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Digital Transformation Monitor

# Low-Earth Orbit satellites: Spectrum access

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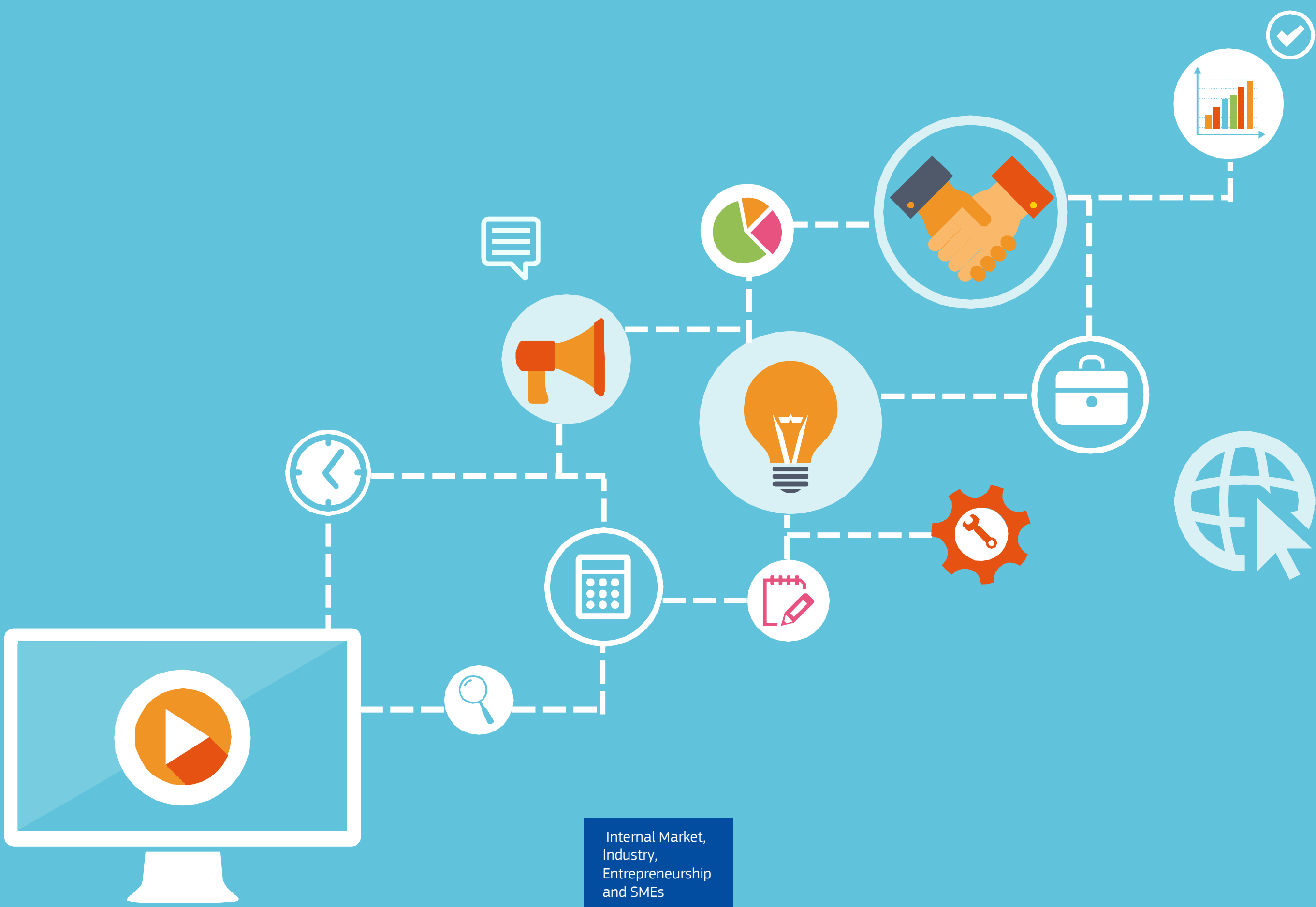

Internal Market, Industry, Entrepreneurship and SMEs

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# Low-Earth Orbit satellites: Spectrum access

*Traditionally, geo stationary satellites located at more than 36,000 km above the earth have been used to provide satellite communication to a wide area. An alternative approach however, once unsuccessfully tried in the past is now surfacing again. The idea is to use considerably massive constellation of satellites at lower altitudes to both densify the network and reduce latency. Although technically feasible, those numerous projects come with challenges and access to spectrum is one of them. At stake, the possibility to provide enough capacity at the right price points to serve markets that remain up to now unserved.*

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## Why are Low Earth Orbit game changers?

Because of their high position above the earth, satellites are very effective in providing wide coverage. Indeed when one cellular antenna on earth covers only a few square km, one satellite, depending on its elevation covers thousands of square km.

This explains why, when terrestrial infrastructures have not been deployed, satellite is usually seen as a better economic and practical solution to bring coverage to areas that would otherwise be left completely unserved.

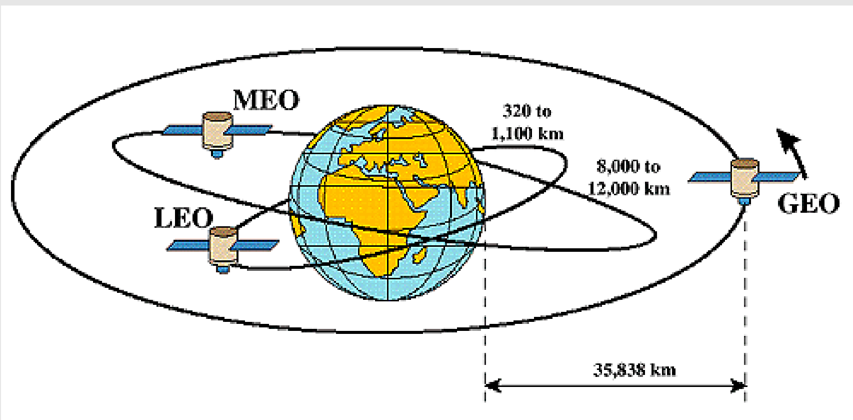
The cost of such solution however remains important in the absolute and solutions are regularly looked after tomake this solution more and more affordable

### Already tried in the past but more prone to succeed today

In the 1990's, several players came with the idea of launching a multitude of satellites in low Earth orbit (LEO) with the aim of providing communication services at low cost.

Instead of using only a few high orbit satellites, especially geostationary orbits where satellites have fixed positions relative to the Earth (at an elevation of around 36,000 km), the idea was to place smaller and lighter satellites orbiting at lower altitude (in the range of 180 km to 2,000 km) and thus drastically reduce the cost of the solution because of satellite less expensive to manufacture and launch. This however came with challenges, both technical and financial.

**Figure 1: Presentation of LEO, MEO and GEO orbits**




*Source: Communication satellites by William Stalling (2001) (1)*

Above all, mobile terrestrial communication systems were about to be launched all over the world and all of a sudden what was supposed to be a revolutionary service was turned into a more expensive and technically less interesting offer than the then exploding GSM. In the end, few low Earth orbit constellations were launched and at the beginning of 2000, most LEO projects had been dropped or had gone bankrupt, only to be purchased by investors at a fraction of the initial cost.

After that, it became pretty clear in the industry that the geostationary satellite, with its wide-coverage capacities and its more recent high throughput system capabilities were the solution to providing communication services in a world with demand increasing by the day for broadband speeds anytime, anywhere.

Fundamentally however the very concept of LEO communication satellites was not dead. While the economic interest of providing voice and narrowband coverage from a low elevation satellite position was not demonstrated, the idea of using LEO position to provide broadband access surfaced few years ago with several announcements from yet unknown players at that time. Technological progress had been made and the market prospect also had changed. If one satellite with a very broad coverage makes sense for narrowband usage, is it powerful enough to provide broadband capacity for a market that is still largely not served?

## LEO: Densifying the network to bring increased capacity and reduced latency

### Reduced coverage as compared to GEO…

The elevation that characterizes LEO has a direct impact on coverage. At an elevation of 36,000 km, coverage from a satellite is 2.7 wider than it is at 1000km above the surface of the Earth. When three satellites are required to cover the Earth on GEO, at least 15 are required to cover the whole Earth on LEO. Since satellites at this elevation are moving, many more are required to provide constant coverage.

### … But reduced latency and increased capacity

But the lower elevation of LEO satellite constellation also has benefits. Indeed, since satellites are closer to the Earth than GEO satellites, the trip time between the ground and the satellite and the satellite and the ground is significantly reduced and so is the latency, which is one of the caveats of GEO satellites in general. Latency is critical for real time applications, of which VoIP notably.

Typical latency of GEO vs LEO:

**280 vs 20 ms** (2)

Similarly, with a densified network, capacity is much more increased because of more important frequency reuse capacity. By adding more satellites in the constellations, capacity and as a result throughput per user can be easily added at a marginal cost.

## Who makes what? Which players, which markets?

### Several new entrants not linked to traditional satellite players

17,000 satellites for more than 150 Tbps

Among the more than 15 LEO projects that have surfaced in the last 3 years, a number of new players is vying to launch new constellation projects focusing on a market where high capacity and high throughputs are required.

The three most publicized projects in this regard are OneWeb, LeoSat and SpaceX initiatives. The latter has received much press because of its CEO Elon Musk, also funder of Tesla, who envisions sending people to Mars. SpaceX is also known for the development of a launcher, whose 1st stage can be reused (3).

This capability is aimed at further reducing the cost of launching satellite to space. The fact that these projects have been the most talked about does not however necessarily mean that they are the most likely to succeed, except maybe for OneWeb, whose status is already well advanced with 1.7 billion USD of funding already secured.

Globally, the full completion of all the LEO projects would result, approximately, in more than 17,000 satellites in various LEOs providing a total aggregated capacity of more than150 Tbps. The main question that is raised here is whether there are enough places on the market for all those players.Most probably, only a few players will succeed in launching their constellation.

### Backhauling, consumer and enterprise broadband as main markets

Given their characteristic, LEO are particularly relevant for use cases where large capacity is required. Not surprisingly, most ambitious projects in their size focus on broadband applications, something that can be served with different approaches:

- Through mobile backhauling: in areas where terrestrial backhauling is too costly to deploy.
- Fixed Broadband access for B2C in remote/unserved/underserved areas including in emerging markets.
- Broadband for high mobility applications (trains, planes, boats).
- Dedicated governmental, scientific and enterprise connectivity.

### M2M and imaging targeted by other players

While broadband focused projects have gotten much of the highlight, M2M, asset tracking and imaging are also targeted by other kind of players.

The only three LEO projects of the 2000s to have survived after bankruptcy (Iridium, Orbcomm and Globalstar) have already launched a second generation of satellite to replace the first one. They, still focus on M2M and relatively narrowband applications (voice, messaging). Those projects thus require less satellite. Iridium NEXT for instance will have 66 operational satellites.

As for imaging, this market has been invested by new players, often start-ups leveraging very low cost micro satellites. Planet is one of them. It aims at photographing the earth every day and thus take quasi real time imagery. Those updates will be critical for cartography and will pave the way for new innovative applications based on low cost earth observation.

**Figure 2: Main broadband-focused LEO constellations**

| Project | Estimated cost | Backers | No. of satellites | Total estimated capacity (Gbps) | Status |
|---|---|---|---|---|---|
| **LeoSat** | 3.5 billion USD | JSAT, TAS (as a satellite provider) | 100 | 1 000 | Fund raising, prototype to be launched in 2019 |
| **OneWeb (World VU)** | 3.5 billion USD for the initial 640 satellites (incl. Gateways) | SoftBank: 1 billion USD + 700 million USD from previous backers of which Intelsat, Qualcomm and Airbus Defence System | 2 862 | 20 000 | Satellite manufacturing started<br>1st 10 satellite to be launched in 2018 |
| **SpaceX** | A potential total cost of 10-15 billion USD according to observers | 1 billion USD investment from Google and Fidelity | 11 518 | 103 662 | Unknown, in regulatory difficulty with the FCC |
| **Telesat** | N/A | N/A | 117 | *936* | ITU rights secured<br>1st two prototype satellite to be launched in 2017 |
| **Boeing** | N/A | Unknown support. Reportedly a big US Internet company is ready to support the project | 2 956 | *26 604* | Unknown |
| **COMMStellation (MSCI)** | N/A | N/A | 84 | 739 | Unknown |
| **Xinwei** | N/A | N/A | 30 | *90* | Unknown |

*Source: IDATE*

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# How will LEO constellations fare with competition

## Which impact of LEO constellation projects on the satellite industry?

Because most ambitious LEO projects in figures are carried out by new players (i.e. not traditional GEO operators), LEO is often seen as a potential disruption in the industry together with the technologies it involves. With their capability to drastically reduce the cost to deliver 1 Gbps, LEO could indeed further increase a price competition that is already installed in some markets and is causing financial difficulties even to biggest satellite operators on the market (Intelsat, Eutelsat, SES…)

If we look at estimated CapEx to deliver a Gbps, we indeed see a sizeable difference between OneWeb for instance and a traditional GEO satellite operator. When OneWeb would invest 260,000 USD to provide 1 Gbps, it takes between 2 and 9 million USD for a traditional GEO satellite operator.

The race toward cheaper satellite connectivity is however not over. GEO connectivity price has already well decreased in the last years with the development of HTS satellites and several innovations will enable GEO carriers to reduce cost even more. A GEO satellite such as ViaSat-3 due to be launched in 2019 should thus provide a 1 Tbps capacity. With 3 satellites required to cover the earth, the cost to produce a 1 Gbps capacity could be well below the 1million USD price point.

**Figure 5: Market potential compared, by technology in low-density areas**

| | Terrestrial | High –altitude platform | LEO | MEO | GEO |
|---|---|---|---|---|---|
| Latency | ++++ | +++ | ++ | + | - |
| Coverage | - - | - | + | ++ | +++ |
| Capacity | ++ | + | +++ | ++ | ++ |
| Mobility | - | - | + | ++ | ++ |
| Most suited for | **Cellular mobile broadband** (relying on microwave or satellite backhaul) | **Short/ mid-term backhauling** and fixed/mobile broadband | **Backhauling for real time applications + very high speed broadband** | **IoT + backhauling** | **Broadcasting** (content / software/ Base stations caching / IoT) + **basic broadband coverage** |

*Source: IDATE*

As another comparison point, Eutelsat expect to lower its CapEx required to provide 1 Gbps to this same 1 million USD threshold in the mid term (4).

**Figure 4: OneWeb vs ViaSat 3**

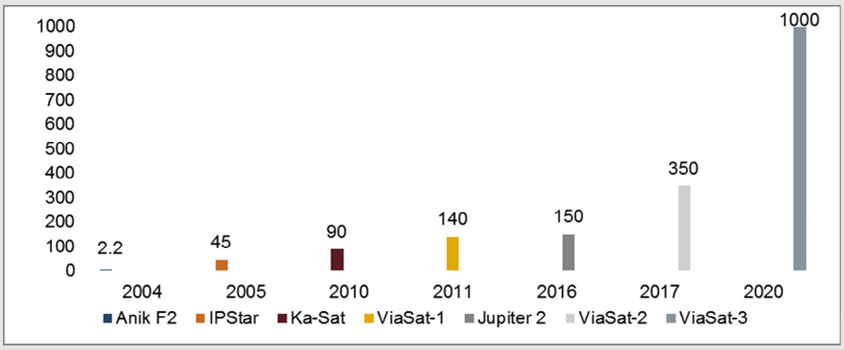
| | OneWeb | Viasat 3 |
|---|---|---|
| **Weight (kg)** | 150 | 6400 |
| **Gbps per sat** | 8.5 | 1000 |
| **Satellite cost ('000 USD)** | 500 | 500 000 |
| **Satellites for 3 Tbps worldwide** | 353 | 3 |
| **Estimated Cost per Gbps (m USD)** | 0.26 | 0.66 |

*Source: IDATE*

However, confrontation between orbits holds true only if LEO, MEO and GEO players remain distinct. It does not now seem to be the case as almost all GEO players are currently involved directly (building) or indirectly (partnership) in LEO / MEO activities. Of the top 5 fixed satellite operator, only Eutelsat has currently no implication in such projects.

In a competitive environment, LEO and MEO are increasingly seen as complementary to GEO and as a way to differentiate from the competition. If LEO seems more adequate to provide high capacity and low latency for most demanding applications, GEO remains the most adapted for broadcast purpose in a context where video still account for the most important part of revenues in the industry.

**Figure 3: Evolution of GEO capacity in Gbps**




*Source: IDATE*

## Is 5G an opportunity or a threat for the satellite industry?

The biggest competition however may not come from the satellite industry but from the further expansion of terrestrial communication itself through 5G. If LEO projects can help decrease the cost of satellite connectivity significantly, it still cannot compete with terrestrial network when fixed infrastructures are already there (backbone and backhaul). This is a threat for the viability of LEO projects.

Using satellite and especially LEO as a backhauling technology will be a way to complement rather than compete with such movement should operator really decide to bridge the connectivity gap. Because 5G will use frequency bands similar to satellites (mmWaves), satellite could also be more tightly integrated into 5G. A 5G device would for instance seamlessly switch to any satellite

connectivity available once connection with terrestrial infrastructure lost. This would enable the persistent coverage goal of 5G. Asset tracking is a good example of service that would benefit from this capability. A plane that would be connected to an Air To Ground 5G networks would similarly benefit from this capability when crossing the oceans.

This kind of complementarity is currently limited. Solutions exist but are often proprietary and costly, hence the requirement for a, cooperation between terrestrial and space sector. This needs to materialize in the standardization space, especially within 3GPP where cellular technologies are defined but also on the regulatory field with the spectrum allocations decided on the international and local level.

For cooperation to be possible or competition to be fair, each player must have a fair access to spectrum depending on its need and the value it bring to the market / society.

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# Spectrum is key to increase throughputs but limited in availability

### The more spectrum, the more capacity and bandwidth

Frequency bands are of course of critical importance for any wireless communication system whether on earth or in the space. This is all the more true as more and more spectrum are required today to increase throughput and capacity. In the past only limited amount of spectrum was required to provide voice or messaging services. With the development of new data intensive usages such as video consumption, access to the cloud, holding a limited amount of spectrum is no longer an option and most players are fighting to get this access.

### Not all frequency bands are equal…

It is important to understand that not all frequency bands have equal characteristics. Therefore frequency bands have different values to players. The position of the band in the spectrum is important but the width of the frequency band is important too. Below are basic principles that need to be understood:

- Lower part of the spectrum favours propagations. It is better for instance for indoor coverage or rural areas for terrestrial players. For satellites it is also better in places where rain falls are important, even though mitigation techniques have been developed
- In turn, higher frequencies are more difficult to exploit but as a result have more bandwidth to use. Satellite players have been historically capable of using higher frequency because more power can be used for transmission and thus compensate for signal degradation,
- Higher frequency bands come with smaller beams. Wider beam are better for broadcast usage while smaller beams are better for capacity.

### Ka band is the preferred band for capacity but its access could prove to be difficult in the future

To facilitate the identification of frequency bands, letters have been assigned to them. The main bands used by satellite players are presented in the following figure, ordered according to their position in the spectrum.

This also corresponds historically to the time when those bands started being mastered and used. Ku band has been used for many years, while Ka band usage, although growing rapidly is much more recent.

Because they provide enough capacity and can be used with smaller antennas but also because satellite operators now have enough experience with them, Ku and above all Ka band are the preferred bands for LEO constellations projects. Ka band is already the preferred band for GEO High Throughput Systems (HTS) with the notable exception of Intelsat who prefers the Ku band because it is less subject to interference created by rain falls.

This means that Ka band is currently much looked after and that using this band will be increasingly complex in the future in order to limit interference. The prospect of 5G networks to use part of this frequency band is a concern for satellite players. In the US, but also in South Korea, it has already been decided that the 28 GHz band, located in the Ka band will be devoted to 5G.

Other bands such as the L, S, C and X band are more common to applications with less important need in throughput such as M2M. It is also commonly used by earth observation LEO projects.

### V bands, the future for next generation Very High Throughput Systems?

In June 2016, Boeing revealed its plan for a LEO constellation made up of 2956 satellites operating at 1200km in the V band. This band is currently quasi unused because of technical difficulties associated with its high position in the spectrum.

However, this band has several merits because of the large amount of bandwidth available. There should not be thus any sharing issue similar to the one experienced in the C and Ka band today, especially for what pertains to the repartition of the usage between terrestrial and satellite players.

Since Boeing announcement, several other projects using this band have surfaced and been filled to the ITU. This interest is not limited to LEO projects but also shared by MEO and GEO players.

In many ways, the V band is today in the same position as the Ka band in the 1990s. It has been identified as promising but propagation characteristics still need to be further studied before commercial equipment can be developed. Those developments could take 10 years, before equipment are available at an economical price point.

**Figure 6: Frequency bands and main areas of use**

| Band | Frequencies (GHz) | Description |
|---|---|---|
| L | 1.518-1.675. | Doesn't require stabilised dish but bandwidth is limited, however. Interesting for M2M and narrowband coms. |
| C | 3.4-7.025 | Widely used for broadcasting and other data transmissions. The size of antenna (4-6 m) required make it unsuited for consumer market services |
| Ku | 10.7-14.5 | Widely used for broadcasting as well as for broadband. It is favoured by Intelsat because it is more immune to rainfalls than Ka band and considered as more secure. Band used by OneWeb |
| Ka | 17.3-30 | Started to be used in the mid 2000s, today the most favoured band for HTS satellites. Preferred band for first generation LEO constellations |
| V | 40-75 | Not used yet but favored for next generation very high capacity satellites including LEO projects |

*Source: IDATE*

# References


(1)Communication satellites by William Stalling

(2) High Throughput Satellite Communications Systems: MEO vs. LEO vs. GEO (http://www.harriscaprock.com/blog/high-throughput-satellite-communications-systems-meo-vs-leo-vs-geo/)

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(4) http://spacenews.com/eutelsat-does-the-math-on-reducing-future-satellite-costs-by-at-least-20-percent/

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The Digital Transformation Monitor aims to foster the knowledge base on the state of play and evolution of digital transformation in Europe. The site provides a monitoring mechanism to examine key trends in digital transformation. It offers a unique insight into statistics and initiatives to support digital transformation, as well as reports on key industrial and technological opportunities, challenges and policy initiatives related to digital transformation.

Web page: https://ec.europa.eu/growth/tools-databases/dem/

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