

LOW EARTH ORBIT SATELLITE COMMUNICATIONS ...2024 ROUND UP

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Welcome to our 2024 roundup of the low earth orbit (LEO) communication satellite space and prognosis for 2025. Let us start with a key insight from Joe Madden [1].

LEO is really two markets:

(i) satellite to small user terminals and (ii) satellite for fixed broadband internet. We need to avoid mixing the two. Satellite to small user terminals are used today for messaging, remote sensing and control. The terminals can be fixed or mobile. These terminals typically support low data speeds and low monthly volumes—think Iridium, Globalstar and Orbcomm with typical data speeds under one Mbps and up to a few GB of monthly data. Today, this is somewhat of a niche market. However, technology for satellite direct to standard cellular mobile handsets is emerging and there is an expectation that this will become a significant market. The second market, fixed broadband, has larger terminals for service to buildings or vehicles—think Starlink and OneWeb with data speeds up to 100 Mbps or so and monthly data volumes on the order of hundreds of GB. Starlink's success has "proved-in" the fixed broadband market. The market for non-broadband satellite service to standard mobile phone form factor is beginning to be tested, with lots of room for speculation.

Below, we cover both of these markets. It is potentially important to note two LEO network operator cross-overs between these markets. First, AST Space Mobile is advancing toward broadband satellite direct to mobile phones; and second, Starlink is combining messaging direct to mobile phones as an adjunct to their fixed broadband constellation.

1. Satellite Direct to Cellular Mobile User Equipment (Sat-to-Cell)

Satellite service direct to unmodified mobile cellular phones has been grabbing the headlines over the past two years. Apple was first to market with a location sharing and emergency message capability, starting in 2022 with the iPhone 14 over Globalstar LEO satellites. The iPhone 14 and subsequent iPhones have modifications to enable this capability. The idea was picked up by the 3rd Generation Partnership Project (3GPP). 3GPP is the global engineering organization developing specifications for the cellular mobile ecosystem. Hooks for non-terrestrial network (NTN) communication were included in recent releases of 3GPP specifications. The term NTN is used because, in addition to satellite, the specifications cover drone and aircraft-based communication with 3GPP user terminals. Regulatory bodies are also making provisions for terrestrial and non-terrestrial spectrum sharing to facilitate an orderly introduction of the service as a supplement to terrestrial networks.

LOW EARTH ORBIT SATELLITE COMMUNICATIONS

LEO FIXED BROADBAND INTERNET

In-service
1. Starlink
2. OneWeb

Planned

1. Amazon Project Kuiper
2. Telesat Lightspeed
3. China G60 Project
4. Europe IRIS²

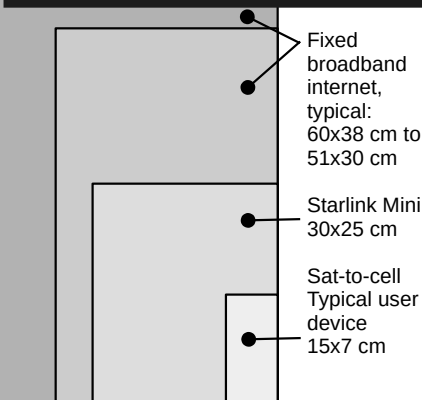
LEO SAT-to-CELL INITIATIVES

In-service with messaging
1. Apple-Globalstar
2. Starlink – One NZ
3. Lynk Global
4. Skylo

Under construction

1. AST Space Mobile - voice
2. Sateliot - messaging

LEO USER TERMINAL RELATIVE SIZES



Trials have been underway to unmodified 3GPP compliant cell phones from LEO satellites by Lynk Global, AST Space Mobile and Starlink. Then, in December 2024, One NZ (New Zealand) became the first mobile network operator to offer satellite-based direct-to-cellular text message service to customers over Starlink's LEO satellites [2]. Many mobile network operators world-wide are signing up and waiting for early message based services to emerge. Watch for beta service, pending the build-up of constellations to enable more continuous service. As more satellites with large array antennas are orbited by AST Space Mobile, real time voice services should become available. Further along on the technology road map, some level of video streaming may also emerge.

In short, the technology works and should improve incrementally over time. A question on the mind of many is the size of the market which, of course, depends on service plans and pricing. Today Apple includes two years of free satellite message service with a new iPhone purchase. It is possible, even likely, that regulators will require emergency call service to be free. Is free a good business model? Although launch costs to LEO have fallen from about \$16,000/kg before SpaceX to about \$3,000/kg today, largely due to SpaceX Falcon 9 launch vehicles [24], the cost per kg to LEO is still expensive. Where is the business case for sat-to-cell, especially for dedicated sat-to-cell satellite payloads? How many players can survive, and which ones? Is the market big enough to support separate dedicated constellations from different providers? Is bundling fixed broadband service and direct sat-to-cell on the same satellite the way to go? Next, we briefly outline progress by the various parties driving development of the technology.

As noted above, **Apple using Globalstar satellites** were first to market with a commercially available satellite to cell phone emergency text and location messaging service. Service is available from anywhere with Globalstar satellite coverage. The service has been available since the 2022 release of the Apple iPhone 14 and subsequent iPhones. Apple's recent release of iOS 18 extends this emergency text and location sharing capability with "Message via Satellite" service enabling these phone users to receive and send texts, including "Tapbacks," when beyond terrestrial coverage [3]. Apple's satellite service is free for two years after purchase of a new iPhone, and apparently extending the service availability without charge.

Lynk Global demonstrated intermittent texting and other low-bandwidth services to unmodified cell phones in 7 countries, including parts of the Solomon Islands, Cook Islands, and Palau via partnerships with local mobile operators. Lynk has partner agreements with 40 mobile network operators world-wide. With 2 new satellites reaching orbit in March 2024, Lynk should have 5 operational with sat-to-cell capability. Original constellation plans in 2020 called for 24 to 36 satellites. Lynk has funds from SoftBank, Qualcomm, and others but likely requires additional funding for more satellites in order to achieve global coverage and for improved service (less delay for messaging) [4].

AST Space Mobile is the most ambitious of the sat-to-cell initiatives—promising to break past the simple text and location services that are currently emerging. They made industry headlines in April 2024 by streaming video over their Bluewalker 3 prototype satellite to an unmodified cell phone using a 10 MHz channel in the 700-800 MHz band. Although only a short advertisement, it served as a technology demonstration. A year earlier, the first two-way voice call over the same satellite was made between an unmodified Apple iPhone and Samsung Galaxy phone. After some supplier delays, 5 Bluebird "Block 1" production satellites launched in September 2024. Each Bluebird has a 64 square meter phased array antenna and weighs-in at about 1.5 tonnes. Google, Vodaphone, AT&T and Verizon have signed investment and commercial agreements with AST Space Mobile. Block 2 satellites are in production for launch in 2025 and should boost the peak data-rate to 120 Mbps. With the 5 Block 1 plus 17 Block 2 satellites, continuous service should be available in equatorial regions. A total of 50 or 60 satellites will be needed for continuous US coverage. US service will use 850 MHz spectrum from AT&T and Verizon. [5], [6], [7].

Starlink, with thousands of satellites and millions of subscribers, leads the broadband LEO internet market by a very large margin. And the number of satellites and subscribers continues to grow. With an eye on the sat-to-cell market opportunity, the first six Starlink satellites supporting text messaging capability to standard LTE phones were launched in early 2024. As of December 2024, 320 satellites with direct sat-to-cell capabilities were in orbit. Starlink has FCC approval to use T-Mobile 1900 MHz spectrum and to orbit these satellites at 340-360 km (down from 525-535 km), reducing both signal delay and path loss. As noted earlier, One NZ announced nationwide texting service in New Zealand using 4 eligible mobile devices over Starlink, with more devices to follow. Texts will typically take 3 to 10 minutes. Over time, with more satellites, delay should fall to about 1 minute. T-mobile announced beta texting service will be available in the US using their 1900 MHz spectrum beginning in 2025. FCC approval to operate the satellites at higher power is pending review of interference concerns. This may enable the introduction of voice calling. Expect beta texting announcements in 2025 from select carriers in several other countries (Rogers in Canada, Japan's KDDI and Optus in Australia, as well as Salt in Switzerland and Entel in Chile and Peru). These announcements mark a shift of Starlink's go-to-market strategy from mainly retail toward

wholesale for mobile network operators. [8], [9], [10], [11], [12].

Skylo provides Non-Terrestrial Network (NTN) service over a group of existing satellites across a range of spectrum bands that are compatible with cellular devices that support 3GPP Release 17 NB-IoT specifications. In 2024, Google and Skylo announced that NTN connectivity is integrated into the Google Pixel 9 series smartphones, enabling emergency communications over the Skylo network. Satellite service is available free for 2 years after purchase. Two-way texting will become available across the continental US on the Pixel 9 if Google Message is set as the default messaging app [13].

Qualcomm and Iridium announced an initiative at CES 2023 to collaborate on satellite messaging to Android based mobile phones, using proprietary technology. The agreement collapsed later that year as smartphone manufacturers favored a standards-based solutions. Qualcomm pivoted to develop 3GPP based NTN technology. And in early 2024, Iridium announced Project Stardust [14]: a direct sat-to-cell device strategy based on 3GPP 5G specifications for Narrowband-IoT (NB-IoT) Non-Terrestrial Network (NB-NTN) service. The project targets testing in 2025 and commercial service in 2026. Stardust requires new software to be developed for Iridium's currently deployed narrow-band LEO satellite constellation. Future Iridium satellites can be expected to have NTN compatibility baked-in.

Sateliot is building an NB-IoT satellite constellation based on 3GPP Release 17 specifications for the 5G New Radio (NR) cellular standard. The service is based on a virtualized cloud-native 5G core hosted by AWS. Sateliot will offer wholesale satellite NB-IoT as a roaming extension for terrestrial operators. Four initial 10-kg "nanosatellites" were launched on a SpaceX mission in August 2024. Telefonica conducted trials in 2024. Sateliot has been working with Swedish power grid firm Sentrisense to use the service for electric grid sensors. The firm claims to have 8 million devices "contracted." In December 2024, the European Investment Bank (EIB) granted a €30 million loan to co-finance the rollout of 100 LEO satellites [15], [16].

2. Satellite for Fixed Broadband Internet

A mere five years ago, high-performance broadband internet by LEO satellite was in its infancy. By the end of 2020, **SpaceX** had over 700 LEO satellites in orbit and was offering "Better Than Nothing Beta" service with 50 to 150 Mbps download speeds. Fast forward to the end of 2024, **Starlink** has over 6,700 active satellites in orbit and over 4.6 million customers world-wide. Starlink is expected to show a net profit on their constellation in 2024 on gross annual revenues of \$6.6-7.7 billion, positioning them to become the first LEO based internet service provider to post a net profit [25], [26]. Starlink has proved to be a game-changer for internet service to remote locations and for post disaster communications, and has even influenced how regional wars are fought. Starlink is the clear market leader and continues to innovate with new technologies and markets. For example, Starlink's latest user terminal offering, the "Mini," is optimized for portability with an

integrated WiFi router, footprint reduced by about 65%, and mass reduced by about 50%.

OneWeb, currently the only other broadband LEO internet provider, has 654 satellites in orbit [17], which should provide full global coverage. While the number of subscribers is not publicly available, OneWeb has activated services in a range of countries including Australia, Canada, New Zealand and countries in Europe. OneWeb's business model appears to be primarily a wholesaler for communication service providers. OneWeb is now part of Eutelsat and has funding from Airbus, Bharti Enterprises, SoftBank and others.

Amazon's Project Kuiper intends to develop and launch a LEO satellite constellation to provide fixed broadband internet. A stated objective is to help bridge the digital divide. Prototype satellites were launched in 2023 and later de-orbited. A suite of three user terminal types were announced, with download speeds ranging from 100 Mbps to 400 Mbps and to 1 Gbps depending on size. Production satellites are being built and should begin launching in 2025. Beta service may be available later in the year. The full constellation is proposed to eventually reach 3,236. How many satellites are needed for initial commercial service is debatable but likely on the order of hundreds. Although Project Kuiper will be late to the party and getting service started is not without challenges, they have a strong backer with Amazon, who has reportedly pledged \$10 billion to the venture [18], [19].

Lightspeed is Telesat's planned entry into the LEO internet market. With subsidy funding from the Canadian government, Telesat hopes to have 198 satellites in orbit by mid 2026. The satellites cleared an early design review in December 2024 and should start construction in 2025. Their target market is backhaul for mobile network operators and internet service providers as well as connectivity for aviation, maritime and government customers [20].

China placed a group of 18 LEO satellites into polar orbit in October 2024 on a Long March 6A launcher. This is the part of the Qianfan (Thousand Sails) constellation, which has a first phase plan for 1296 satellites, with 648 of these planned to be in orbit by the end of 2025. The launches are part of the Shanghai Spacecom Satellite Technology (SSST) G60 project. The G60 project is one of three constellations that China is planning. The others include the Guowang project, run by state-owned China Satellite Services, and the Honghu-3 project, led by Shanghai Lanjian Hongqing Technology Company. This satellite infrastructure will support China's rapidly growing commercial space sector, which includes satellite internet [21], [22].

The European Infrastructure for Resilience, Interconnectivity and Security by Satellite (**IRIS²**) project is Europe's LEO infrastructure initiative. In December 2024, the European Commission announced a contract with Europe's leading space companies to begin development of a 290 satellite constellation to provide broadband internet. The estimated cost: over €10 billion [23].

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