Technology Trends

Low-Earth Orbit Satellite Systems

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Business Brief

Low-Earth Orbit (LEO) is a category which applies to a piece of electronic equipment that revolves around the Earth at lower altitudes, generally between 200 and 2,000 kilometers (km) above the Earth's surface, as opposed to objects in geosynchronous high orbit, generally 35,786 km above the Earth. For comparison, the International Space Station (ISS) is a LEO object which revolves approximately 400 km above the Earth's surface.

Objects in high geosynchronous orbit, such as satellites, match the Earth's rotation and appear stationary, although they may drift north or south.[1] Whereas LEO objects move at extremely high speeds and are not fixed in space in relation to the Earth.[2] Geosynchronous satellites orbit in time with the Earth's rotation at about 3.06 x 103 meters per second, whereas an LEO-satellite might travel at 7.78 x 103 meters per second, revolving around the Earth many times a day. An object in LEO is closer to the Earth which causes the object to orbit faster due to the Earth's gravity. The ISS revolves around the Earth at 28,000 km/hr, completing one revolution around the Earth in 90 minutes for a total of 16 Earth revolutions per day, covering multiple regions of the Earth at different times.[3]

However, LEO objects tend to be satellites, and are used mainly for data communication such as email, video conferencing and paging. LEO-satellites are also used for military reconnaissance, spying, and other imaging applications.[4] Additionally, LEO-based telecommunication systems can provide sparsely populated territories and underdeveloped countries with the ability to acquire satellite telephone service in areas where it otherwise would be too costly or even impossible to put up telecommunication towers or lay land lines.[5]

In 1998, the first LOE satellite systems started providing services. The LEO technology allows users to make and receive telephone calls from anywhere in the world through a single, small, hand-held transmitter. Unlike the traditional geostationary (GEO) satellites which remain at a fixed point higher above the Earth, the LEO systems provide global coverage by employing multiple satellites which orbit the earth at a relatively low altitude. Most of the man-made objects orbiting Earth today are in LEO.

Technical Brief

Technically, a LEO satellite requires the lowest amount of energy for placement since it is closer to earth than high orbit satellites. In order to maintain a LEO, a satellite must have a sufficient orbital velocity, generally 7.8 km/second. They will remain in orbit until they run out of fuel. The last bit of fuel is actually being used to slow them down. That way they will fall out of orbit and burn up in the atmosphere[6]. NOAA, NASA and other US and international organizations are keeping track of all the satellites in space. When a satellite is launched, it is placed into a specific orbit to avoid collisions with others. However, collisions are inevitable, sometimes a satellite will fall out this orbit and potentially collide with another one.

As LEO is much closer to the Earth, the LEO-satellite provide better signal strength and high bandwidth since the signal travels less distance and therefore can reach its intended receiver much faster as well. It also eliminates the communication latency since the signal has least propagation delay comparing to the signal emitted from other orbits due to the closeness of LEO to the earth. With the lower latency, it can be used for real time critical applications. By being close to the earth, LEO-satellite are also used for earth observation and spying.

On the other hand, because the LEO has less distance from the surface of the earth, the communication of LEO satellites covers less area or region of the earth. In order to cover all of the area of the earth, a group of satellites, called a satellite constellation, is required to provide continuous coverage and some kind of redundancy at the same time. Generally where one satellite falls out of range, another one will be able to pick up the signal and continue sending it down the chain of satellites until the receiver is within range. In addition, the ability to send signals from satellite to satellite is much quicker since each satellite is very close to its neighbours, allowing for a smooth transition and less latency.

Industry Use

The global space marketplace has evolved and grown over the past decade. From a valuation of $176 billion in 2006, the global space marketplace has expanded to an estimate exceeding $345 billion in 2018. Perhaps the clearest illustration of the expanding interests of the private sector in space endeavors is the growth in venture capital investments over the past 2 decades. Consider that from 2000 through 2014, space start-ups received a total of $1.1 billion in venture capital investments, or roughly $73 million per year. In 2015 alone, more than $1.8 billion in venture capital investments were made. In 2016, more than 100 investors contributed $2.8 billion into 43 space-related start-up companies in 49 deals, with an average deal size of $57.1 million. In 2017, more than 120 investors contributed $3.9 billion into commercial space companies—an investment increase of nearly 40% within one year[7].

With the advantage of high bandwidth and low latency, a LEO satellite can be used for telecommunication, such as telephone and data. The Iridium satellite constellation is an example of communication satellite system which orbits in a LEO. This satellite system is of 66 active communication satellites and spares around the Earth. It allows worldwide voice and data communications using handheld devices. The Iridium network is unique in that it covers the whole earth, including poles, oceans and airways. The satellites are frequently visible in the night sky as short-lived bright flashes, known as Iridium flares.

Companies like Oneweb and SpaceX are currently deploying a large amount of satellites that will eventually form Mega constellations to provide internet access on all parts of the globe.

However, many companies have plans to launch their own fleets of these satellites so proper examinations will soon be readily available. Theoretically speaking, LEO satellites are supposed to improve upon the technology offered by the geostationary satellites without replacing them. They are simply supposed to offer additional abilities to the communications services with both types of satellites working together. Eventually, they could have plans for a few companies to move completely to LEO satellites but the complexity of managing an entire fleet at all times makes this idea unappealing for most.

With the global coverage, there is now the possibility for a truly global "information superhighway" provided by LEO satellites. The possible applications of LEO technology present the potential benefits to the international community or developing countries, such as, Instant Infrastructure for Developing Countries, Improved Education and Health Care Promotion of Political Globalization Control of Global Health Problems Emergency Communications

Canadian Government Use

In Budget 2019, the Federal government has announced $1.7 billion CAD of funding for the Connect to Innovate program as well as for the creation of the new Universal Broadband Fund. Part of the Universal Broadband Fund will be directed towards securing low-latency LEO satellite capacity for broadband internet.[8] The aim of this initiative is to offer universal access to affordable, reliable, and high speed broadband connectivity to Canadians, no matter where they are located, and allow them to access the internet.

In July of 2019, the Government of Canada partnered with Telesat for the development of a LEO satellite constellation that will provide high-speed internet connectivity across Canada, with a focus on rural and remote communities in the North. The GC has pledged $85 million CAD in funding through the Strategic Innovation Fund for Telesat to develop and test its planned LEO constellation.[9] There is also a proposed contribution on the part of the GC of up to $600 million CAD to Telesat over a 10 year period to support the company's deployment efforts. [10] The constellation will be stationed at an approximate altitude of 1000km and nearly 120 satellites will be included in the constellation. [11]

The Canadian Space Agency (CSA) has upgraded its earth monitoring capabilities with the launch of the RADARSAT Constellation: a trio of satellites at an altitude of 600km that take images of the earth and they equipped with radar and ship detection technology to monitor Canada's coasts.[12] The main uses for the constellation include monitoring the environment, oceans, ice conditions in northern communities, and supporting emergency response teams during natural disasters.

LEO satellites have been used by GC for Voice and Data Services, Geolocation Tracking Services, Short-burst Data and Iridium Router-based Data Services through Iridium satellite constellation providers. With Iridium satellites, Parks Canada rangers and fire wardens use Iridium satellite phones and pagers to report possible emergency situations, such as fires. Environment and Climate Change Canada have buoys equipped with Iridium transceivers, which are used to transmit surface current, sea-surface temperatures and provide GPS positioning, among other information, of the buoys at sea. The Department of National Defence uses the Iridium systems tracking and messaging equipment and services to track and send messages to their personnel for operations[13].

Implications for Shared Services Canada (SSC)

Value Proposition

At present, Shared Services Canada (SSC) already uses LEO satellite systems from Iriduim, Inmarsat, MSAT, and Globalstar[14] to deliver satellite-based voice, fax, data and geolocation services that can be accessed from anywhere in the world. In 2017, SSC awarded three Iridium Satellite Services contracts totalling $13.2M to MetOcean Telematics and Track24 Canada for them to continue the Government of Canada's provision of satellite services.[15]

The growth being seen in the LEO satellite market can be leveraged to complement the services that SSC already offers. As a service provider for the Government of Canada, SSC's satellite team will be able to offer high-speed internet access at a lower cost to other departments that have operations in rural and remote communities. Additionally, the partnerships with satellite communication companies that SSC has already solidified could bring along with it some valued aid in delivering services.

Being closer to the earth has an obvious benefit for many types of earth observational satellites by resolving smaller subjects with greater detail.

LEO-satellites made for communications benefit from the lower signal propagation delay. This lower propagation delay results in less data transmission latency.[16] Due to their lower orbit, LEO-satellites are generally less costly to place as they require a great deal less rocket power to place. As compared to geosynchronous satellites at 36,000 km, LEO-satellites travel through a much denser atmosphere and thus experience far more aerodynamic drag. This means they require more power to travel at higher speeds and make corrections to maintain their lower orbits.[17]

Challenges

By launching more satellites in orbit the Government of Canada (GC), and by extension SSC, will be contributing to the issue of space debris. Over the years as more and more objects are launched into space, the accumulated deactivated satellites and "junk" from tests are now dangerous hazards that risk damaging active infrastructure.

The European Space Agency estimates that nearly 166 million objects that range in size from less than 1mm to the size of a refrigerator are orbiting around the Earth at average speeds of 10km/second or 36,000 km/hour.[18] Any of these objects can cause considerable damage if they were to ever hit active satellites or even the International Space Station, and these impacts can even lead to the creation of more debris.

A theorized situation called the "Kessler Syndrome", hypothesizes that a chain reaction of exploding space debris could create a deadly barrier around the earth that will prevent future space endeavours.[19] The NASA scientist Donald J. Kessler (after whom the effect was named) has warned that continued launches into LEO could create a dense environment above the planet where there is an increased likelihood of objects crashing into each other and creating an exponential amount of space debris.

The planned launch of around 120 satellites for the Telesat constellation, as well as all of the proposed 12,000 satellites for SpaceX's Starlink constellation, and OneWeb's 648 satellite constellation, will add considerably more objects to the LEO. The project listed here are not an exhaustive list, and other companies have expressed interest in launching their own constellations. The increase of satellite traffic creates new and unique challenges where no regulatory frameworks have previously been put in place. At present, when an organization seeks approval to launch satellites, they communicate with regulatory bodies from their own countries[20].

The U.S. Federal Communications Commission (FCC) has been licensing LEO constellations like OneWeb and Starlink, but this begs the question: does the FFC, a national entity, or any other national organization have the authority to grant access to an international resource? The International Telecommunications Union (UTI), a United Nations organization, allocates the use of radio frequencies and orbital positions in the geostationary satellite orbit, but not yet in low earth orbit.[21] There have been talks about expanding their mandate to include it, but the UTI doesn't yet have that authority.

At present, no international body monitors space debris. This task is currently carried out by the U.S. Air Force's 18th Space Squadron who operates the Space Surveillance Network (SSN), can track objects larger than a softball in LEO and can predict close approaches, re-entries, and the probability of collisions.[22] The SSN notifies organizations via email[23] if satellites are on collision paths, but this system is in the process of being automated but current satellites do not have automatic collision detection capabilities. There are currently no space traffic laws or proper communication protocols for when satellites are on a clear collision course. In 2019, a recently deployed Starlink satellite was on a highly probable collision path with a satellite from the European Space Agency (ESA). Although both organizations were aware of the issue, only the ESA took steps to avoid the collision and changed their satellite's trajectory. This near miss could have been avoided, had Starlink responded to the emergency and coordinated with the ESA.[24]

Low earth orbit satellites are close enough to the earth to be affected by atmospheric drag which means they will eventually crash down unless their courses are changed. Current disposal plans for LEO satellites simply involve them re-entering the atmosphere and being burned upon re-entry.[25] Although this is an industry standard, satellites don't always get burned up completely and crash into the surface of the earth. Point Nemo, a remote uninhabited section of the Pacific Ocean has been designated as a "spacecraft cemetery" and large satellites are directed to crash into that area upon re-entry.[26] However, it is difficult to predict where pieces will actually fall, as fragments get broken off of large spacecraft throughout the re-entry process and land in unintended areas. Even with this designated area, there are no regulatory frameworks to enforce re-entry targets and to protect inhabited areas from falling debris.

Current satellite disposal standards indicate that satellites should be de-orbited 25 years after their end of life date.[27] This presents a regulatory gap, as more satellites are placed into LEO than are falling back down. Proposals have been put forward for space sustainability pitching the idea of "one up, one down". Where for every satellite launched, an inactive one is taken out of orbit. Experiments[28] are being carried out in orbit to test various debris capture and disposal methods, and there is also the possibility of old satellites being recycled for parts in space. However no formal standards are in place.

Concerns have been put forward by the astronomy and star gazing communities that the increased number of satellites in space will alter the view of the night's sky. As they pass across the sky, a satellite's solar panels can reflect the light from the sun back to the earth and create a visible streak.[29] With the increase in satellites, astronomers will need to adjust captured images to eliminate reflected light streaks. Additionally, there have been no studies made yet on the impact of thousands of unnatural light sources on nocturnal life. Satellites will also be operating close to frequencies used by radio astronomers who monitor far away celestial objects, and this can interfere with their operations.[30]

Considerations

As mentioned above, the GC and Canada's people have much to gain from LEO-satellite systems. SSC in particular already has experience offering satellite services and is well positioned to handle the new services that can be offered with satellite technology. Many of its partnered departments would benefit from accessing the added strength of LEO satellites from the current system in place. There are many of these other departments that require fast internet speeds but have not yet acquired such promises due to the lack of the current technologies' abilities.

SSC will also need to consider the future

Most LEO-satellite system operations will need skills both in maintaining and managing the LEO-satellite service. Some skills may have to be leveraged from third parties to fill the gaps in SSC expertise. SSC should consider the talent it requires to continue offering LEO-satellite system services, as well as integrating and aligning new LEO-satellite service offerings with current legacy equipment, newer network and infrastructure, and the greater SSC corporate strategies.

SSC should also ensure that future infrastructure strategy include policy and operational instruction or direction on LEO-satellite infrastructure operations. Different operational requirements from partner departments will drive different

LEO-satellite system offerings and storage requirements. SSC will need to have a plan in place to manage the future infrastructure and network needs if partner departments pursue greater LEO-satellite system operations.

SSC and the GC need to carefully consider all of the challenges. The concerns of sustainability, pollution, regulation, and international relations will need to be delicately balanced before Canada should move forward with large investment in the LEO market.

SSC should consider evaluating the current Service Catalogue in order to determine where LEO-satellite can be further leveraged to improve efficiency, reduce costs, and improve services in the Service Catalogue. Additionally, determining how LEO-satellite systems will continue to integrate into existing services on a consistent basis. Any new procurement of devices or platforms should have high market value and can be on-boarded easily onto the current SSC satellite policy and operations. SSC should continue LEO-satellite based services in pilots and push forward on offering services in test clusters and scale the success. With all new cloud-based technologies being added to SSC's capabilities, focus should first be on a narrow set of objectives and building success.

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