INDUSTRY MANIFESTO FOR A RESILIENT SATELLITE SYSTEM FOR SECURE CONNECTIVITY…

…to Make Europe Fit for the Digital Age

EUROSPACE PRELIMINARY CONTRIBUTION IN SUPPORT OF THE AMBITIONS EXPRESSED BY COMMISSIONER BRETON – OCTOBER 2020

I. INTRODUCTION

Europe has already at its disposal the best satellite-based navigation and positioning system (Galileo) and the most advanced Earth monitoring systems (Copernicus and the EUMETSAT meteorological satellites).

But as far as communication is concerned, Europe (as the other economies) rely on terrestrial networks solutions which will be more and more integrated (5G…) and that are highly susceptible to disruptions and exhibit numerous blank/uncovered/underserved areas. An increased use of communication satellites will improve the resilience, security and capabilities of the overall network infrastructure whilst augmenting its coverage over Europe but also worldwide.

It would therefore be wise that the European Union decides now to increase its autonomy (and control) relating to critical network infrastructures, from the operations and manufacturing point of views, and so respond to the related expectations and worries both of its institutional actors, its economic sectors and its citizens.

Commissioner Thierry Breton, President of the European Commission Ursula von der Leyen and President of the European Council Charles Michel have expressed their political interest for high speed connectivity everywhere, and for a European secure space-based connectivity system.

With this paper, the European space industry would like to collectively express its support to these ambitions and its readiness to contribute achieving these objectives as soon as possible.

An ambitious new strategic satellite system for global connectivity would, in an area where European industrial and design capabilities have already been demonstrated, answer some of the most important policy challenges set out by the European Union, while at the same time having a beneficial effect on the competitiveness of the European space sector as a whole. Most importantly, Europe's legitimate goals in terms of strategic autonomy would be secured.

While the US private actors are focusing on the consumer-end of global LEO connectivity, Russia and China are announcing government-backed LEO deployment plans with a variety of strategic intentions. Furthermore, the US Space Force is also considering a global LEO/MEO/GEO infrastructure with a view of ensuring US dominance in this new segment of space operations.

More generally, the advent of the "digital economy" has an inevitable consequence, already observable in the US (or even in Europe with Copernicus): the ongoing "shift of power" from the data supply side to the processing and distribution of information. This trend benefits the large IT companies which are particularly strong in the US but largely absent in Europe. As they become a key channel to the markets, those owning data management platforms will want to take control of the distribution of critical information. This speaks even further for the necessity in Europe to control the distribution of data, thus making the constellation initiative a key asset in this frame.

The European space industry is proposing an innovative and forward-thinking approach towards a new space-based strategic system for connectivity that would:

- Meet the objectives already laid out by the European Union with regard to:
  - the access to a Govsatcom capability and associated services and to
  - the space component of the EuroQCI Flagship initiative;
- Anticipate emerging and expected institutional needs i.e. secure and resilient mobile communications for both public and private entities (that respects and adheres to European safety and privacy standards) and access to satellite broadband for remote users to bridge the digital divide, while at the same time respond to needs not yet covered by the commercial offer;
- Provide the opportunity to the European telecommunication industry to use this infrastructure to develop a commercial offer.

The goal of this document is to express the support of the European space industry to the initiative, to propose possible ways forward and to use these preliminary ideas to initiate a dialogue with the European Commission, the European member states and, especially, the stakeholders of the telecommunication sector to discuss their involvement and possible ways to team up.

II. WHY DOES EUROPE NEED A NEW CONSTELLATION FOR CONNECTIVITY?

EU KNOWN NEEDS IN TERMS OF SECURE COMMUNICATION

In terms of secure satellite communications, the European space industry is aware of the existing needs of the European Union. The Union has indeed expressed its need for secure satellite communication through the proposed Govsatcom programme and the ongoing work on the Quantum Communication Infrastructure. These projects aim at responding to the Union's objectives in terms of security, autonomy, non-dependence and leadership; in a world where data and information is becoming a key primary resource, and where hybrid threats are growing, the need for secure communications are more essential than ever.

GOVSATCOM/ REGULATED – SECURE COMMUNICATIONS

In 2013, The European Council welcomed the preparation of Govsatcom, in the area of satellite communications, which has also been identified as one of the elements of the Global Strategy for the European Union's Foreign and Security Policy of June 2016. Govsatcom should contribute to the EU response to Hybrid Threats, provide support to the EU Maritime Strategy and to the EU Arctic Policy. As part of the proposed "EU Space Programme" Regulation, the EU foresees Govsatcom to be used to cater for the secure telecommunications needs of three different types of missions: crisis management, surveillance and for key infrastructures.

QUANTUM COMMUNICATION INFRASTRUCTURE

The development of the Quantum Communication Infrastructure has two main objectives[1]:

- First, it will contribute to make government and critical infrastructure communication secure across the European Union.
- In a second stage, the full-fledged quantum communication goes well beyond secure communications. It will prepare the connection of quantum computers and sensors in a full Quantum Information Network.

An entity that will be able to master the quantum communication technologies will be able to communicate in a controlled/concealed way from any other actor. These two objectives and the technology aspect to support them are thus obvious for European sovereignty. It is thus critical for Europe to take the step to make this technology operation in a space system. Such a space component of QCI can be integrated within a new space-based system for connectivity.

EU KNOWN NEEDS IN TERMS OF ACCESS TO BROADBAND

Broadband connections are now the prerequisite for home working, home learning and for new important services. Without broadband connections, it is now barely possible to build or run a business effectively. This is a huge opportunity and the prerequisite for revitalising rural areas. The European space industry is aware that the expansion of 5G, 6G and fibre is a first step to bridge the digital divide. The deployment of these new networks will most likely start by privileging large cities and highly populated areas. It has therefore to be complemented by a new space-based system for ubiquitous connectivity that will allow to bring secure broadband connections in support of all European businesses and citizens, anywhere in Europe.

The European space sector, in this sense, can be a major promoter of Europe's new ambitions to bridge the digital divide. Indeed, satellite networks can bring the latest technology on an accelerated basis to everyone, everywhere, including areas that 3G and 4G have not reached yet. This has been demonstrated during the Covid-19 crisis where satellites were being used to support a range of services including the rapid establishment of direct broadband connectivity to new medical facilities and to support tele-education and teleworking to

[1] Commission Staff Working Document on Quantum Technologies https://ec.europa.eu/digital-single-market/en/news/commission-staff-working-document-quantum-technologies

otherwise disconnected groups at home and elsewhere[2]. The non-discriminatory nature of satellite technology allows these services to be available to all citizens, regardless of country, population density, or economic.

Furthermore, the need for secure broadband communication is also expressed by an increasing number of European businesses and companies, particularly those who are active in strategic and sensitive sectors. This is an issue which was further exacerbated during the pandemic, when European companies had to rely heavily on communication assets and data links belonging to, routed through, or based in non-European countries. This constantly leaves the information exchange and flow between European businesses open to electronic eavesdropping and monitoring by foreign entities, thus constituting a critical strategic weakness as well as increased risk of intellectual property theft.

OTHER EMERGING INSTITUTIONAL NEEDS / POLITICAL AMBITIONS IN THE EUROPEAN UNION REGARDING CONNECTIVITY

Secure communication and access to broadband are the two key objectives that can be supported by the emergence of a new space-based strategic system for connectivity. Other emerging institutional needs exist, which can also benefit from a new space architecture, in particular the very large array of systems that would benefit from the technologies related to the "Internet of Things":

- Satellite-based automatic identification system, for vessel traffic services
- Space ADS-B, a cost-effective surveillance technology for air traffic management
- Space-based STM[3], a new approach to space traffic management – made even more necessary due to the increased number of constellations – could use EGNSS transponders to report a spacecraft's position accurately to space-based receivers onboard on this new constellation, hence offering a real competitive advantage to European space operators.

HOW ARE OTHER SPACE POWERS RESPONDING TO EXPONENTIAL (SECURE) CONNECTIVITY NEEDS?

Until now, geostationary satellites, with their wide-coverage capacities and more recent high throughput system capabilities, were considered as the best solution to providing communication services in a world with increasing demand for broadband access at any time and place.

However, the concept of non-GEO communication satellites was not completely discarded. While the economic interest of providing voice and narrowband coverage from a low altitude satellite position is still difficult to demonstrate in an indisputable way, the idea of using LEO infrastructures to provide broadband access was initially proposed in the mid-nineties[4], and re-surfaced a few years ago fuelled by regained interest of new investors communities (at the forefront of which are the "Big Players of the Web Planet" (GAFA) with deep pockets, and VC-backed new ventures, such as SpaceX or OneWeb).

These new players have been betting on technological progresses to address untapped market demand for global broadband connectivity to back the business plans of their LEO constellation projects. Their progresses have also attracted governmental interest in China, Russia, and the USA, that are now considering strategic applications. Consequently, LEO/MEO constellation projects are currently under development and initial deployment at a very high pace in the US, China and Russia (to a lesser extent). They will offer global connectivity already in 2021.

An indicative list about the main current Broadband/Communication LEO constellations projects is provided in Annex 2.

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[2] https://www.esoa.net/cms-data/positions/2020-07%20ESOA%205G%20Ecosystems%20Whitepaper.pdf

[3] The Earth orbit is experiencing – and will continue to experience – a growing congestion, especially in LEO. The current trend towards more and bigger constellations call for a global Space Traffic Management system and an international regulation. The European industry considers that the European Union has an opportunity to seize to be at the forefront of the discussions on the topic of Space Traffic Management. By being proactive, the European Union will allow the European space sector to use agreed rules and procedures at its advantage, especially regarding Europe's strategic autonomy and its direct links to standardisation touching upon Europe's industrial strategy.

[4] Notably with the Teledesic project backed by Microsoft chairman Bill Gates.

In tomorrow's digital world, Europe is facing a huge threat in terms of independence, security and industrial downgrading if absent of such similar initiatives.

SOCIETAL AND ECONOMICAL BENEFITS

1	To interconnect people to people, people to things, things to things, in Europe	100% coverage Internet, end-to-end European controlled inside Europe, interoperable with non-European systems
2	To fit for the digital age	Advanced communications, optronics, Artificial Intelligence, Quantum science, autonomous mobility, Internet of Things
3	To boost an economy that works for people	Relocalisation in Europe of space downstream applications markets, unlocking access to services, tackling tax abuse and tax evasion (by re-localisation of datacentres in Europe, or in space for that matter), employment (downstream European applications developments and exploitation) …
4	To combat digital divide	Enhance knowledge sharing, regional and international cooperation, access to science and technology and innovation
5	To strengthen Europe's role in the world	Tackling extraterritoriality (sovereign data remain in a sovereign environment), International cooperation and development (reversing competition with China and USA, offering European services to third countries), civil protection, export of services
6	To ensure secured information	Autonomous data management and exchange, protection of fundamental freedom, conscious and non-altered decision-making (not filtered or altered data from USA, Russia or China), sovereignty, resilience
7	To combat climate change	Earth monitoring, education and awareness, transparency, institutional capacity for implementation, limitation of transport…
8	To protect natural resources	Natural resources monitoring and sustainable use on land and water, natural heritage protection… (extended exchange of data and IoT can highly contribute to environmental monitoring)
10	To improve security and to mitigate disasters	Protection of critical infrastructures, disasters resilience and mitigation, police and security-related missions, borders protection…

A CONTRIBUTION TO EU SPACE POLICY OBJECTIVES

A new European secure space-based connectivity system will help to achieve several of the EU policy objectives, especially some of the EU Space Programme Regulation:

- It will help the Union to remain a leading international player with freedom of action in the space domain, and will support the competitiveness and innovation capacity of space sector industries within the Union
- In particular, it will:
  - Initiate the further integration of the European space sector into the larger digital sector;
  - Increase the visibility of the European industry on the export market (promote the European space industry and telecom industry as key players worldwide on constellations);
  - Explore new innovative procurement approaches with the EU;
  - Contribute to Europe non-dependence (in access to space but also, one can expect, in operating in space).

THE CONSTELLATION AS A CATALYZER OF "ENTREPRENEURIAL SPACE"

A lot is going on around the world with the bubbling of bold initiatives from private actors, some of them being new-comers in the sector. It is today too early to assess how many will ultimately prove to be successful, both technically and financially. However, all claim – and to some extent demonstrate – that relaxation of constraints inherent to public procurement allows them to dramatically increase effectiveness in the development phase, and to radically optimise recurring and operational costs. This trend, supporting what can be called "entrepreneurial space", means that the implementation of operational programmes, even institutional ones, is left to the Industry with a greater degree of freedom, while the customer commits to long-term use of services. These evolutions are still struggling to fully materialise in Europe, both because of a lack of resources in the public demand and, very probably, because of a certain level of conservatism in public procurements. The current constellation initiative would represent a perfect opportunity for the European space sector to explore such an approach.

SPACE AND THE ICT SECTOR: A NEW HOPE

The hybridisation between space and the ICT sector also implies increased participation of the stakeholders involved in the ICT sector, which is itself confronted to major disruptions – in particular the globalisation and acceleration of the development cycles of new products and services. Moreover, the institutions in charge of regulating and supporting the ICT sector, at least in Europe, have always had difficulties in structuring their relation with the space sector, because of their completely different and much smaller markets, particular standards, quality management methods and the perception that it represents very expensive investments at least in the "business to consumer" context.

Now, we believe that this new constellation initiative, combined with the emergence of new standards and the expected emergence of the "Internet of Things" and of "Machine to Machine" communications, might make the situation rapidly evolve. This constellation would indeed provide a major opportunity for satellites to become integral parts of the future generation of communications networks and services. Furthermore, the traditional "competition" between terrestrial networks and space could decrease as the density of the objects to be connected will not necessarily superimpose itself onto the density of the population.

The next urgent step for the European space sector is now to establish the contact and partner with the telecommunications and satcom operators aiming at proposing a "trans-sectoral" approach to the Commission.

THE SUPPORT TO AN AUTONOMOUS, RELIABLE AND COST-EFFECTIVE ACCESS TO SPACE

The development and implementation of such European connectivity system would also greatly contribute to ensure Europe's autonomous access to space in the coming years.

Preserving and supporting an independent access to space is one of EU's Space Policy strategic objectives and a key pillar of Europe's sovereignty in space. One of the main leverages of the EU and other European public stakeholders to support and achieve this objective is to create a large enough and sustainable institutional market for launch services in Europe, allowing European-developed launchers to optimise their production and operational costs and further improve their competitiveness both on the institutional and commercial markets.

The European Commission being already the first institutional customer of Arianespace (sole operator of the future European launchers Ariane 6 and Vega-C), its support to the development of a sovereign connectivity system would further consolidate the role of the EU as a strong and sustainable anchor customer. The launch services required to deploy such system could also contribute to the EU objective of aggregation of the European institutional demand, in line with the provisions of the Article 5 of the draft Space Regulation.

The potential size and scale of such European multi-orbital connectivity programme, which could encompass a constellation of satellites in Low Earth Orbit, would have a critical and profound positive impact on the European launchers' exploitation models. This would decrease the exploitation costs and directly benefit both the European institutional launch-services customers and the institutional partners of the programme, as well as the European manufacturing industry and the whole supply chain in Europe. The scale and requirements of such project is also an opportunity to consolidate the development of innovative technologies, which would benefit the deployment of the European connectivity system while constituting the building blocks of the next generation of European launchers.

III. KEY ASPECTS OF THE EUROPEAN SPACE INDUSTRY APPROACH

GENERAL TECHNICAL SOLUTION

The considerations on a services approach drives the definition of technical solutions and architecture concepts. Whilst the objective of this paper is not to provide a detailed architecture approach, the aim is to support high level explanations for a first level indicative budget.

ARCHITECTURE CONCEPT & KEY TECHNOLOGIES

To meet the requirements for security and resilience when designing a European satellite connectivity system, a number of trade-offs have to be performed considering parameters such as geographical coverage, autonomy, performances requirements (such as data rates, signal sensitivity, etc.), latency, resilience, as well as availability and network topology or resources allocation flexibility. Most of these aspects are being addressed in the study launched by the European Commission ("GOVSATCOM and EuroQCI: building blocks towards a secure space connectivity system"). In parallel, ESA has recently initiated two parallel studies with the aim of sketching a first vision of European satcom secure infrastructure as well as two parallel studies on Quantum Key Distribution.

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The European space industry provides below a first assessment of the sizing of such European satcom secure infrastructure, leveraging on a world class heritage in that domain for Non-Geostationary satellite Orbiting (NGSO) systems (Galileo, OneWeb, Iridium Next, Globalstar, O3b) and Geostationary satellite Orbit (GEO) satellite systems ones (EDRS, MilSatComs, etc.).

To achieve European coverage, including Arctic regions, the system will include a Low Earth Orbiting (LEO) satellite constellation. The satellites to be part of this LEO constellation, possibly based on a mix of polar and inclined planes to take into account potential area of services, will embark a fully processed payload with inter-satellite link to guarantee autonomy of access from EU territory to any point in the world, supporting broadband services and IoT services. It is also envisioned that a number of these satellites will embark payloads to address different IoT or Quantum Key Distribution missions.

A few dozens of mixed heavy and small launchers will be necessary to deploy this constellation in orbit. Complementing this LEO satellite constellation, GEO satellites would also be used with the capability to host payload associated with institutional missions. A dedicated ground infrastructure will be deployed to manage the system securely, as well as to allow its interconnection with terrestrial networks. Some specific efforts and a good cooperation with terrestrial telecommunication networks operators will be needed, for instance on the user terminals; this aspect will definitely be assessed further.

Some specific areas have been identified where further efforts will be needed to increase industry expertise with the objective to implement this new initiative while reducing the technical risks to a minimum:

- 5G satellite system design (broadband, M2M) and associated technologies and solutions, where the European satellite industry has played a global leading role in promoting successfully satellite components and associated features in the 3GPP global telecom arena thanks to the support of EC R&D grants;
- New European launchers Ariane 6 and Vega C with an increased capacity to perform complex missions and to accommodate multiple satellites, allowing the European launch service provider to offer perfectly adapted solutions to deploy and maintain (replenishment) such space infrastructure;
- Cyber security solutions to further enhance access to satellite networks and the associated availability;
- Artificial Intelligence, to optimise the use of such satellite networks, and contributing as well to cyber security;
- Cloud computing, as contributor to the ground infrastructure to this European infrastructure;
- Optical Laser communication (Inter-Satellite Links, Feeder links between satellite and anchor stations) for very high data rate communication;
- Digital on-Board Processors for routing, secure payload technologies;

- Quantum communication technologies, for the specifics of the Space QCI component of the Euro QCI initiative;
- Further develop the capability to make efficient serial production of satellites including the most modern techniques and technology in the field of MAIT (manufacturing, assembly, integration and testing), which the US and China have already implemented (or are preparing to).

NON-LINEAR DEVELOPMENT PHASE:

The satellites of the constellation cannot all be manufactured or assembled at the same time. It can result in a need to accommodate different versions of the satellites as upgrades are developed and implemented during the construction process (i.e. associated multiplicity and fast evolution of requirements, which makes it difficult for suppliers to adapt their product policy, their R&D effort whilst maintaining an adequate level of profitability).

Procurement issues between manufacturers and operators can appear (i.e. corresponding difficulty of public organisations in defining their strategic roadmaps): it is understood that constellation satellites renewal occurs in a 3 to 5-year period. With such a short lifetime compared to the multi-year process of deploying a constellation, there can be an almost continuous process of redesign, development, assembly and deployment.

DAILY MANAGEMENT OF THE CONSTELLATION:

A constellation consisting of hundreds or thousands of satellites need advanced control and monitoring systems as satellites need to work together as a single system. Highly automated solutions to manage this number of systems should be considered.

The need for the constellation to function as a system also extends to ground systems and software.

FREQUENCIES

Any ambitious space programme cannot be launched if it is not duly supported by International frequency rights registered with the International Telecommunications Union (ITU[5]) in Geneva. In November 2019, ITU adopted new guidelines[6] regarding constellations. Under the newly adopted regulatory approach these systems will be required to deploy 10 per cent of their constellations within two years from the end of the current period for bringing into use, 50 per cent within five years, and complete the deployment within seven years.

The EU Member States regulators have a leading role in the international regulatory arena and are at the forefront of the world negotiations for the evolutions of the ITU Radio Regulation in order to accommodate the ever-growing need for wireless communications systems spectrum allocations.

Many Low Earth Orbit constellation projects for broadband and narrowband connectivity are starting up and the Geostationary orbit are extremely crowded in many bands used by satellite players. This is especially the case with the frequency band that are dedicated to broadband connectivity applications where the Ku band has been used for many years, while Ka band usage, although growing rapidly is much more recent. Because these frequency bands provide enough capacity and can be used with smaller antennas, Ku and Ka band are the preferred bands for LEO constellations projects. Any undertaking that wishes to establish a LEO satellite constellation should ensure that the spectrum they choose to use does not interfere neither with any existing GEO satellites, nor with other satellite constellation nor with terrestrial networks. There is a formal process in filing an application to get this approval with the ITU and the national administration, which include an in-orbit validation between the filing recording and the final operational space infrastructure, this requires an anticipation several years in advance.

[5] *The United Nations specialized agency for information and communication technologies, which notably aims at allocating global radio spectrum and satellite orbits*

[6] https://www.itu.int/en/mediacentre/Pages/2019-PR23.aspx

GENERAL APPROACH REGARDING BUSINESS MODEL

The European Commission with the support of MS could structure the initiative as a Public Private Partnership (PPP). Each PPP is unique and is structured to address specific projects. The priority is to define EU objectives in order to define the optimal risk and responsibilities allocation, and align the PPP structure with these high-level requirements. The "business model" and the possible distribution of risks between PPP stakeholders is intentionally left very open, first as this issue will be addressed in the study launched by the Commission, but also, as Industry does not want to prejudge about the financial and political choices of the Commission.

SYNERGIES BETWEEN PUBLIC & COMMERCIAL SERVICES

The overall objective of the initiative is to provide the EU, its Member States and citizens a European space-based infrastructure capable of serving their connectivity needs.

The baseline infrastructure should allow addressing EU government-related services for safety and security, regulated services and critical services.

In addition, the European satcom secure infrastructure should also be able to contribute (with terrestrial and GEO satellite solutions) in providing affordable, secure and quality broadband connectivity to all citizens and businesses in Europe in full respect of EU regulations (and among them, the one on data protection in particular).

The project's business model consists in combining these public (government-related) and commercial services, addressing all critical connectivity needs in the EU from various public and private end users, in order to achieve a critical mass of capacity requirements and leverage synergies in terms of design, procurement and operation of the infrastructure.

The European space industry is aware that synergies with the private telecom operators will have to be commonly discussed and harmonised. Indeed, it is a priority of the European space industry to avoid a duplication of services or that would be antagonistic with each other. This would endanger both the private telecom operators and the space industry by unnecessary competition.

A PUBLIC PRIVATE PARTNERSHIP SET BY THE EUROPEAN COMMISSION

The European Secure Connectivity System Initiative is viewed as being based on two main constituents:

- A "sovereign & autonomous" missions pillar, that will secure connectivity meeting the needs of governmental and institutional customers, connecting key infrastructures, contributing to crisis management, providing surveillance data. This infrastructure will also integrate the Govsatcom Hub and interface with the EuroQCI system infrastructure.

- A "Broadband connectivity" missions pillar, that will contribute to Europe 2020's strategic ambition by providing fast broadband connectivity for all European citizens and enterprises by 2022, and will also interface / integrate with 5G mobile networks.

The "sovereign & autonomous" missions pillar will secure regulated communications. The resilient and secure services would be provided on a worldwide basis by a Low Earth Orbit (LEO) satellites constellation. The infrastructure (including the space segment and the corresponding control and network operation segment) would be funded, owned and operated by the European Commission. The user segment would be procured by institutional customers (Member States, EU agencies…). Available capacity not used for the benefit of European institutional users could be provided as a commercial service by private European operators (on a competition basis), under control of the Commission.

The "Broadband connectivity" mass market missions would contribute meeting the EU objective in bridging the Digital Divide in particular in areas where no other infrastructures are available. This would require a dedicated action at European level to enhance the integration of satellites solutions in the global connectivity mix. The role of the EU institutions is key to achieve such an ambition. As a complement to "traditional" MEO/GEO satellite capacities, lower latency LEO satellite capabilities (enabling IoT applications, autonomous driving etc.) can piggy back on the LEO constellation in the form of "hosted payloads" financed by private operators, which take on the demand risk and receive payments directly either from the final users or from distributers of the capacity.

PROGRAMMATIC APPROACH

Should one assume initial contacts to be engaged by Q1 2021 to finalise by beginning of 2022 the consolidation of the requirements and definition of the system, the details of the development roadmap of the system, as the well as the identification of the associated enabling technologies, a first operational capability of the European Satellite Connectivity Infrastructure could be delivered in orbit not later than 2025. The full operational capability should then be expected by 2028. The initial operational capability could address for instance the Artic coverage, including the technological QKD demonstrator for SpaceQCI. Upon exploitation of the results of the technological QKD demonstrator, the operational SpaceQCI will be introduced during the full deployment of the European Secure Connectivity operational Infrastructure. The level of integration between the SpaceQCI and the Broadband Secure capability remains to be defined in order to optimise the schedule and the associated budgets, whilst taking into account different initial maturity level.

It is expected that the European Union will be responsible of the procurement and operations of this new Infrastructure, as well as granting "concession" to private operators. To ensure the development of a consistent European market, the system requirements, specifications, R&D efforts and associated certification effort would be led at EU level.

ANNEX I: A BRIEF HISTORY OF LEO CONSTELLATIONS

According to statistics, almost 4.57 billion people are today active internet users, encompassing 59% of the global population.[7]

Businesses, citizens and public administrations are demanding better and more efficient connections. To meet the growing number of Internet users and their demands, increasingly efficient communication technologies are being developed and implemented.

Although little known to the general public, satellite Internet has been available since the 1990s. It has remained marginal in the face of the arrival of much more powerful technologies such as 4G/5G or fibre optics.

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 considerable numbers of satellites, operating in constellation at much lower altitudes to both densify the network and reduce latency.

In the 1990s/2000s, several players (i.e. Globalstar, Iridium, Odyssey, Orbcomm, Skybridge and Teledesic) came with the idea of launching a multitude of satellites in low Earth orbit (LEO):

- The aim was to provide communication services at low cost.
  - More precisely, 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)
  - The low altitude positioning would then significantly lessen the requirements for power and general transmission capacities, and would drastically reduce the cost of individual satellites. Launch costs would be lower as well. The downside was related to the need to launch a sufficient number of satellites to ensure complete coverage of the areas to be served.

In the end, few LEO constellations were launched and at the beginning of 2000, most LEO projects had been discontinued before deployment or had gone bankrupt after deployment, only to be purchased by investors at a fraction of the initial cost.

One reason for the failed market success of these projects was their inability to compete technically and economically with mobile terrestrial communication systems that developed fast all over the world. Only three LEO projects of the 1990s have respawned after bankruptcy (Iridium, Orbcomm and Globalstar), they have refocused their business models and have already launched a second generation of satellite to replace the first ones.

Eventually, geostationary satellites, with their wide-coverage capacities and more recent high throughput system capabilities remained the best alternative to ground solutions for data communication services in a world with increasing demand for broadband everywhere.

However, the concept of LEO communication satellites was not completely discarded. 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 re-surfaced a few years ago fuelled by regained interest of new investors communities (at the forefront of which are the "Big Players of the Web Planet" (GAFA) with deep pockets, and VC-backed new ventures, such as SpaceX or OneWeb). These new players have been betting on technological progresses to address untapped market demand for global broadband connectivity to back the business plans of their LEO constellation projects. They will offer global connectivity already in 2021.

In this environment, the European space industry has been a pioneer in the domain of private constellations, for instance:

[7] https://www.statista.com/statistics/617136/digital-population-worldwide/

- SkyBridge LLC, which at the beginning of the 1990s was a 64-satellite-constellation promoted by the Alcatel Group together with Loral, extending the reach of ADSL networks. This network was aimed at being operated in the Ku band frequency band (11/14 GHz) as well as in Ka band introducing for the first time the concept of frequency sharing with geostationary-satellites, whilst offering protection to these networks. The International Radio Regulations have been modified thanks to this initiative, and all sub-sequent initiative have been benefiting since then of this regulatory framework.
- O3b is a twenty-satellite constellation designed for telecommunications and data backhaul from remote locations.
  - The satellites were constructed by Thales Alenia Space in the Cannes and Rome facilities
- Iridium Next is the new generation of satellites designed to upgrade the first Iridium constellation (telephony and low data rate in LEO).
  - Iridium Next and its 81 satellites have also been developed, manufactured and successfully delivered in orbit by Thales Alenia Space.
- One of the most important space upstream start-up worldwide is Oneweb, a company having strong ties with Europe, that has leveraged 3,4 billion $ in capital, is partner with Airbus Defence and Space and Arianespace and has established manufacturing operations via a JV with Airbus Defence and Space in Florida.
  - Oneweb employed directly 500 to 1000 workers, and supported probably as many via its procurement chain, including a few European equipment suppliers.
  - The aim was to build 600 satellites to provide high-speed internet to isolated regions.
  - ➔ However, in the midst of the Covid-19 crisis, the company has announced its bankruptcy and the sales of its share because it was unable to attract significant investments to continue its activities (i.e. OneWeb being since then bought out by the British Government and Bharti Global Group).

But, the recent financial failures of OneWeb and LeoSat confirm the fragility of disruptive projects and questions the capability of these Newspace companies to establish themselves as sustainable space actors in the long-term. They are a warning of the difficulty to put in place such ambitious constellations systems without deep knowledge and appropriate financial backing. Indeed, while the promise for revenues is significant, huge capital expenditure is necessary before a hypothetic return on investment.

ANNEX II: SHORT OVERVIEW OF CURRENT BROADBAND/COMMUNICATION LEO CONSTELLATIONS PROJECTS

Amazon Kuiper (USA – Private – Broadband – 3236 satellites – 10B$) *In development*

In April 2019, Amazon, founded by Jeff Bezos, who also founded the launch company Blue Origin, announced the development of a 3 236 satellites' constellation, under the name Project Kuiper. Amazon's focus with the Kuiper System is to connect "tens of millions of unserved and underserved consumers and businesses in the United States and around the globe". It will especially target Transportation systems and Consumer demand.

Boeing V-Band (USA – Private – Broadband - 2956 satellites): *In development*

Boeing's broadband-satellite constellation seeks "to provide broadband Internet and communications services to residential consumers, governmental, and professional users across the USA". The objective is to provide very high speed, low latency internet connectivity for user terminals via the system's network access gateways and associated terrestrial fibre network.

Globalstar 2 (USA – Private – Communication - 24 satellites): *In operation*

Globalstar 2 is the second-generation constellation of Globalstar satellites; it is deployed since 2010. It targets satellite phone and low-speed data communications

Hongyan (China – Public – Broadband - 864 satellites): *In demonstration*

The Hongyan constellation is being developed by the China Aerospace Science and Technology Corporation (CASC). The initial 320 satellites plan has now reportedly been expanded to 864, with an initial service in operation by 2022. The Hongyan mega-constellation will provide two-way communications and shall provide a range of services such as ground data collection and exchange, ship identification and tracking, mobile broadcasting, and positioning, navigation, and timing (PNT) signal enhancement. The Hongyan mega-constellation will reportedly be capable of providing mobile connectivity to 2 million users, satellite broadband to 200 000 users, and Internet of Things (IoT) coverage to 10 million users within China and in countries participating in the Belt and Road Initiative (BRI). The constellation will also support China's 5G network, by connecting the constellation directly with 5G base stations for lower latency.

Galaxy Space (China – Private – Communication - 144 satellites): *In demonstration*

Galaxy Space plans to launch 144 satellites for the constellation across the next three years. The firm wants to provide high-speed, low-latency communications services globally, including remote areas.

Iridium Next (USA – Private – Communication - 81): *In operation*

In 2017, Iridium began launching Iridium NEXT, a second-generation worldwide network of telecommunications satellites, consisting of 66 active satellites, with another nine in-orbit spares and six on-ground spares. It provides L-band voice and data information coverage to satellite phones, pagers and integrated transceivers over the entire Earth surface.

Kepler (Canada – Private – Communication - 140): *In development*

The Kepler system will consist of up to 140 satellites, inclusive of in-orbit spares, with the capability to increase the number of satellites in operation to meet user demand. It will enable IoT aggregation, backhaul and spectrum sharing. It will also make real-time connectivity available for devices both on and off Earth's surfaceO3b is a satellite constellation designed for telecommunications and data backhaul from remote locations. O3b stood for "other three billion," or the other three billion people at the time that did not have stable internet access. bSES S.A. in 2016 and ownership and operation of the constellation passed to SES Networks, a division of SES. The O3b constellation began offering service in March 2014.

SpaceX Starlink (USA – Private – Broadband - 12000): *In deployment (andnetwork Beta testing)*

SpaceX is building and launching up to 12 000 Starlink satellites, and has filed regulatory paperwork with the United Nations' International Telecommunications Union for another 30 000 satellites. The objective is to develop a low-cost, high-performance satellite bus and requisite customer ground transceivers to implement a new spaceborne Internet communication system. SpaceX intends to provide satellite internet connectivity to underserved areas of the planet, as well as provide competitively priced service to urban area. SpaceX also plans to sell some of the satellites for military, scientific, or exploratory purposes (especially in polar regions)

The total cost of the decade-long project to design, build, and deploy the constellation was estimated by SpaceX in May 2018 to be about US$10 billion

US Space Development Agency (USA – Public – Communication/Data/Remote Sensing - 1200): *In development*

The Pentagon's Space Development Agency is soliciting pitches for technologies that will be used to build a network of satellites in low Earth orbit that would help the military find targets on the ground and track enemy missiles in flight. The SDA intends to ultimately deploy multiple constellations that collectively could amount to thousands of satellites. The constellation will have a mix of sensing and communications satellites so data collected by the sensors can be passed to the communications satellites, sent down to commanders on the ground or used to directly tip and cue a missile interceptor.

Telesat (Canada – Private – Broadband - 117): *In development*

Telesat's system would be comprised of at least 117 satellites in two orbits, with Telesat stressing that it designed its combined polar/inclined-orbit system with U.S. military users in mind. Telesat plans to address mobility markets, beaming Wi-Fi to ships and aircraft, as well as businesses and government users. Telesat is not focused on the consumer broadband market. Telesat LEO constellation will have 16 to 24 terabits per second of total capacity, of which about 8 terabits will be sellable.

On top of these projects, an additional 45 other projects in various stages of fund raising and development are listed below:

Company	**Country**	**Market/App**
AST Science	USA	Mobile
Astranis	USA	Broadband
Kineis	France	IoT
Cloud constellation	USA	Broadband
Sky and Space Global (UK) Limited	United Kingdom	Broadband
Myriota	Australia	Data relay
Omnispace	USA	IoT
Swarm Technologies	USA	Broadband
Hiber	Netherlands	IoT
Fleet Space technologies	USA/Australia	IoT
Audacy	USA	Data relay
Vetaspace	India	Broadband
NSLComm	Israel	IoT
Helios Wire (Echostar)	Canada	IoT
Speqtral Quantum Technologies, Inc.	USA	QKD
Transcelestial	Singapore	Data relay
SAT4M2M UG	Germany	IoT
Astrapi Corporation	USA	Broadband
Solstar	USA	Data relay
Skyloom Global	USA	Data relay
Aquarian Devices	USA	Data relay
Indicium	Canada	Cloud/Data center
mBryonics	Ireland	Data relay

Celestial	Germany	Data relay
Laser Light	USA	Data relay
Empower Space	USA	Data relay
Sirion Global Pty. Ltd.	Australia	IoT
Lacuna Space	United Kingdom	IoT
SpaceChain	Singapore	Blockchain
Apogee Networks	New Zealand	Broadband
KLEO Connect (wass eightlyLEO)	Germany	Broadband
Outernet	USA	Broadband
Microsat Systems Canada Inc.	Canada	Broadband
Galactic Sky	USA	Cloud/Data center
Transcelestial Technologies	Singapore	Data relay
Stara Space	USA	Data relay
Analytical Space	USA	Data relay
NuSpace	Singapore	IoT
Guodian Gaoke	China	IoT
Ligado Networks	USA	IoT
Ragnarok Industries	USA	IoT
Lynk	USA	IoT
Dunvegan Space Systems	USA	IoT
Blink Astro	USA	IoT