online each year[25]. In terms of the leading operators, EUTELSAT 70B and EUTELSAT 172B satellites provide high bandwidth services to Asia, Australia, Japan, New Zealand and the Pacific Islands. Its HOTBIRD and EUTELSAT 7 West A & 8 West B satellites provide TV channels across Europe, the Middle East and North Africa. Other Eutelsat satellites are optimized to reach into regional broadcast markets in Central Europe and the Russian Federation, Central Asia and the Americas[26].

Latin America has a strong concentration of population in urban centres, but it also has a dispersed population in rural areas and government support for Latin American satellite projects. Starlink has services available throughout most of the region. In June 2024, Amazon announced a deal with Vrio Corporation to provide connectivity services when Amazon's constellation is operational to residential customers in Argentina, Brazil, Chile, Colombia, Ecuador, Peru and Uruguay[27]. Orbith plans to launch a dedicated MicroGEO communications satellite in 2025, manufactured by Astranis to cover Argentina[28].

The Madrid-based company Hispasat (with its Brazilian subsidiary, Hispamar) uses capacity from its GEO satellite fleet, as well as third-party capacity for enterprise customers, telcos and governments. Hispasat uses GEO to provide the quality of service needed for professional customers, and high-growth LEO services for the low latency needed by some other applications. Hispasat has signed an agreement with the IoT company IOTLatam to incorporate sensors and video cameras into its Tower Insight satellite infrastructure monitoring solution.

Internet of Things (IoT) networks can use satellite connectivity to bring efficiencies and new capabilities to multiple sectors, including agribusiness, transport and logistics. Combining IoT and satellite technologies enables continuous attention to be paid to an entire network of towers, regardless of geographic location for remote monitoring to identify and resolve incidents from central control centers[29]. Intelsat is using satellites to enable smart precision farming in Brazil, especially in rural and remote areas (Insight 5).

25 www.kratosdefense.com/constellations/asia-pacific-satcom-market-overview
26 www.eutelsat.com/satellite-services-asia-pacific.html?ref=xranks
27 https://interactive.satellitetoday.com/via/july-2024/latin-america-a-growing-market-for-satellite-connectivity-services
28 www.satellitetoday.com/connectivity/2024/03/21/astranis-to-build-dedicated-microgeo-satellite-for-argentina/
29 www.hispasat.com/en/press-room/press-releases/archivo-2025/481/hispasat-incorpora-los-sensores-y-la-analitica-de-iotlatam-a-su-solucion-tower-insight

Insight 5: The Role of Satellite in Transforming Agriculture

Satellite connectivity is vital to ensuring communities beyond the reach of terrestrial networks are included in an ever-evolving digital world. By providing fast and affordable internet, satellite technology enables rural populations to access the same benefits in healthcare, agriculture, business, and education as those in urban areas, facilitating rapid social and economic development.

Technological advances in space are increasingly instrumental in enabling smart precision farming, especially in rural and remote areas. This approach leverages technology to improve yields and profitability, while reducing environmental impact. According to Grand View Research (GVR), the global precision farming market size was valued at US$10.5 billion in 2023 and is projected to grow at a compound annual rate of 12.8% from 2024 to 2030. This growth, according to GVR, is attributed primarily to the proliferation of the Internet of Things (IoT) in addition to the growing use of advanced analytics by farmers.

Intelsat continues to address connectivity gaps in hard-to-reach areas worldwide. With the UN calling for urgent action to tackle the global food crisis, reliable satellite connectivity is needed more than ever to enable the digitalization of farming for increased production and operational efficiencies. Intelsat's connectivity solutions aim to meet the growing demand of a modernizing agriculture industry. By combining the availability and consistency of Intelsat's high-throughput, secure geostationary satellite network with the lower latency of a low Earth orbit network, Intelsat's connectivity solution keeps heavy farm equipment connected in remote areas to support enhanced telematics, monitoring, autonomy, and remote control.

For example, in Brazil, less than a quarter of farmland lies close enough to a cellular tower to make a connection possible. Recently, the farming equipment manufacturer, CNH, agreed to install, connect and operate Intelsat's connectivity solution on their farm equipment in remote farmland throughout Brazil. As the first satellite communications company to provide multi-orbit connectivity to farm equipment, Intelsat's collaboration with CNH will unlock new capabilities in the most isolated locations. Intelsat has proven that built-for-purpose terminals can access multiple satellite orbits from anywhere to offer high network reliability, greater throughput and optimal user experience.

Source: Intelsat.

Oceania comprises Australia, a country with a large interior region, and many smaller islands and archipelagos in the Pacific. Satellite coverage is able of covering both. Telstra offers a range of satellite data services to connect both residential and enterprise customers, including VSAT, high availability C band Geostationary Earth Orbit (GEO) satellites, low latency Medium Earth Orbit (MEO) satellites[30] and LEO services (in conjunction with Starlink)[31]. Sky Muster satellite service delivers the National Broadband Network (nbn) network to homes and businesses in regional and remote Australia, via two state-of-the-art satellites[32]. Optus Networks is a leading provider of satellite services. Globalstar offers reliable satellite and terrestrial connectivity throughout Australia. Vocus was the first Australian carrier to partner with Starlink, delivering Vocus Satellite-Starlink for Australian enterprise and civil government customers[33].

In India, the Indian Space Research Organisation (ISRO) spearheads the Indian Space Programme, as well as partnering with the private sector for commercial small satellite launches.

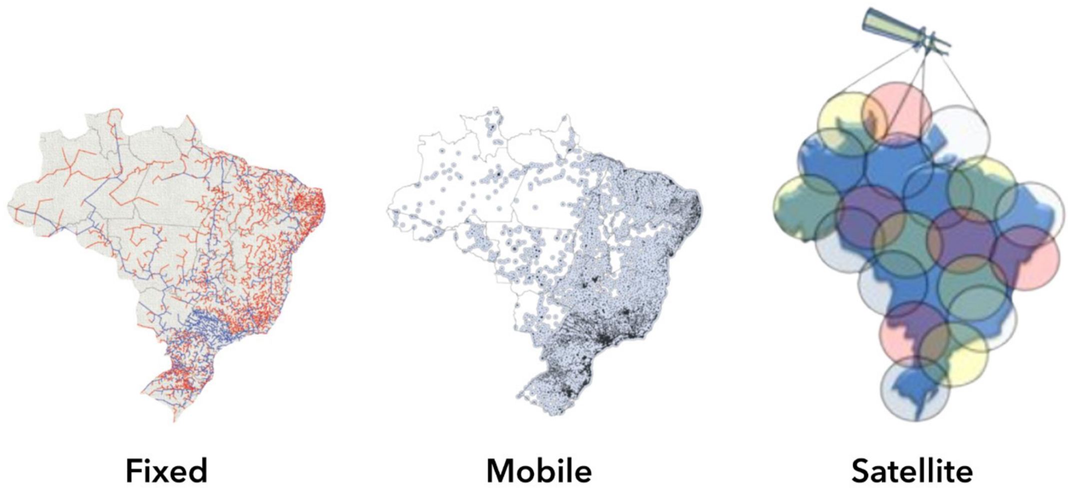
30 www.telstrainternational.com/content/dam/shared-component-assets/tecom/networks/satellite-services/satellite-data-services/Satellite%20Services_Enterprise_Datasheet.PDF
31 www.telstrainternational.com/en/products/global-networks/satellite-services/satellite-data-services
32 www.nbnco.com.au/learn/network-technology/sky-muster-explained#accordion-76721c7574-item-89f5f6e60d
33 www.vocus.com.au/enterprise/connectivity/satellite-services

For example, in November 2020, ISRO launched EOS-01, an Earth Observation (EO) satellite for applications including forestry, disaster management, and agriculture activities, from India's polar satellite launch vehicle (PSLV). Several other customer satellites have also launched with NewSpace India Limited, a public sector undertaking responsible for producing, assembling and integrating launch vehicles, with the help of an industry consortium.

In China, China Satcom holds a "Basic Telecommunications License" to operate satellite telecommunications, alongside the big three state-owned telecom operators and the China Transport Telecommunication Information Group Company (CTTIC). In April 2021, China Satellite Networks Limited (SatNet) was established to launch and operate multiple LEO communication satellites in China. In October 2023, the Ministry of Industry and Information Technology (MIIT) opened its consultation on the "Opinions on Innovating the Management of Information and Communications Industry to Optimize the Business Environment". In August 2024, MIIT published guidelines encouraging private-sector involvement, and supporting reforms in satellite Internet to boost the growth of private telecom enterprises[34].

In Brazil, satellite coverage is becoming ubiquitous within the country (Image 2). The satellite market is growing strongly, due to surging demand for high-speed internet and mobile connectivity across the country's vast rainforests and rural areas. The Government is actively encouraging investments in satellite technologies to enhance communication capabilities and open up economic opportunities in remote areas. Companies such as Sky Brasil Services, Via Direta Telecom and Viasat are leveraging their capabilities to serve both rural communities and expanding towns.

Image 2: Universal Connectivity in Brazil



Source: Government of Brazil. Note: Brazil is served by multiple satellites, the single satellite shown is illustrative.

34 https://www.globaltimes.cn/page/202408/1317505.shtml

6 Sectoral Trends

Space-based technologies also offer important advances in different sectors. For example, geo-information products (such as maps) support civil protection and humanitarian affairs, including prevention, preparedness and reaction to damage and destruction of terrestrial-based networks (e.g. by earthquakes, landslides, hurricanes, wildfires or flooding) caused by humanitarian and natural disasters. For example, oceanographic satellites such as Topex-Poseidon provide scientists, meteorologists and weather forecasters with information required to forecast likely weather patterns in the oceans and identify nascent storms and hurricanes. Many of the sectoral applications of data are also based on the analysis of geospatial data (Box 2).

Space technology can strengthen early warning capabilities by providing real-time information to mitigate the impact of natural disasters, which are becoming more frequent and severe. Satellite services can help provide communications and information based on satellite imagery during emergencies to support disaster management. For example, Vodafone and Intelsat operate in partnership to offer wider coverage of temporary and on-the-move satellite connectivity services to organizations operating in hard-to-reach areas or disaster zones, responding to emergency situations. Using Intelsat's network of GEO satellites, Vodafone provides a Communications-on-the-Move (COTM) service using a vehicle-mounted antenna, and Communications-on-the-Pause (COTP) connectivity using a compact satellite terminal[35]. Satellite-enabled technologies are also helping prevent disasters in large-scale infrastructure and mining projects. For example, Viasat is partnering with Worldsensing to create early warning systems for landslides and disasters[36].

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35 www.vodafone.com/news/technology/vodafone-intelsat-expand-satellite-connectivity-services-for-private-and-public-sector

36 https://www.viasat.com/perspectives/enterprise/2024/how-viasat-satellites-are-supporting-early-warning-systems-for-landslides-and-disasters/

Box 2: Using geospatial data

Applications of geospatial analysis include ICT infrastructure gap analysis and connectivity modelling, climate change modelling, weather monitoring, tracking human and animal population distributions, and planning telecommunication systems. GIS applications are used to predict, manage, and learn about different phenomena affecting the Earth, its systems, and its inhabitants.

Geospatial analysis has recently advanced considerably in terms of its:

1. Scope, precision, accuracy and granularity.
2. Easier and faster transmission, analysis and manipulation;
3. The number and type of devices equipped with geospatial and location identification (which can include satellite, mobile, fibre, IoT devices, sensor networks, as well as connected cars and vehicles).

Combining global with local data can yield some of the biggest insights of all. However, the use of geospatial data is not without its challenges, including: restrictive data access; lack of standardization; data that are not fit enough for purpose; lack of analysis of ready data; insufficient frequency of observations; and long-term trend analysis. There is a long journey from validation data (which are expensive to collect and sometimes difficult to obtain from third-parties) and analysis-ready data (which involves collating and correcting data from different sources).

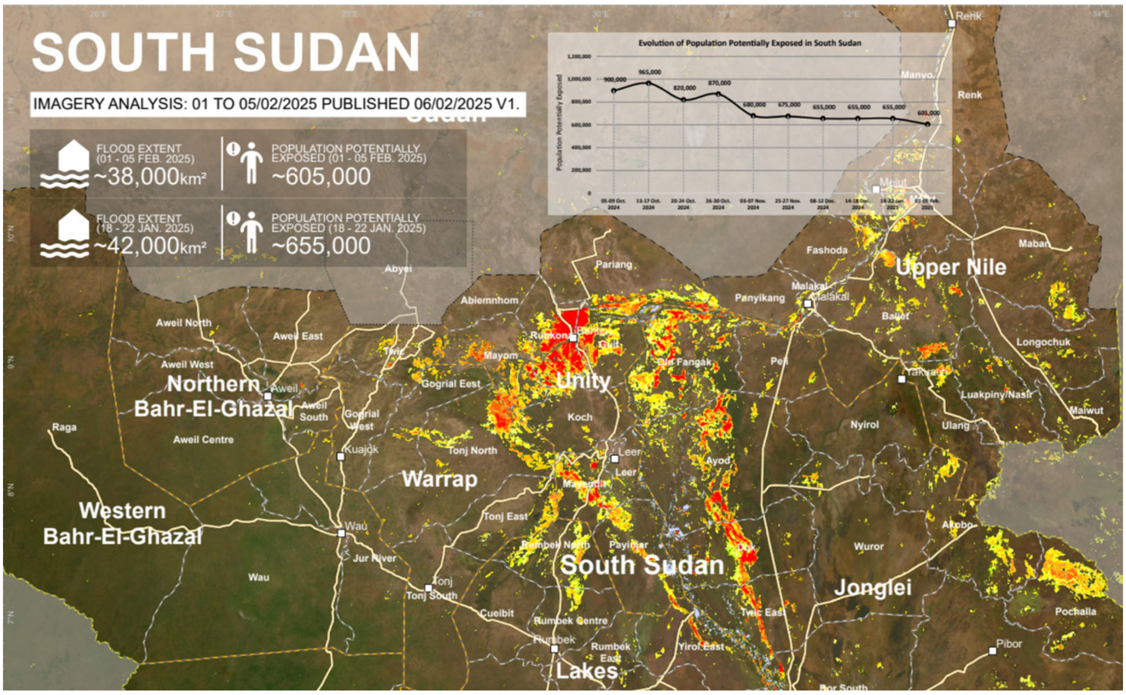
Source: ITU, adapted from: www.itu.int/en/mediacentre/backgrounders/Pages/geospatial.aspx

Under the International Charter: Space and Major Disasters, 17 Charter Members share data gathered by 270 satellites in 35 constellations to provide valuable information about disasters in up to 133 countries that is not possible to obtain on the ground. The Charter has provided information about floods in Brazil and Scotland, mudflows in Kyrgyzstan and landslides in Papua New Guinea[37]. Advanced sensors and lower latency can help provide more effective response through monitoring of natural disasters and conflicts on-the-ground, helping with recovery and response times. They can also help first responders communicate, issue early warnings and get continuous updates, even in the most remote areas.

For example, since 2003, UNOSAT has provided an Emergency Mapping service providing satellite image analysis during humanitarian emergencies[38] related to disasters, complex emergencies and conflict situations. This service provides satellite imagery derived maps (both web and static maps), reports and data ready for inclusion in Geographic Information Systems (GIS) enabling evidence-based decision making and operational planning. This service has been used to monitor water availability and cloud cover in South Sudan (Image 3), damage after earthquakes in Vanuatu, flooding in Malawi and Mozambique and volcanic eruptions in Ethiopia[39].

37 https://disasterscharter.org/library/quickviews
38 https://unosat.org/services
39 https://unosat.org/products/

Image 3: Water Availability in South Sudan



Source: UNOSAT, 6 February 2025, https://unosat.org/products/

Space agencies are working together using Earth Observation satellites to try to understand climate action and disaster risk reduction. There is growing interest in monitoring air quality, for example, through products developed through the Copernicus Atmosphere Monitoring Service (CAMS) and the Climate Change Service (C3S). Copernicus Sentinel data and services provide free and open data for interested stakeholders.

Satellite services can help map land use, such as natural or managed/planted forests and deforestation rates. For example, satellite images of tropical forests in Brazil and Malaysia (Image 4) have helped reveal illegal logging and show that the most important precursor to illegal logging is the development of a road.

Satellite imagery can also be used to map human settlements, including the growth and expansion of towns and urban centres. These images can also reveal the type of settlement, including high-income neighbourhoods versus shanty towns, to estimate poverty rates (Image 5 in Mexico and Image 6 of Mumbai, India), including in estimations of insurance losses.

Image 4: Forestation & Land Use in Malaysia

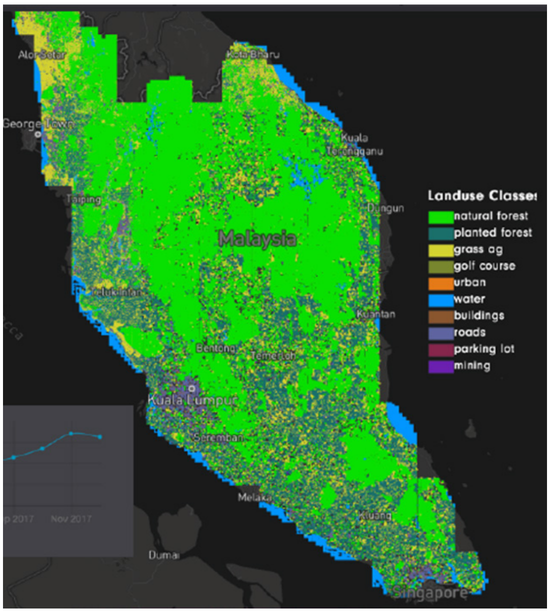
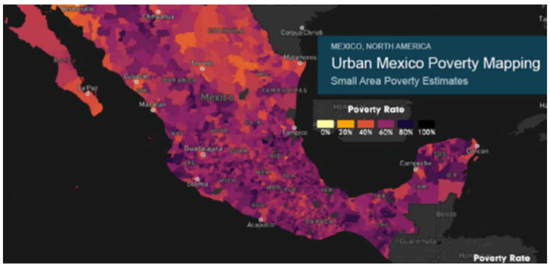


Image 5: Poverty Rates in Mexico



Source: Orbital Insight, World Bank.

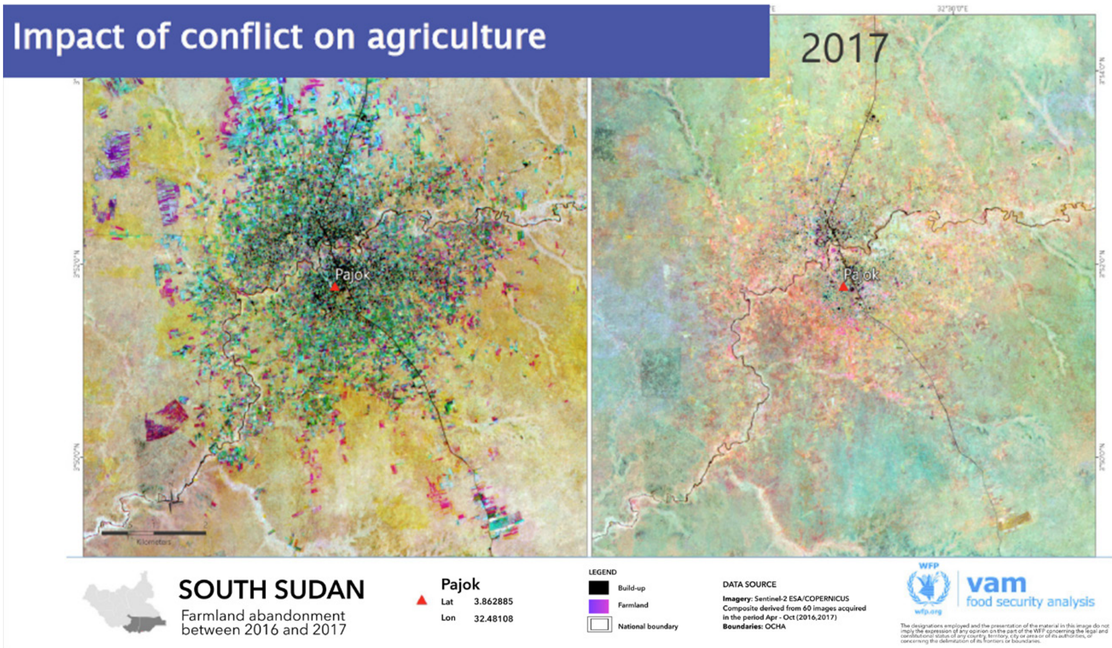
Image 6: Inequality in Mumbai, India, seen from above

Source: Unequal Scenes project, at: https://unequalscenes.com/

Technology-enabled healthcare applications available through Internet connectivity can also help boost health and wellbeing. Connecting communities means that healthcare workers can receive remote training in detecting diseases and making recommendations for preventive care, while clinics and medical providers can connect with each other to collect data and share information, facilitating better health outcomes across an entire country. In-home monitoring systems mean that patients in rural and remote areas can avoid the costs associated with travelling to medical appointments.

Satellites have also helped to make harvesting more efficient and have served as a monitoring tool for planning purposes. The data-rich analyses made possible through satellite imagery contribute to climate action and can help government authorities to provide farmers with best-practices and advice on cultivation and climate information, as well as to provide insurance and financial instruments to help mitigate risk. Low data and wide area network use cases are often seen as an ideal sweet spot for satellites and one key example is use in agriculture, although returns on investment in agriculture may prove relatively lower. Image 7 illustrates how the impact of conflict on agricultural yields can be explored using satellite imagery.

Image 7: Impact of Conflict on Agriculture in South Sudan



Source: WFP/VAM.

7 Conclusions

Space-based technologies offer exciting prospects for strong continuing growth, as well as opportunities for innovation in the future. Space-based communications are no longer acting just as backhaul or as competitor to terrestrial broadband technologies, but will increasingly work in combination with mobile technologies to ensure more widespread connectivity, including cell phones and other personal devices.

The unprecedented growth of space-based activities brings both challenges and opportunities. Space-based solutions are unlocking transformative opportunities for economic and social growth across the globe. By empowering communities with data-driven insights and greater access to information and connectivity, space technologies help bridge gender, social, and economic divides, fostering more inclusive and equitable societies.

Policy and regulatory mechanisms need to evolve and be strengthened at the national and international levels to accommodate this growth and the associated responsibilities by stakeholders and to mitigate risks of service disruption.

Satellite imagery and satellite services can also offer improved insights into land use, agricultural yields, water management and emergency response. Such rapid technological evolution is challenging existing frameworks for cooperation and coexistence. Regulatory frameworks will have to evolve to match the strong growth and evolution of space-based technologies.

Ultimately, the space industry, government agencies and regulatory mechanisms need to continue to collaborate, adapt and evolve, to help ensure that access to space remains equitable for all.

International Telecommunication Union
Place des Nations
CH-1211 Geneva 20
Switzerland

BROADBAND COMMISSION
FOR SUSTAINABLE DEVELOPMENT

ISBN 978-92-61-40581-6

9 789261 405816

broadbandcommission.org

Published in
Switzerland Geneva,
2025