Market perspectives of Ground Segment as a Service (GSaaS)

Research Paper

Published at the 71th International Astronautical Congress (IAC) – the Cyber Edition 2020 (IAC-20,B6,1,5,x60462)

October 2020

www.pwc.fr/space

Contents

Acronyms

aaS	as a Service
ADS-B	Automatic Dependent Surveillance – Broadcast
AI	Artificial Intelligence
AIS	Automated Identification System
API	Application Programming Interface
AWS	Amazon Web Services
CAPEX	Capital Expenditure
CELP	Colombo-Ecuadorian Lunar Program
CONOPS	Concept of Operations
DoD	Department of Defence
DSA	Deep Space Antenna
EO	Earth Observation
EXA	Ecuadorian Space Agency
FCC	Federal Communications Commission
FPA	Flat Panel Antennas
GAC	Global Affairs Canada
GEO	Geosynchronous
GS	Ground Segment
GSaaS	Ground Segment as a Service
HA	High Availability
IoD	In-orbit Demonstration
IoV	In-orbit Validation
ISP	Innovation, Internet Service Providers
ITU	International Telecommunication Union
KSAT	Kongsberg Satellite Service
LCT	Laser Communication Terminals
LEO	Low-Earth Orbit
LEOP	Launch and Early Orbit Phase
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NRT	Near-Real Time
OPEX	Operational Expenditure
PoC	Proof of Concept
RF	Radio Frequency
RSSSA	Remote Sensing Space Systems Act
SSC	Swedish Space Corporation
TT&C	Telemetry Tracking and Control
UHF	Ultra High Frequency
USAF	US Air Force
USGS	United States Geological Survey
VHF	Very High Frequency
VHR	Very High Resolution
VPC	Virtual Private Cloud

Abstract

The emergence of NewSpace has led to a surge in new satellite operators entering the market. In order to offer the best service to their customers, these operators need to communicate with their satellites, relying on an effective ground segment. The latter requires specific expertise and infrastructure, as well as significant resources – both human and financial. Yet, these new satellite operators do not always have the experience, the capital or the willingness to invest in their own ground segment – risking a financial overkill for their project. Satellite operators are thus looking for a ground segment sold "as a service", to flexibly and efficiently communicate with their satellite without having to invest upfront in a wholly dedicated ground segment or having to deal with licensing issues. However, until recently, there was no specific offer on the market adapted to answer these new needs. This mismatch between supply and demand created a gap in the ground segment market, which gave rise to a new type of offer: Ground Segment as a Service (GSaaS).

GSaaS abstracts ground segment infrastructure similarly to Infrastructure as a Service (IaaS) and cloud computing. Indeed, GSaaS mutualises ground segment infrastructure, relying on a network of ground stations which capacity is shared among different satellite operators. Thus, GSaaS acts as a lever that enables satellite operators to launch their business faster and to focus on their core business, which is, in essence, the provision of data. Acknowledging these advantages, new users, including public entities, have started expressing interest in utilising this service.

The paper provides a comprehensive understanding of GSaaS, its current market and its potential evolution in the future. The paper first aims to present the context in which GSaaS was born. It then provides a definition of GSaaS, together with a state-of-play analysis of the current market, assessing both demand and supply. Finally, the paper offers perspectives on the market evolution. To do so, it explores the market drivers that could impact the GSaaS market in the future and assesses their potential impact.

1 Introduction

1.1 Context and paper description

At the end of 2018, news outlets specialized in space released several articles regarding new business models in the ground segment (GS) industry, especially after AWS announced the creation of AWS Ground Station, offering Ground Station as a Service. However, back then, AWS was not the only actor proposing such a service: companies like Leaf Space or Infostellar had already started to offer Ground Segment as a Service years before, and other GS incumbents like SSC or KSAT had also started to offer similar services.

However, since then, no official definition of Ground Segment as a Service has been given. This paper aims at filling in this gap.

More specifically, this paper attempts to provide an understanding of the context in which Ground Segment as a Service (GSaaS) was born, describe GS activities and satellite operator's pain points (*1.3 Preamble*). The context being set, the document provides a definition of the GSaaS, presents the main benefits of the concept, and explains how GSaaS answers to satellite operators' needs (*2.1 GSaaS Service definition*). This paper also gives an overview of the variety of the current GSaaS users (*2.2 GSaaS demand*) and providers (*2.3 GSaaS supply*), but also lists the main criteria used by satellite operators to select a GSaaS provider (*2.4 Matching supply with demand*) An identification of the main market drivers that could influence the GSaaS market in the future is equally provided in the document. Drivers identified stem from demand (*3.1 Potential evolutions on the demand side*), supply (*3.2 Potential evolutions on the supply side*), but also technology and regulation (*3.3 Technological and regulatory evolutions*). Finally, this paper aims to determine the main barriers to entry in the GSaaS market (*3.5 Evolution of barriers to entry in the GSaaS market*)

1.2 Methodology and caveats

Considering the limited information available, this paper is based on observations and facts collected during desktop research and stakeholder consultation with industry experts listed in Acknowledgements. Also, it shall be underlined that all information available in this paper is based on research performed until Summer 2020 only. Evolutions in the market that happened since then are thus not included in this paper.

1.3 Preamble

1.3.1 Defining Ground Segment activities

When thinking about space, most people first think of satellites or launchers, but very rarely about ground segment. The latter is the *sine qua non* condition to operate satellites and ensure mission success for satellite operators (e.g. provision of EO images, telecommunication and navigation signals, etc.). In order to communicate with satellites, ground stations are necessary. Located in various parts of the world, they support different types of satellites, depending on their inclination and orbit [1]. For example, polar orbiting satellites need to connect with ground stations in the poles (e.g. Inuvik or Kiruna in the North Pole and Punta Arenas or Dongara in the South Pole), which provides rather long duration passes, enabling increased amount of data downloaded. The ground stations are made of one or more antennas, that enable satellite operators to communicate with the satellite, sending telecommands and downlinking telemetries (e.g. mission data, satellite status). This communication is performed all along satellite lifecycle, from Launch and Early Orbit Phase (LEOP), going through commissioning, routine and critical operations, up to satellite end-of-life and decommissioning.

1.3.2 Ground Segment value chain

In order to ensure such operations, a typical GS entails various infrastructure and activities that can be depicted using a value chain (Table 1: Ground Segment value chain), made of three main blocks: upstream, midstream and downstream as depicted below.

Table 1: Ground Segment value chain

Upstream/ Infrastructure	**Midstream/ Operation**	**Downstream/ Data usage**
Ground station development	Ground station operation	Data storage
Data system development	Spacecraft operation	Data pre-processing
Ground networks	Signal downlinking	Services based on data analysis

The three blocks are detailed as the following:

- The upstream involves all the hardware and software components that enable mission operations. It encompasses ground stations (e.g. antennas, modems, radio, etc.) construction and maintenance, development of data systems (for ground station control, spacecraft control, mission planning and scheduling, flight dynamics, etc.), and the ground networks (i.e. infrastructure necessary to ensure connectivity among all operations GS elements),
- The midstream is composed of all activities that support mission operation. More specifically, it encompasses the operation of the ground stations, performs spacecraft and payload Telemetry Tracking and Control (TT&C), and the signal downlinking and data retrieving,
- The downstream encompasses all activities performed once the data is retrieved on Earth, that include data storage, pre-processing (e.g. error corrections, timestamps, etc.), and all services based on data analytics.

1.3.3 The model “as a Service”

“as a Service” (aaS) initially stems from the IT industry, and more specifically from cloud computing. Software as a Service (SaaS) is a well-known example of “aaS” model, where infrastructure and hard, middle and software are handled by cloud service providers and made available to customers over the Internet, on a “pay-as-you-go” basis. “aaS” offers various benefits to the customers, as it helps them minimize upfront investment while avoiding operation, maintenance, and other ownership costs. Customers can thus transform their capital expenditure (CAPEX) into operational expenditure (OPEX). Considering such benefits, “aaS” has recently become widely spread even beyond the IT world, and into the ground segment industry.

1.4 Genesis of Ground Segment as a Service

1.4.1 GS activities require investment and time

In order to perform ground segment activities, significant investment and efforts are required to build and maintain a dedicated ground segment, but also to deal with licensing issues.

On the one hand, building, operating and maintaining a ground segment is an expensive endeavour that requires many resources including ground stations (i.e. antennas, modems, land) and dedicated personnel with specific skills. Building ground stations is particularly costly for high-frequency bands (requiring more expensive antennas) or satellites in Low Earth Orbit (LEO). Indeed, satellite operators having satellites in LEO usually require a global network of ground stations installed in multiple countries, in order to download data when and where they need it without having to wait for the satellite to pass over a desired location. In addition, investments in specific infrastructure (i.e. servers, networks and power) are required to process, store, and ensure transport data. In the end, the cost of ground segment over the entire satellite lifecycle can reach one third of the total cost for large programmes and can represent between 10 and 15% of satellite operators’ OPEX, according to industry experts. Consequently, such important expenses can make it difficult for satellite operators to invest in a wholly dedicated network.

On the other hand, building a dedicated ground segment involves dealing with important regulatory constraints, especially to get licensing for both space and ground segments. Licensing is key to ensure that Radio Frequency (RF) interferences do not negatively impact satellite operators. Indeed, satellite signals can be overridden by a rogue or unlicensed system, which can jeopardize satellite operators’ activities and business. In order to ensure such situation does not happen, licensing procedures are inherently demanding. Satellite operators not only have to deal with licensing of the space segment from the International Telecommunication Union (ITU) – in charge of spectrum assignment – but also to deal with licensing for the ground segment with the country in which they want to build and operate their ground station. Though regulatory frameworks do not vary much from a country to another, some countries sometimes lack transparency and clarity as regards to their rules, which can result in difficult procedures to follow. In addition to these, when missions involve various stakeholders, each of them must hold a license for their respective elements, which adds complexity. Finally, licensing requires to pay fees that vary depending on country, bands used, license type (i.e. commercial or experimental), mission type and duration [2]. Thus, dealing with licensing can be time-consuming, expensive and even sometimes cause delays in business development. The example of KSAT and Planet in Canada between

2017 and 2019 shows how long acquiring licensing can be, especially when unclear licensing process exists, like the one resulting from the Canadian Remote Sensing Space Systems Act (RSSSA) [3].

1.4.2 GS activities have been outsourced for decades

Considering all the efforts required to ensure ground segment activities, satellite operators have already been outsourcing their activities to GS experts for decades.

When satellite operations started in the 1970-80s, satellite operators were mostly large entities (e.g. heritage space agencies, large satellite operators), looking to control their satellites using their own ground stations. However, they quickly realised that, in order to ensure regular connection with their satellites, they needed a global coverage of ground stations. Acknowledging the difficulties mentioned in the section above, satellite operators started to partner with GS service providers like SSC or KSAT as early as in the 1990s with the first shared antennas, and in the 2000s (e.g. SSC created *Prioranet* in 1999).

Over time, these GS service providers have developed large networks of ground stations across the world, including in harsh environments, such as polar areas. These networks enabled them to offer comprehensive services to a wide variety of customers – whatever their satellite inclination, orbit (e.g. polar, LEO, GEO, etc.) or mission type. GS providers could support their customers all along the mission lifetime (e.g. routine, LEOP, decommissioning), providing support not only for TT&C and data acquisition services in various bands, but also for many other services spanning hosting and maintenance services (i.e. install, operate and maintain a ground station on behalf of a satellite operator), licensing support (for space and ground segment), and data handling. GS service providers would thus provide their customers with a "top assurance level" offer. In exchange, satellite operators would agree to commit for various years, and pay relatively high price. Such price would enable GS service providers recoup the newly created ground stations.

This premium offer was specifically designed for large satellite operators with unique and expensive satellite, with complex mission requirements and a need for highly reliable ground segment. However, such an offer quickly proved to be unsuitable for New Space satellite operators that usually had less demanding satellites. Consequently, ground segment services had to be more adapted to these new needs.

2 Ground Segment as a Service today

2.1 GSaaS Service definition

With New Space, the needs of satellite operators evolved: missions were shorter, satellite development time was dramatically reduced, and the budget dedicated to GS was much smaller. The GS services offered by incumbents were thus not adapted, deemed too complicated (notably because of international standards) and costly.

In order to fill in the gap between supply and demand, new GS services providers entered market, with the objective to offer New Space satellite operators a simple, elastic and cost-effective way to communicate with their satellite: GSaaS was born.

Borrowing concepts and methods of IaaS and cloud computing, GSaaS abstracts GS infrastructure. To do so, it mutualises GS infrastructure, relying on a single network of ground stations in order to enable satellite operators communicate with their satellites.

GSaaS is however not the first concept of antenna sharing. Indeed, GS providers incumbents (e.g. SSC, KSAT) were already exploiting "white space" (i.e. spare capacity) of ground stations for decades already, enabling various customers to use the same antenna. Thus, though GSaaS concept entails similar services as incumbents used to provide in the past, GSaaS distinguishes itself offering enhanced flexibility, cost-effectiveness and simplicity:

– **Flexibility**

  GSaaS is a suitable solution for both satellite operators that already have ground stations (looking for complementary solution for punctual support or backup), and the ones that do not (looking for a reliable solution to ensure satellite contact). It offers GS services depending on the satellite operator's needs, providing on-demand but also reserved contacts.

– **Cost-effectiveness**

GSaaS enables satellite operators to switch their CAPEX to OPEX, enabling them not to invest upfront in a wholly dedicated ground segment. Instead, they can choose the paying scheme that suits their needs the best, opting either for “pay as you use” or subscribing on a monthly/annually-basis.

– **Simplicity**

The interface and API are designed to be easy to use, to enable all types of satellite operators (e.g. universities, public and private) control their satellites. The API enables satellite operators to interact with the ground station network, determine their satellite parameters and constraints, retrieve the schedule of operations, as well as all the data collected.

2.2 GSaaS demand

As depicted above, GSaaS was initially developed to answer New Space satellite operators' needs. However, with time, GSaaS users became more diverse, including not only New Space actors but also more established players. GSaaS users can be characterized using various segmentations:

– **Entity type**

As of today, most GSaaS users are civil commercial satellite operators. Undisclosed GSaaS users include for example Spire, Maxar Technologies, Iceye, Astrocast, Myriota, Capella Space, NSLComm or D-orbit. In addition to these companies, public entities have showed interest in using GSaaS as well. For example, KSAT supports the US National Aeronautics and Space Administration (NASA), the US National Oceanic and Atmospheric Administration (NOAA), and the US Geological Survey (USGS) for their ground communications. RBC Signals also signed an MoU with the Ecuadorian Space Agency (EXA) in the frame of the Colombo-Ecuadorian Lunar Program [4]. Defence actors tend to be more protective using their own ground segment, mostly for security and sovereignty reasons. It is however believed that they could also become GSaaS customers in the future. The United States Air Force (USAF) for example signed a contract with RBC Signals [5], and the US Department of Defence (DoD) contracted KSAT for support in satellite communication.

– **Mission type**

When it comes to satellite mission types, most GSaaS users are EO and Internet of Things (IoT) satellite operators. There are also technology satellites such as In orbit Demonstration (IoD) and In orbit Validation (IoV). EO satellites usually need to download as much data as possible and depending on their business, they look for near-real-time images. They however do not necessarily need low latency (i.e. maximum time between satellite data acquisition and reception by the user). For example, Eumetsat EO satellites in LEO have a latency of 30 minutes, which is enough to provide adequate services to their customers. As compared to EO satellite operators, IoT satellite operator’s priority is more about number of contacts, and they look for low latency (down to 15mn for Astrocast for example). They thus tend to select highly reliable GS that ensure satellite connection in a timely manner. Finally, technology satellites are also very interested in using GSaaS as they do not require extensive GS to test and demonstrate the value of their technology. Once technologies and concepts are validated, these satellite operators look to scale up and represent a true market opportunity for GSaaS providers.

– **Ground station ownership**

There are two types of GSaaS customers: the ones that own ground stations, and the ones that do not. The first usually want to use GSaaS to complement their ground station network. They can use it in a punctual manner, to answer to specific events (e.g. LEOP, catastrophes, etc.), as backup ground stations (e.g. in case of a problem on one of their ground stations), or to download more data. This is for example the case of Spire Global Inc. that uses AWS Ground Station to satisfy growing demand by flexibly enlarging their ground network capabilities. The second almost entirely rely on GSaaS to communicate with their satellites. They sometimes partner with various GSaaS providers to guarantee continuity of service (e.g. Astrocast using both KSAT and Leaf Space GSaaS services).

– **Orbits**

The need for GSaaS also depends on the orbit type. Indeed, as compared to GEO satellite operators that usually need few ground stations located in their targeted region to perform their mission, LEO satellite operators look for a global coverage. Indeed, as satellites move around the Earth, they need to be able to connect with ground station in different parts of the world. However, in order to offer lower latencies, more ground stations are necessary, which can be a major hindrance. For this reason, so far, a large majority of GSaaS customers are LEO satellite operators.

2.3 GSaaS supply

In order to answer these new needs, and fill in this market gap, new GS providers came into play and started to offer adapted services to the new needs. The family of GS service suppliers thus got extended, involving a variety of new actors. It now includes new start-ups (e.g. Leaf Space, Infostellar, RBC Signals, Atlas Space Operations, etc.), IT-born companies (e.g. AWS) but also GS incumbents (e.g. SSC, KSAT). Building upon their experience in satellite operation and leveraging their global network of ground stations, GS providers incumbents designed solutions specifically adapted to small satellite operators and large constellations with SSC Infinity and KSATlite for example. To do so, incumbents standardised their ground station equipment and configurations, and developed web-based and API customer interfaces, notably to enable pass scheduling. The main GSaaS providers are mapped in the diagram provided below.

Figure 1: Mapping of main GSaaS providers (as of Summer 2020)

It worth noticing that the above map presents the companies' headquarters, and not their ground station footprint. All these companies indeed have a global network of ground stations, as detailed in the following section.

2.3.1 Differences in ground station ownership and coverage

In order to differentiate the solutions that GSaaS suppliers offer, three aspects can be scrutinised: ownership, coverage and location of ground stations.

– **Ground station ownership**

  A first distinction can be made between GSaaS providers that own their ground stations (e.g. Leaf Space), and the ones that do not (e.g. Infostellar). The latter can be seen as "brokers" that use the white space (i.e. available time for satellite communication) of idle antennas in already existing ground stations. They thus cannot always offer highly reliable or guaranteed contacts, especially if they rely solely on their partners' antennas.

– **Ground station coverage**

  As mentioned earlier in the paper, ground station coverage is key to ensure frequent contacts with satellites and offer recent data. GSaaS providers can also be compared based on their ground station coverage on Earth. Some providers indeed have a large network (e.g. SSC owns and operates more than 40 antennas in its global network and hosts more than 100 customers' antennas) and others have more limited network with fewer ground stations (e.g. Leaf Space has a network of 5 operating ground stations and 3 being installed). Also, brokers usually have large network of ground stations. For example, back in December 2019, RBC Signals network was made of more than 70 antennas located in more than 50 locations [6].

– **Ground station location**

  Looking at the number of antennas is not enough, and the location of the antennas is even more important, as it will determine the capacity of the GSaaS provider to answer a variety of customer needs (i.e. depending on the satellite orbit and inclination). The example of AWS GS decision to change their rollout strategy to adapt their antenna location to their customers' needs is a good example of how choosing the best antenna location is key [7].

2.3.2 Comparison of selected GSaaS suppliers

Beyond these distinctions, GSaaS providers can also be differentiated by their offerings. The table below provides a comparison between various offers as of Summer 2020 and based on available information.

Table 2: Comparison between the GSaaS suppliers

Criteria	Infostellar	Leaf Space	AWS Ground Station	KSATlite
Frequency band coverage	UHF, S, X	VHF, UHF, S, X	Common freq., S, X	UHF, S, X, Ka
Ground station network	Low	Medium	Medium	High
Autonomous scheduling	No	Yes	No	No
Consulting services	Yes	Yes	No	Yes
Dedicated/ shared antennas	Shared only	Both	Shared only	Both

In order to compare these four actors, the following criteria were used, and can be understood as the following:

- Frequency band coverage criteria depends on the satellite application. For example, Ka/Ku band tend to be used for high-speed communication, X band is usually used for uplink and downlink, UHF is ideal for telemetry data, and S-band is ideal for telemetry but is also used for uplink and downlink.
- Ground station network assesses the ground station ownership and the network coverage, as well as its reliability.
- Autonomous scheduling is based on customer constraints and not on booking. With autonomous scheduling, GSaaS providers have the responsibility to schedule contact windows on behalf of their customers, based on their constraints. This enables satellite operators to avoid having to book themselves whenever they wish to contact their satellite.
- Consulting services entail all additional services GSaaS providers can offer, beyond communication services, such as support for ground station development for example.
- Dedicated/shared antennas correspond to the capacity of GSaaS providers to offer their customers with both shared antennas (used by various satellite operator) and dedicated antennas (only used by a single satellite operator).

From one satellite operator to another, all these criteria are more or less valuable, as the following section shows.

2.4 Matching supply with demand

Considering the diversity of suppliers, in order to select the offer that suits their mission requirements the best, customers have various criteria they can use, that are summarised in the table below.

Table 3: Criteria valued by satellite operators to select a GSaaS offer

Types of criteria	Criteria
Pricing	Intensity of GSaaS usage
	Commitment capacity
Ground station performance and service quality	Reliability
	Number of contacts
	Security
	Latency
	Ground station location
Service extensiveness	Autonomous scheduling
	Data storage
	Data processing and analysis
	Support for ground station development
	“one-stop-shop” solution
Others	Geographic preference and sovereignty
	Maturity and longevity

2.4.1 Pricing

One of the most important criteria for satellite operators to select a GSaaS offer is the cost of the service. In order to select the most suitable pricing model that corresponds to their needs, satellite operators can take decision based on two aspects:

- **Intensity of GSaaS usage**

  Pricing can be performed by the minute (correlated to the number of minutes used), by the pass, or on a subscription base (not correlated to the number of minutes/passes to be made). For example, as of Summer 2020, the pricing per minute of AWS Ground Station would vary between 3 and 10 USD for narrowband (<54MHz bandwidth) and between

10 and 22 USD for wideband (>54MHz bandwidth) [8]. In December 2019, RBC Signals equally launched a low-cost offer called “Xpress” enabling X-band downlink, with prices down to 19.95 USD per pass, with a monthly minimum of 595 USD [6]. To choose the most suitable pricing scheme, satellite operators must think about how intensively they will use GSaaS. For example, satellite operators using GSaaS punctually tend to pay per pass or per minute, whereas satellite operators relying entirely on GSaaS and looking for regular and reliable contacts tend to subscribe on a regular basis. In addition, for satellite operators that need to download important amounts of data, the “pay as you use” (i.e. satellite operators pay for each satellite pass) can quickly become very expensive at the end of the month. These operators thus tend to subscribe on a monthly or yearly basis.

– **Commitment capacity**

  GSaaS customers usually have two main ways to pay as they use, either reserving passes, or paying on-demand. Usually, prices go down as the customer commitment level increases, which explains why on-demand pricing is usually higher than reserved minutes. For example, AWS offers discount pricing if satellite operators reserve a minimum of 150 minutes/month during a year, which is not the case for customers using AWS service on-demand [8]. Deciding whether to commit for reserved minutes or access to the service on-demand mostly depends on the capacity for satellite operators to communicate with their satellite using other ground stations. Indeed, if satellite operators have their own ground station network and only use GSaaS solutions in exceptional cases (e.g. environmental disaster requiring more EO images can push EO providers to use GSaaS to download more data), they would tend to opt for on demand access to GSaaS, as can be hard for them to predict the number of minutes they will use the GSaaS service.

2.4.2 Ground station performance and service quality

Another criterion that is key in the selection of a GSaaS provider is the ground station performance, together with the service quality. Both involve criteria like reliability, number of contacts, security of communications and data transfer, latency (i.e. time between the satellite acquires data and the ground station receives this data), and ground station location:

– **Reliability**

  Some GSaaS providers can guarantee their customers with highly reliable satellite communications (e.g. guaranteed passes, high number of contacts, etc.). However, other GSaaS providers that do not own their own ground stations or have a limited network of ground stations have more difficulties to offer such high reliability. Satellite operators expected to use these less reliable GSaaS solutions are notably entities looking to demonstrate their technology.

– **Number of contacts**

  For some applications, such as IoT, satellite operators need to contact their satellite a certain amount of times per day that are uniformly spaced. Such service can usually be reached using dedicated antennas. On the contrary, satellite operators looking for backup ground stations or not having the necessity to communicate regularly with their satellite tend to use shared antennas.

– **Security**

  Security is another criterion that satellite operators can value to select a GSaaS provider. Indeed, some satellite operators, such as defence actors, need to download sensitive and/or valuable data. In order to protect this data, security of satellite communications must be guaranteed by GSaaS providers. To do so, the latter invest in highly secured infrastructure, with end-to-end protection for satellite communications against attacks, especially cyber ones. However, security is not a key criterion for all satellite operators. For example, entities that perform Proof of Concept (PoC) or demonstrators do not see always consider security as a top priority.

– **Latency**

One definition of latency corresponds to the maximum time between satellite needs to send data and the user receives this data. It includes time to wait for a satellite pass over a terminal, to transmit a message between multiple satellites, to get a ground station in view, to download a message and to process a message. Latency is usually key in today's satellite applications as customers want to have the most updated data available as soon as possible. However, latency criterion is highly dependent on the business. As we have seen earlier in the paper, EO satellite operators are not always looking for low latency, as compared to IoT satellite operators.

– **Ground station location**

Depending on the satellite orbital mechanics and on the mission type, satellite operators tend to look for GSaaS with ground stations in specific areas. More specifically, satellite operators with satellites in polar orbits tend to look for GSaaS providers with ground stations in polar poles. Whereas low-inclination or equatorial orbits tend to look for ground stations near Equator. For example, if the ideal ground station location of a satellite operator is Japan, it will tend to look for the GSaaS provider with antennas located there. It worth noticing that GSaaS providers that are brokers can be particularly competitive on this aspect, as they benefit from a wide and extensible network of ground stations, though they do not guarantee contacts. Considering the importance of ground station location in the satellite operator decision to select a GSaaS providers, the latter tend to be very careful to install ground stations where customers want to receive their data, even if the location is sometimes inconvenient (i.e. in harsh environments).

2.4.3 Service extensiveness

An additional criterion that can be valued by satellite operators is the GSaaS offer extensiveness, meaning the capacity of the GSaaS provider to offer a wide range of services. This criterion can be important in the eyes of satellite operators looking for a one-stop-shop solution. Indeed, such end-to-end packages enable satellite operators to gain time and effort, limiting the number of providers while benefiting from high-performant services:

– **Autonomous scheduling**

Autonomous scheduling is based on customer constraints and not on booking. Autonomous scheduling enables the customer to only provide the GSaaS provider with a set of constraints together with an indication of capacity needs in terms of passes per day. It is then the responsibility of the GSaaS provider – using algorithms – to provide a 72h schedule that satisfies both the constraints and the capacity needs. On the contrary, with booking, satellite operators have to indicate time and location for passes, and the GSaaS provider books the passes accordingly (or sometimes the customer directly books the passes autonomously using an API), usually on a "first come, first served" basis. Depending on the GSaaS provider, satellite operators can cancel or reschedule their reserved contacts, up to 15 minutes prior to start for AWS Ground Station for example.

– **Data storage**

Most GSaaS are interoperable with every major cloud infrastructure and data storage using cloud, as they only need connectivity to provide such a service. The main difference between suppliers resides in the speed of data transmission from the ground station to the storage location. Indeed, installing servers directly in the ground station enables to reduce this speed to the maximum. Various GSaaS providers have opted for such solution, such as AWS, that has the advantage of sending the data right from their ground station to their customer's Virtual Private Cloud (VPC). This can be particularly beneficial for satellite operators wishing to process their data directly in their VPC.

– **Data processing and analysis**

Some GSaaS providers have the capability to provide their customers with data processing and analysis services, in order to provide final users with actionable insights. For example, AWS Ground Station provides Capella Space with AWS services to process their data in real-time, within minutes of satellite capture. This enables Capella Space final users in various sectors (e.g. agriculture, defence, etc.) to make data-driven decisions and solve their problems in a timely manner.

- **Support for ground station development**

  GSaaS providers start diversifying their offer providing consulting services. Indeed, building on their internal know-how, some GSaaS providers (e.g. Leaf Space, Infostellar, KSAT, etc.) can assist their customers in building their own ground stations, managing licensing aspects, ground segment concept of operations (CONOPS), simulations and testing, and other technical aspects such as RF systems or digital signal processing.

- "**One-stop-shop" services**

  As some GSaaS provider partner with companies offering services all along the space value chain (e.g. launch service providers, satellite manufacturers, storage service providers, etc.), GSaaS providers can offer end-to-end services to their clients, that can benefit from a "one-stop-shop" service. Companies like Atlas Space Operations or RBC Signals for example partnered with AWS in order to offer data storage solutions to their end customers, promising them reduced latency between the data downlink at the ground station and the data processing.

2.4.4 Other criteria

- **Geographic preference and sovereignty**

  Sovereignty is an important issue when it comes to GS activities. Public and private satellite operators handling sensitive data tend to be reluctant in using foreign private companies' services and ground stations. Indeed, industry experts mention that the regulation in some countries (e.g. USA, UK, Australia) stipulate that data that was received in these countries are a property of their country. Thus, satellite operators that want to ensure their data sovereignty tend to favour GSaaS providers that downlink their data using ground stations located in countries where the risk of the data falling into undesired hands is minimal. GSaaS providers capable of guaranteeing such service could have a competitive advantage.

- **Maturity and longevity**

  The service quality also encompasses the maturity and longevity of the GSaaS provider. Indeed, this can have an impact on the GS service quality provided to the customers in the long term. For some satellite operators, such as Eumetsat, highly reliable satellite communications are needed over time. This is especially true when the missions are very long (i.e. more than 20-year long), as the satellite provider must be sure that the GSaaS provider will survive and/or will not be merged with another company before the mission ends. Satellite operators can thus be relatively sensitive to the capacity of their GSaaS service provider to provide services in the long run, in order not to put their own business/activity at risk.

3 Market perspectives of GSaaS

Studying the current demand, supply and matching between demand and supply in the GSaaS market, it is interesting to wonder how the GSaaS market could evolve in the future. It can be expected that the evolution will depend on a variety of factors, coming from demand and supply sides, but also from other sources (e.g. technologies, regulation, etc.).

3.1 Potential evolutions on the demand side

There are different factors that are expected to have an influence on the evolution of the GSaaS demand in the future, including the interest from new entity types and new satellite applications.

3.1.1 New entity types

So far, GSaaS demand has been pushed by private entities but there is a possibility that other types of entities – especially public ones – show increasing interest in having their satellites operated and their data downlinked by GSaaS providers.

- **Public entities – governments**

  Governments could show more willingness to outsource their ground segment activities. This trend is already observable in the US market, as NASA recently announced its willingness to intensify the outsourcing of their satellite operation to commercial companies to exceed the current 67% of already outsourced operations [9]. Also, we have seen earlier in the paper that GSaaS providers like RBC Signals or KSAT already provide US agencies and departments with ground communications as a service. However, this trend is mostly observable in the US so far. Indeed, US public entities are culturally more prone to outsource their activities to commercial providers, in order to boost their private sector and enhance their competitiveness at the international scale.

Outside the US, institutions have not shown important interest so far. However, stakeholder consultation showed that governments could decide to outsource their ground segment activities, at least for their scientific missions. Indeed, in Japan for example, the public ground stations are shared between different departments, and the scientific department is sometimes left with a very limited amount of ground station. The scientific community could thus be the most interested in using GSaaS offer in Japan. Other non-US space agencies already outsource a part of their satellite operations to private companies.

Another reason that could push public entities to outsource their GS activities to national private actors would be for economic and sovereignty reasons. Indeed, outsourcing their activities to national private actors could help them scale up. This could boost their private sector, while ensuring independent satellite operation.

- **Public entities – military/defence entities**

  Apart from the US, where companies like Atlas Space Operations and RBC Signals already have governmental customers (including USAF), it is unlikely that military customers will use GSaaS solutions. They indeed tend to prefer controlling their satellite operations end-to-end and to be more security-driven than cost-driven. However, military actors already use GS services from some providers as a backup. If GSaaS providers can provide guaranteed security, military customers could possibly use GSaaS solutions as well in the future.

- **Emerging space agencies**

  Emerging space agencies could also become a potential customer of GSaaS. Indeed, as these newly created entities usually have relatively limited budget and have few satellites to operate, they are not expected to invest in a wholly dedicated ground segment. GSaaS could thus act as an enabler for emerging space nations that wish to kickstart their space activities and prefer to concentrate their financial and human resources on space segment or downstream activities.

  However, emerging space agencies could adopt another strategy, deciding to favour capacity building instead of services in order to develop indigenous space capabilities.

3.1.2 New mission types

Satellite operators with new mission types could start to show interest in using GSaaS services, including for lunar and deep space missions, for low-latency applications, for emerging EO constellations or for large Internet Service Providers (ISP) constellations.

- **Lunar and deep space missions**

  GSaaS applications could go beyond Earth orbit, to support deep space missions in further orbits. Indeed, as the deep space is experiencing commercialisation too, with projects like BlueMoon or Beresheet, GSaaS providers could also potentially provide services in deep-space mission operations. However, there are two main challenges that could make this scenario possible. On the one hand, GSaaS providers should have the capabilities to operate these spacecrafts using dedicated infrastructure including hardware and software (e.g. Deep Space Antennas – DSA, software to enable flight dynamics, etc.) that are capital-intensive. Indeed, considering the size and the associated cost of DSA [10], such investment could be profitable only if the number of missions supported is important enough. This challenge could thus deter GSaaS providers from investing in such costly infrastructure. On the other hand, it remains to be seen if space agencies that are today operating themselves these missions will be willing to outsource these activities. NASA already announced it wanted to increase its outsourcing including for lunar missions, and emerging space agencies like the Ecuadorian Space Agency (EXA) showed interest in collaborating with RBC Signals to ensure satellite communication in the frame of the Colombo-Ecuadorian Lunar Program.

- **Large Internet Service Providers (ISP) constellations**

  Constellations aiming to launch a very large number of satellites are surging, especially to provide internet services, such as OneWeb or Starlink. These Internet Service Providers (ISP) constellations have different needs as compared to other applications like EO. They indeed are not looking for additional data or backup solutions using GSaaS. They rather tend to look for High Availability (HA) services, ensuring highest satellite communication using redundancy to offer reliable internet services. In order to answer these different needs from ISP constellation operators, GS service providers like KSAT or GMV have adapted their solutions but are currently not providing GSaaS services.

However, GSaaS could be potentially used for ISP constellations, provided GSaaS providers adapt their service architecture of ISP constellations, ensure the scalability of their operations and processes, and increase the speed (up to 100 Gbps) of their infrastructure for Tier 1 connection at gateways. In addition, enhanced coordination with satellite operators would be needed to ensure efficient handover procedures. Thus, if GSaaS providers succeed in adapting their offer to meet ISP needs, the latter could possibly enlarge GSaaS customer base.

– **Low latency applications**

  If GSaaS providers succeed in offering NRT communications, satellite operators offering services such as Automated Identification System (AIS) or Automatic Dependent Surveillance – Broadcast (ADS-B) that require data that is less than 10 to 15 minute-old could show interest in using GSaaS services, at least as a back-up solution.

3.1.3 Security-driven satellite operators

Security is a key aspect to consider when it comes to GSaaS market evolution. Indeed, ground station terminals constitute an important vulnerability as an access point to a satellite, which is sometimes unprotected by authentication. The software installed on terminals can be compromised and need to be upgraded regularly to prevent attacks of various types, such as signal jamming or spoofing (i.e. to mislead the data transmitted). In addition, with the advent of reprogrammable spacecraft in orbit, operations will have to be even more secured.

3.2 Potential evolutions on the supply side

Factors like the number of partnerships stroke, the longevity of the GSaaS provider, the capacity of GSaaS providers to offer new services, altogether could influence the supply side of the GSaaS market in the future.

3.2.1 Enhanced and new services provided by GSaaS providers

In order to answer the variety of satellite operators' needs, GSaaS providers are expected to enhance their current services, while also expanding their offer to additional services.

On the one hand, GSaaS suppliers are expected to enhance their service quality. For example, they could build larger networks of ground stations to ensure NRT communications and enable low-latency applications to rely on GSaaS. GSaaS providers could also offer more secured satellite communications, building GS networks cyber-secured "by design" to ensure their resilience towards cyber-attacks.

On the other hand, GSaaS providers could offer additional services. For example, as LEOP requires global ground station coverage, satellite operators have been outsourcing this activity to GS experts. GSaaS providers could offer such a service as well in the future, provided they have enough capital to invest in additional ground stations, and enough demand for such a service. Parallelly, decommissioning is another critical phase that GSaaS providers could cover.

3.2.2 Partnerships between GSaaS providers and other companies

In order to offer a more extensive range of services and enhanced service quality – as described in the above section – GSaaS providers are partnering with other companies. More specifically, there are four types of partnerships between GSaaS providers and other companies that can be currently observed.

– **Partnership with companies in other streams of the space value chain**

Various GSaaS providers have partnered with companies in other streams of the space value chain. For example, KSAT and RocketLab partnered together as the latter intends to offer satellite operators with support from mission services with their Photon bus, launch services with the Electron launcher, but also satellite operation services with KSAT [11]. Similarly, Leaf Space and GomSpace partnered in order to enable the latter to offer a solution to its customers looking not only for satellite manufacturing services, but also a solution to communicate with their satellites [12]. Leaf Space also stroke a partnership with Alen Space in order to offer a more complete service to their customers during the satellite operational phase, by providing an integrated solution between Alen Space mission control software and Leaf Space network.

– **Partnerships with experts in specific domains**

Various GSaaS providers collaborate with cloud service providers. For example, Atlas Space Operations [13] and RBC Signals [14] partnered with AWS, in order to provide their satellite operators access to AWS Ground Station's cloud computing infrastructure and associated services (e.g. data processing and distribution). Another partnership that worth noting is the one between Leaf Space and CYSEC, a company specialised in cybersecurity. This type of partnership gives an idea of how GSaaS providers intend to answer the needs of satellite operators that value security (e.g. military, private operators caring about confidentiality and privacy aspects, etc.) in the future.

– **Partnerships between GSaaS providers**

GSaaS providers can partner with other GSaaS providers, in order to enlarge their respective network of ground stations. This is for example the case between RBC Signals and AWS, consisting in adding AWS antennas to RBC Signals network of ground stations [6]. This is specifically beneficial for both partners as their have complimentary locations. AWS indeed has antennas located in mid-latitude, whereas RBC Signals has antennas notably located in poles. Such partnership offers GSaaS users with increased possibilities to communicate with their satellites.

– **Partnerships with local actors to increase local footprint**

In order to easily build ground station in another country or to have a favoured access to the GSaaS market in that country (especially governmental project), partnering with an aerospace company based in this country can help. This is what happened with the partnership between Small Spark space system and Leaf Space in order for them to offer ground station services in the UK.

To conclude, these partnerships between GSaaS providers and other companies are expected to be beneficial for all parties. On the one hand, it will enable GSaaS providers to offer end-to-end services to their customers, while making access to space easier (e.g. reduced complexity, better efficiency, faster launch). On the other hand, most of these partnerships are expected to be win-win. Consequently, these partnerships are expected to boost the GSaaS market, enabling GSaaS providers to extend their footprint on a global scale while enlarging their customer base.

3.3 Technological and regulatory evolutions

There are other factors that are expected to have an influence on the GSaaS market in the future, including aspects regarding regulation and new technologies. These factors are expected to act as enablers, to allow GSaaS suppliers adapt their service offering to the satellite operator's needs.

3.3.1 Evolution of technologies

New technologies are expected to have an influence on the GSaaS market, especially as it could enable GSaaS suppliers adapt their service offering to answer their customer needs. These technologies notably encompass optical communications, Flat Panel Antennas (FPA) or Artificial Intelligence (AI).

3.3.1.1 Optical communications and intersatellite laser links

As compared traditional RF communications, optical communications present various benefits such as substantially higher data rates, increased security in data transmission but also the absence of interferences or the absence of spectrum licensing required. However, optical communications between Earth and space are dependent on weather conditions, as optical beams performance can be negatively affected by atmospheric turbulences.

In order to avoid such challenges while benefiting from all benefits, optical communications are increasingly used for inter-satellite links in space. It consists in having GEO satellites acting as relays, communicating with user satellites with laser links. Such technology provides many benefits:

– Satellites can push the data collected directly to the GEO node, that is constantly connected to the ground. This enables almost constant satellite coverage, even when it is beyond the line of sight. Such system also enables satellite operators to limit the number of ground stations needed,
– Depending on the Laser Communication Terminals (LCT), data rates can be very high (up to 1.8 Gbits/s),
– Inter-satellite links offer capacity to communicate with satellites for a longer period, which is key especially for satellites in LEO that have low and short contact windows.

Intersatellite laser links are currently notably provided by Airbus in the frame of “Space Data Highway”, offering data rates up to 1.8 Gbits/s. However, to benefit from such performance, satellite operators need to carry onboard their satellite an LCT that is relatively heavy, and that must be integrated in the spacecraft design from the start. Consequently, only relatively large satellites (more than 500kg) are currently able to integrate such LCTs in the future. In order to enable small satellites to communicate using laser links, lighter LCTs weighting up to 15kg are being designed, and are currently being tested by SpaceX for their Starlink constellation for example [15]. In parallel of these projects, various initiatives using optical communications have been launched, especially for small satellites. For example, TESAT, KSAT and Gomspace announced in 2019 their partnership in the frame of the PIXL project, to demonstrate the potential of optical communications not only for inter-satellite links but also for satellite downlinks for smallsats [16]. KSAT also started to build their own optical communication network – with already one station in Greece – and look for missions for beta testing. Another example that can be given is the MoU signed between RBC Signals and the Ecuadorian Space Agency (EXA) on an optical communication system for LEO and lunar and deep space programs [4].

Finally, the impact of optical communications could be positive for the GSaaS market, as it would make network operations more efficient and thus possibly more profitable. This is particularly true for applications that require to download big amount of data (e.g. EO), but less true for telecommunication satellites because of the potential link unavailability (due to cloud or rain). However, it should be noticed that inter-satellite links will most probably result in fewer number of ground stations needed on the ground, that will impact GSaaS current way of working. GSaaS providers will thus have to adapt to ensure intersatellite link do not harm their business. Therefore, industry experts believe that communication networks will probably be integrated with operational RF network in the future, in order to ensure continuity of service when optical communications are impossible to perform.

3.3.1.2 Flat Panel Antennas

Flat Panel Antennas (FPA) – also called Phased Array Antennas or Electronically Steered Antennas – are computer-controlled array of antennas, that create a beam of radio waves that can be electronically steered to point in different directions, without having to move the antennas (as compared to classic dish antennas). Thought not new, industry experts consider FPAs are very promising, especially for future mobility applications in maritime or aviation for example. Indeed, their flat design makes them ideal to install on cars or airplanes. FPAs present other benefits such as the absence of mechanical parts that is expected to make configuration and maintenance easier. Also, FPA are expected to make it easier to communicate with various satellites simultaneously, as it could quickly switch from one satellite to another. All these benefits pushed a variety of companies to start developing such antennas, such as Kymeta, Thinkom, Ball Aerospace, Telesat or Phasor. GSaaS providers like KSAT also announced their plan to install an FPA in Svalbard.

However, FPA present various downsides that prevent them from being widely adopted. First, they are currently very expensive as compared to parabolic antennas. Second, the design of the FPA could make it hard to use them in harsh environments, especially polar ones. Indeed, installing such antenna under a dome would require specific domes to be designed and could consequently be costly.

Some experts assert that, if FPA prove they can handle ten simultaneous connections to LEO satellites, their cost will not necessarily be ten times more expensive than a parabolic antenna [17]. They would thus become more competitive as compared to dish antennas. However, the capacity of FPA to generate simultaneous multiple beams remains to be confirmed.

Consequently, some industry experts estimate that FPA capacity will not be heavily used before at least ten years from now. When FPA technology is proven, and their cost is low enough to make them accessible [18], FPA could have a positive impact on the GSaaS market, as they would enable GSaaS providers to track more satellites using less antennas, while reducing their maintenance and operation costs.

3.3.1.3 Artificial Intelligence for data processing

Artificial Intelligence (AI) is expected to be useful for data processing not only in space (i.e. onboard processing) but also on the ground (i.e. for daily operations).

In space, AI would enable data processing onboard, which would enable satellites filter data to only downlink the most exploitable data to Earth (i.e. images not altered by other factors). For example, EO missions providing Very High Resolution (VHR) images currently require important bandwidth to downlink their heavy images. Antennas used for such applications are thus intensively used to download important amount of data that will not be all useful. This results in wasted communication time of the antenna. Using AI in space, images could be filtered directly onboard, which would lead to antenna time optimisation on the ground. Consequently, AI in space could have a positive impact on the GSaaS market, as it would allow providers to use their antenna time in a more optimized way, resulting in increased revenues and potential new clients.

On the ground, AI could also be beneficial. Indeed, as the amount of data downlinked on Earth is increasing importantly, AI could be useful to automatize data handling. Such possibility would unlock new business opportunities for GSaaS providers, that could offer additional services such as data processing and analysis. GSaaS providers could then provide their customers with better end-to-end services going down in the ground segment value chain (see downstream of the Table 1).

3.3.1.4 Evolution in “plug and play” capabilities

Currently, the capacity to effectively “plug and play” ground stations remains to be seen. Indeed, some industry experts currently doubt that a single ground station network is suitable to communicate with satellites having different frequencies or waveforms (i.e. modulation and coding) and such diverse mission requirements. It thus remains to be seen if the GSaaS providers will have the capacity to really enable any satellite to connect with any ground station, using a software enabling true “plug and play”.

3.3.1.5 5G and frequency bands interferences

5G technology is expected to have impacts on the satellite communication in the future. On the one hand, 5G is expected to increase data rates up to 20 Gbits/s, but it is expected to cause major interference for spacecraft already in orbit. This could have negative consequences notably for EO satellites (especially for satellites using the 23.8 GHz band). Interferences could indeed degrade the communication quality, leading to misinterpretations of results and thus resulting in inaccurate weather forecasts [19]. On the other hand, as 5G satellite missions are expected to surge, which could represent potential demand for GSaaS providers.

3.3.2 Evolution of licensing regulation

The capacity for satellite operators to invest in dedicated ground stations will be heavily influenced by the evolution of national regulatory schemes. The latter today can make it hard for satellite operators to predict the date of completion and activation of their ground stations. Furthermore, these delays vary from one country to another, as the licensing frameworks (i.e. procedures, fees, etc.) are not harmonized on a global scale. Such harmonization could make it easier and faster for satellite operators to obtain licenses worldwide, and thus could facilitate the ground station building. Industry experts consider that the Federal Communications Commission (FCC) already attempts to streamline and provide various paths for licensing, which is expected to alleviate various pain points experienced by satellite operators.

However, if the regulatory framework does not evolve to adapt to the increasing satellite activity (i.e. forecasts show increasing satellites operated in the future), ground segment licensing could become an even bigger hurdle for satellite operators that wish to establish their own ground stations. In such a scenario, it is expected that GSaaS providers and GS service providers in general will benefit from this situation having an extended demand. Finally, geopolitical conflicts could also prevent some countries to install ground stations in non-allied countries. In this situation, these satellite operators could decide to use GSaaS solutions to get around this hurdle.

3.4 Summary of drivers influencing the market

Considering all the drivers identified earlier in the section, it is expected that the following factors will have a positive influence on the GSaaS market in the future and will contribute to its growth.

Table 4: Summary of drivers that could positively influence the GSaaS market

Driver types	Main findings
Demand	New entity types could start to use GSaaS, including public entities – governments and defence actors
	New mission types are expected to use GSaaS solutions, such as low latency applications or lunar/deep space missions
	Satellite operators valuing security could start to use GSaaS solutions if increased levels of security are proven
Supply	Partnerships between GSaaS and other companies (either in different streams of the value chain, providing GS services or providing specific expertise) could boost the GSaaS market, as it could enhance service quality or offer end-to-end services
	If GSaaS providers become more mature and prove their longevity capacity, this could attract new customers for whom long-term service provision is key
New technologies	Intersatellite laser link technology could have a positive influence on the GSaaS market if GSaaS providers start to use such technology to provide highly secured and high data rated communications to their customers, and adapt their ground infrastructure accordingly
	Flat Panel Antennas could positively impact the GSaaS market, as it would make ground station operation easier and cheaper, while enabling increased number of satellite communications
	Artificial Intelligence could allow GSaaS providers to optimize their antenna time and offer new services in the downstream of the space value chain (e.g. data processing and analysis)
	If technologies enable true "plug and play" capacity for antennas, GSaaS suppliers would be able to smoothly use the same ground stations for a greater variety of satellite operators
Regulation on licensing	GSaaS providers could leverage on current complex licensing regulation to grow in the future, offering turnkey ground segment services

3.5 Evolution of barriers to entry in the GSaaS market

In addition to the drivers that are expected to influence the market, different elements identified earlier in the paper enable to identify potential barriers to entry to enter the GSaaS market as a supplier.

As we have identified earlier in the report, the main barrier to entry identified is the building, maintenance and operations of ground stations. This is indeed not just a hurdle for satellite operators to operate a dedicated network of ground stations. It is also a hurdle for companies that would like to enter the GSaaS market. It is indeed capital intensive. This is expected to be enhanced by the arrival of new technologies. The important cost of new technologies like FPAs are expected to contribute to high barriers to entry as it will be hard for new entrants in the GSaaS market to enter this market if equipment costs are prohibitive. Thus, GSaaS players mastering these technologies will have a critical differentiator on the market, and companies that do not will most probably have more difficulties to compete.

Another barrier that could be important is one related to licensing regulation. Indeed, as we have also seen, dealing with licensing requires significant time and effort. We expect that current GSaaS providers having already established ground stations in various countries will have less difficulties to expand their network of ground stations. They indeed have experience, knowledge, and also contacts in different countries that altogether makes licensing easier for them. This is especially true for heritage GSaaS providers like SSC or KSAT as they have long experience dealing with such regulatory aspects. New entrants are expected to have more difficulties as they will start from scratch.

The geographical preference can also be seen as a potential barrier to entry. Sovereignty issues may contribute to the conservation of rather high barriers in the GSaaS market, as GSaaS suppliers will have to guarantee the sovereignty of their customers' data. This will mostly affect GSaaS suppliers having ground stations located in countries where data ownership cannot be guaranteed to the satellite operators (e.g. US, UK, Australia, etc.) considering their legislation in this aspect.

Also, security aspects may constitute an important barrier to entry for GSaaS providers that are not capable of ensuring their ground segment resilience towards threats of many types, including cyber threats, they will have less chances of gaining market shares. If current GSaaS providers continue to invest heavily in offering more and more secured systems for satellite communication, the gap to jump for new entrants is expected to be even bigger, making it more complex for them to be competitive on the GSaaS market.

Ultimately, the barriers to entry are expected to remain rather high in the future, but not impossible to overcome if new entrants have investment capacities to build and operate ground stations with new technologies embedded, but also the knowledge to ensure secured satellite communications. It shall be noted that another possibility for GSaaS providers to overcome some of these barriers is to become a broker. In this case, the constraint of having to invest in a network of ground stations is replaced by the need to design a powerful software for contact scheduling and to build a network of GS partners large enough to offer customers with a minimum service level.

4 Conclusion

As the number of satellites is expected to continue growing in the future, especially with constellations, the GSaaS market is also expected to gain momentum. GSaaS is indeed expected to continue making access to space easier, acting as an enabler for satellite operators that want to benefit from performant ground segment while concentrating their resources on their core business. These new customers are expected to stem from different entity types – public and private, but also different mission applications.

To answer these new needs, GSaaS providers are expected to increasingly listen to their customer desires, providing more extensive networks of ground stations located in strategic areas, ensuring enhanced security to customers requiring it, offering more “end-to-end” services for customers looking for “one-stop-shop” solutions, etc.

To offer such services to their customers, GSaaS providers are expected to rely on technical advancements and emerging technologies such as optical communications, Artificial Intelligence or Flat Panel Antennas. These technologies constitute a source of innovation capable to unleash the complete potential of GSaaS providers.

In order to significantly grow in the future and follow an evolution similar to the one that IaaS experienced in the cloud services market, GSaaS providers will need to have significant volumes. However, it is not expected that all satellite operation activities will be entirely outsourced in the future, for not only technical but also cultural reasons.

Finally, it seems realistic to imagine a cohabitation in the future between satellite operators using exclusively their own ground segment, satellite operators preferring to outsource their ground segment activities to GSaaS suppliers, and satellite operators being “hybrid” and relying on both proprietary and outsourced GS. In the end, investing or not in a dedicated ground segment is expected to remain a “make or buy” decision, thoroughly made by satellite operators.

Acknowledgements

We would like to sincerely thank the following people and entities for their participation in the stakeholder consultation. They all contributed to enrich the paper with valuable insights. Thank you to Amazon Web Services Ground Station; Diego Vanelli from Airbus Defence & Space; Federico Belloni from Astrocast; Jean Marc Soula from Centre National d’Etudes Spatiales (CNES); Sean Burns from Eumetsat; Kaz Ishigame from Infostellar; Katherine Monson and Rolf Skatteboe from Kongsberg Satellite Services (KSAT); Jai Dialani and Giovanni Pandolfi from Leaf Space; Aurélie Domargård, John Stuart, and Iraklis Hatziathanasiou from Swedish Space Corporation (SSC); and Baptiste Fournier from Université Paris Saclay – CentraleSupélec.

References

[1] Holli Riebeek, Catalog of Earth Satellite Orbits, NASA Earth Observatory, 4 September 2009, https://earthobservatory.nasa.gov/features/OrbitsCatalog#:~:text=A%20satellite%20that%20orbits%20directly,an%20orbit%20and%20the%20equator

[2] Hywel Curtis, How to secure a license for your space mission ground segment, 30 July 2020, https://blog.satsearch.co/2020-07-30-how-to-secure-a-license-for-your-space-mission-ground-segment

[3] Ram S. Jakhu, Aram Daniel Kerkonian, Independent Review of the Remote Sensing Space Systems Act, 17 February 2017, https://www.international.gc.ca/arms-armes/assets/pdfs/2017_review_of_remote_sensing_space_systems_act.pdf

[4] RBC Signals Press Release, RBC Signals and Ecuadorian Civilian Space Agency announce collaboration for optical communication system, 4 October 2018, http://rbcsignals.com/rbc-signals-and-ecuadorian-civilian-space-agency-exa-announce-collaboration-for-optical-communication-system/

[5] RBC Signals Press Release, RBC Signals announces second SBIR Phase I Award by U.S. Air Force, 10 September 2019, http://rbcsignals.com/rbc-signals-announces-second-sbir-phase-i-award-by-u-s-air-force/

[6] RBC Signals Press Release, Space as a service takes root at RBC Signals, December 4, 2019 http://rbcsignals.com/space-as-a-service-takes-root-at-rbc-signals/

[7] Caleb Henry, AWS completes six ground stations, changes rollout strategy, 4 August 2020 https://spacenews.com/aws-completes-six-ground-stations-changes-rollout-strategy/

[8] AWS Ground Station pricing, https://aws.amazon.com/fr/ground-station/pricing/ (accessed 13 September 2020)

[9] Debra Werner, NASA to hand off spacecraft communications to industry, 24 March 2020, https://spacenews.com/nasa-to-hand-off-spacecraft-communications-to-industry/

[10] William A. Imbriale, Deep Space Communications and Navigation Series, Volume 4, Large Antennas of the Deep Space Network, Chapter 10, The Next-Generation Deep Space Network Chapter 10, https://descanso.jpl.nasa.gov/monograph/series4/Mono4_Ch10.pdf

[11] KSAT Press Release, Rocket Lab partners with KSAT for Electron and Photon ground station support, 22 October 2019 https://www.ksat.no/news/news-archive/2019/rocket-lab-partners-with-kongsberg-satellite-services-for-electron-and-photon-ground-station-support/

[12] GomSpace Press Release, GomSpace and Leaf Space sign MoU to strengthen ground segment collaboration, 17 September 2019 https://gomspace.com/news/gomspace-and-leaf-space-sign-mou-to-strengthe.aspx

[13] Jeff More, Atlas Space Operations Announces Support for AWS Ground Station, 17 July 2019, https://www.businesswire.com/news/home/20190717005620/en/

[14] RBC Signals Press Release, RBC Signals Announces Collaboration with Amazon Web Services (AWS) Ground Station, 10 July 2019, http://rbcsignals.com/rbc-signals-announces-collaboration-with-amazon-web-services-aws-ground-station/

[15] Jeff Hecht, Laser Links will link small satellites to Earth and each other, 24 March 2020, https://www.laserfocusworld.com/lasers-sources/article/14104017/laser-links-will-link-small-satellites-to-earth-and-each-other

[16] GomSpace Press Release, Nanosatellites see the light - laser communication for a new age in space, 4 October 2019, https://gomspace.com/news/nanosatellites-see-the-light-laser-communicat.aspx

[17] Caleb Henry, Lockheed Martin mulls electronically steered antennas for Verge ground station expansion, 8 May 2019, https://spacenews.com/lockheed-martin-mulls-electronically-steered-antennas-for-verge-ground-station-expansion/

[18] Debra Werner, Inexpensive flat-panel antennas will be a “game-changer”, 10 September 2019, https://spacenews.com/wsbw-2019-flat-panel/

[19] Alexandra Witze, Global 5G wireless deal threatens weather forecasts, 22 November 2019, https://www.nature.com/articles/d41586-019-03609-x#:~:text=Water%20vapour%20in%20the%20atmosphere,interpret%20it%20as%20water%20vapour

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