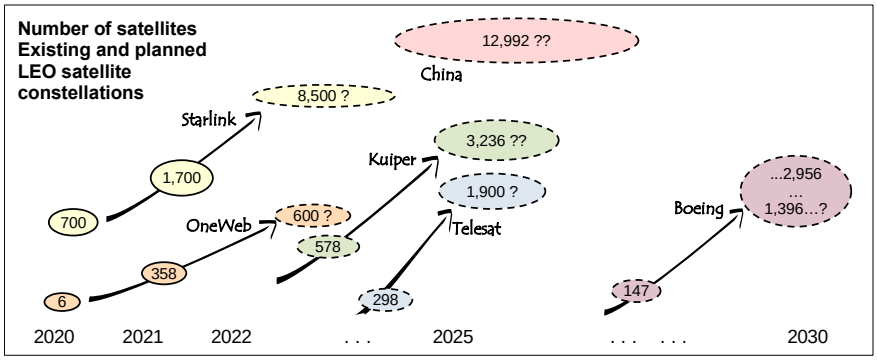
UPDATE: INTERNET SERVICE via LOW EARTH ORBIT SATELLITE ...an overview and summary of the current LEO hopefuls



Our first low earth orbit (LEO) satellite review looked at: (i) internet market drivers (underserved areas world-wide); key enablers (lower costs from technology advances and from higher volumes of equipment and launches); and (iii) challenges (technical, market, and business). Over the past year, Starlink beta service has pretty much confirmed that the technical and market challenges can be overcome. The jury is still out on the size of the market at each price point, and which of the LEO hopefuls can hit these points and establish a viable long-term business. The following summary paragraphs outline the current state of the leading hopefuls.

STARLINK has a significant head start with over 1700 operational satellites in a 547 km orbital shell inclined 53° and 10 satellites in polar orbit as of December 2021. Public beta service began in November 2020 and as of October 2021 the beta service was available in 18 countries with over 100,000 users and 500,000 on a wait list. Full commercial service may be imminent. Beta service performance: speed: 50 to 150 Mbps downlink and 10 to 40 Mbps uplink with delay typically 20 to 40 ms. The beta service costs US$500 for user equipment (user installed) then US$100 per month. The beta service targets the rural consumer market. In addition to consumers, other market segment aspirations include government, enterprise and network operators. System build-out is expected in two major phases. Phase-1 includes 3 orbital shells with 1584 satellites at ~540 km in 72 planes (22 satellites per plane) inclined 53.2°, 720 satellites at ~570 km inclined 70° and 508 satellites at ~560 km inclined 97.6°. The Phase-2 plan adds over 7000 satellites split into 3 shells at 335 km, 340 km and 345 km inclined 42°, 48° and 53°. Investments to date will be multi-billion dollars and when fully built out may reach US$30 billion. Starlink benefits from ownership by SpaceX, a satellite launch company and guidance by Elon Musk, the well-known technology pioneer behind Tesla.
Links:
https://planet4589.org/space/stats/star/starstats.html
https://www.lightreading.com/satellite/us-years-ahead-in-leo-broadband-but-6g-battle-looms/d/d-id/773758

ONEWEB was quick off the mark, launching its first six satellites in February 2019. Thirteen months later, in March 2020, OneWeb filed for bankruptcy protection. By December the company emerged from bankruptcy with funding from the UK Government and Bharti and satellite launches resumed. By October 2021, with further funding from SoftBank, Hughes Network Systems, Eutelsat and others, OneWeb had 358 satellites in orbit at 1200 km altitude. A constellation of 600 satellites plus 48 in-orbit spares are required for global coverage. System performance expectations: 50 Mbps downlink and 25 Mbps uplink with 50 ms round trip delay. Target markets will be businesses, governments (including defense) and network operators. BT has an agreement in place with OneWeb and expects trials in early 2022. Global coverage and commercial service is targeted for 2022. Total system investment to reach global coverage is estimated at US$2.4 billion. The UK Government is the largest shareholder.
Links:
https://www.bloomberg.com/news/articles/2021-07-29/inmarsat-challenges-musk-and-oneweb-with-new-satellite-network
https://www.canadasatellite.ca/OneWeb.htm
https://www.lightreading.com/satellite/bt-and-oneweb-ink-shiny-satellite-broadband-deal/d/d-id/773200

TELESAT branded their LEO service initiative "LightSpeed." In November 2021, Telesat was merged with Loral Space Communications, becoming a public company. LightSpeed plans call for an initial constellation of 298 satellites (78 in polar orbit and 220 inclined) operating in the Ka-band at an altitude of about 1000 km. A $3 billion satellite build contract has been awarded to Thales-Alenia Space. The current satellite launch schedule is 2023 which means first service may be available in 2024. LightSpeed will be a wholesale provider to retailers such as internet service providers and mobile network operators in rural and remote areas. Up to 7.5 Gbps should be available to each customer terminal. The government of Canada will be an anchor tenant and will use LightSpeed to provide subsidized internet service to remote Canadian communities. The future constellation size was revealed in a recent request to the FCC tob authorize an additional 1,671 satellites.
Links:
https://www.telesat.com/wp-content/uploads/2021/04/Telesat-Lightspeed-Specifications-Sheet.pdf
https://advanced-television.com/2021/12/02/telesat-slips-launch-of-lightspeed/
https://www.lightreading.com/satellite/funding-its-constellation-telesat-does-dual-ipos/d/d-id/773485

KUIPER SYSTEMS, although slower than other LEO initiatives to make announcements, is now moving forward. The FCC approved a 578 satellite constellation at 590 km altitude inclined 33° and there are plans to expand to some 3,236 satellites. A funding requirement of $10 billion has been reported. Kuiper needs to be taken seriously as it is a subsidiary of Amazon, and through Jeff Bezos, Kuiper potentially has access to launch capabilities by Blue Origin. The first two satellites are set for lift-off in late 2022 on a launch company startup, ABL Space Systems. A 300 mm flat panel phased array user terminal antenna is under development with support for speeds to 400 Mbps. A recently announced partnership with Verizon, presumably to offer improved broadband and perhaps IoT related services in rural areas, indicates existing network providers will be a target market.
Links:
https://www.inverse.com/innovation/amazon-kuiper-details
https://www.aboutamazon.com/news/innovation-at-amazon/project-kuiper-announces-plans-and-launch-provider-for-prototype-satellites
https://telecoms.com/511916/verizon-chooses-amazon-as-its-leo-satellite-buddy/

CHINA appears to be launching LEO networks through two state-owned satellite operators: China Satellite Network (China SatNet) and China Spacesat. Not much is known about the technology or program schedule. A few technology verification satellites have been launched. In 2021, China SatNet filed for spectrum with the ITU to support a constellation of 12,992 satellites in orbits from 500 to over 1000 km and inclined 30° to 85°. Analysts suggest the Chinese initiatives will focus on integration of LEO with terrestrial cellular technology. There have been satellite tests with 5G cellular and China may seek to be a global leader in future 6G technology.
Links:
https://spacenews.com/china-is-developing-plans-for-a-13000-satellite-communications-megaconstellation/
https://spacenews.com/china-establishes-company-to-build-satellite-broadband-megaconstellation/
https://www.lightreading.com/satellite/us-years-ahead-in-leo-broadband-but-6g-battle-looms/d/d-id/773758

INMARSAT's planned Project ORCHESTRA is a hybrid comprising GEO and LEO satellite networks integrating with terrestrial 5G networks. Technology verification is reported to be progressing for terrestrial 5G integration with LEO. The LEO constellation size may be on the order of 150 to 175 satellites. Launch is unlikely before 2026. Target markets will be Inmarsat's current customer base of maritime operators, airlines and governments. Inmarsat recently agreed to a purchase offer by Viasat (November 2021), a well-established GEO satellite network operator with

a global footprint. This is seen as a potentially synergistic combination of satellite incumbents.
Links:
https://www.bloomberg.com/news/articles/2021-07-29/inmarsat-challenges-musk-and-oneweb-with-new-satellite-network
https://telecoms.com/512674/inmarsat-celebrates-moving-into-the-leo-space/
https://spacenews.com/viasat-buying-inmarsat-in-7-3-billion-deal/

INTELSAT was formed in 1964 as an inter-goverment consortium to provide international satellite services. In 2001, the company was privatized and 2013 went public with an initial public offering to reduce debt. In 2020, the company filed for bankruptcy protection as the FCC reassigned the legacy C-band satellite spectrum used by Intelsat to be auctioned for 5G cellular mobile networks. The company is expected to restructure and emerge from bankruptcy in 2022 with plans to develop a hybrid satellite and terrestrial 5G “unified” global network. Initial plans include a fleet of 10 satellites that are software defined for in-orbit reconfiguration.
Links:
https://www.lightreading.com/satellite/funding-its-constellation-telesat-does-dual-ipos/d/d-id/773485
https://telecoms.com/512691/intelsat-gets-the-ok-for-restructure-after-bankruptcy-filing/
https://www.lightreading.com/satellite/intelsat-kymeta-show-off-sat-5g-in-moving-car/d/d-id/773449?itc=lrnewsletter_lrdaily&utm_source=lrnewsletter_lrdaily&utm_medium=email&utm_campaign=11122021
https://spacenews.com/intelsat-gets-bankruptcy-court-approval-to-exit-chapter-11-in-early-2022/
https://spacenews.com/betting-on-flexibility-intelsats-post-bankruptcy-growth-strategy/

BOEING aspirations were advanced in November 2021 when the FCC approved Boeing’s plan for 147 satellites operating in the V-band and Ka-band. The constellation will consist of 132 satellites at 1,056 km and 15 at altitudes between 27,355 and 44,221 km (note that the geostationary arc is at about 36,000 km). In theory, the program schedule can be deduced from the license conditions that half the constellation must launch by November 2027 and the balance by 2030; however, Boeing has requested a slower rollout. The initial target market will be the US market for broadband internet and communications services to residential consumers, government and professional users, with later expansion to global coverage. Note that plans have scaled back from the original application in 2017 which cited a 1,396 to 2,956 satellite constellation.
Links:
https://www.lightreading.com/satellite/boeing-satellite-broadband-nears-fcc-approval/d/d-id/772697
https://spacenews.com/boeings-leo-constellation-hinges-on-v-bands-viability/
https://www.seattlebusinessmag.com/technology/boeing-back-race-build-space-based-internet
https://telecoms.com/512044/fcc-allows-boeing-to-get-into-the-broadband-satellite-game/
https://www.datacenterdynamics.com/en/news/fcc-approves-boeing-leo-satellite-constellation/

WHAT NOW?

Clearly, there is no lack of interest and enthusiasm. The prognosis for something good to happen in underserved areas is favorable. What can go wrong? Nothing if price points find viable markets. However, each LEO hopeful will not be alone in the internet service delivery market. Each LEO will potentially compete with other LEOs. How many LEO networks can the market support? While this is playing out, terrestrial fiber and broadband cellular radio networks will continue to expand into the most attractive of the underserved areas. Our second LEO review took a customer viewpoint and compared Starlink beta pricing with typical fiber to the home (FTTH) cost and pricing; the conclusion: FTTH will have a life-cycle cost advantage for many relatively small communities. Other LEO competitors include high altitude platform stations (HAPS) that operate in the stratosphere up to an altitude of some 20 km. Although the Google/Alphabet project Loon failed to establish a sustainable commercial service and other ventures eventually backed away, the HAPS space continues to attract investment. In short, unless a disruptive price-performance point can be reached, the addressable market for satellite will shrink over time.

A potentially more important development is the integration of satellite, HAPS and unmanned aerial vehicle (UAV or drone) with terrestrial cellular mobile radio base stations. As noted above, Inmarsat, Intelsat, China and others are moving in this direction. There are hooks in the 5G cellular standards for satellite integration. The advantage of this integration is that each type of traffic can by carried over the set of networks with the best price performance match. For example, carry video streaming for entertainment and other delay tolerant content delivery broadcast traffic on GEO satellites, and carry delay sensitive traffic such as conferencing, telephony and gaming on lower-level networks. Research directions and early work by global standards bodies, including ITU and 3GPP, signal that next generation 6G will feature deeper standards-based integration of GEO, MEO, LEO, HAPS, UAV and terrestrial cellular base station networks. The tricky part for the HAPS and UAV networks where components must stay aloft in the atmosphere will be solving the high maintenance problem. If not solved, high maintenance networks will be relegated to temporary and emergency communication services.

In any event, the integration of terrestrial networks with multi-layered hierarchical non-terrestrial networks may be a differentiating and driving characteristic for 6G. This could improve the "late-to-market" LEO satellite players chances of carving out market share from the first-to-market leaders.

HAPS links
https://www.itu.int/en/mediacentre/backgrounders/Pages/High-altitude-platform-systems.aspx
https://www.satellitetoday.com/opinion/2021/05/27/are-haps-a-viable-way-to-provide-telecom-infrastructure-to-underserved-regions/
https://www.hapsmobile.com/en/haps-alliance/
https://www.lightreading.com/5g/stratosphere-emerging-as-next-big-internet-battleground/d/d-id/772813#:~:text=Amid%20a%20dramatic%20rise%20in,all%20those%20airborne%20Web%20surfers.

Issued 2022-01-03 by D. Sharp, Planetworks Consulting Corp. (TN211017r0)