AEROSPACE MBA

MCTP

Convergence between internet and space

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Acronyms

API	Application Programming Interface
CNES	Centre National d'Etudes Spatiales
DRL	Demand Readiness Level
EO	Earth Observation
GEO	Geostationary Orbit
GPS	Global Positioning System
ICT	Information and Communication Technologies
ITU	Union Internationale des Télécommunications
JAIN	Java APIs for Integrated Networks
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
MRL	Market Readiness Level
MVNO	Mobile Virtual Network Operators
NGN	Next generation Network
NGCN	Next Generation Core Network
SME	Small Medium Enterprises
TCP/IP	Transmission Control Protocol/Internet Protocol
TRL	Technology Readiness Level
WACC	Weighted Average Cost of Capital

Executive summary

The goal of this research study is to explore the convergence between space and internet industries. The relations between the main players of both the industries and the nature of these relationships is analyzed. The foundation of this research are the value chain and ecosystem concepts that determine the relative position of the main actors within the industry.
Telecommunication and specifically broadband are determined as the common links between the two industries under investigation.

The report further uses three main convergence factors; economic, technological and legal to analyze the developments in each of these areas, with specific focus towards broadband satellites.

Investigation of these factors leads to two main conclusions, one looks at the growing proportion of revenue from broadband satellites within telecommunication industry and the second that investigates further the rate of telecommunication revenue growth.

The aim of the second conclusion is two-fold; one to create a foundation for further study into this area to understand the relationship between rate of revenue growth and that of internet traffic growth to eventually help development of businesses in the industry. Secondly, and for the purpose of this investigation, more relevant and significant, this conclusion indirectly reiterates the convergence indicators established in the first conclusion.

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1 Introduction

This analysis aims to investigate the connection between internet and space industry. Nowadays, internet industry is growing faster than the other industries. The Internet is increasingly becoming part of both private and business life. The number of data used on a daily basis is becoming more and more important year after year. The internet market and its development have been modified with young and new firms which have decide to use different business models. The current business models are not able to meet future growth of the basic information exchange platform that internet is becoming.

This report focuses on internet and space over the past years and the dynamics that are shaping its future. Today, the largest players in any given internet segment are able to deliver higher returns and profit margins than in 2010.

The report uses exploratory research approach, in attempt to gain deeper understanding of the relationships between actors within space and telecommunication industry. The main idea of this study is to create a foundation that can be used for further analysis into this area.

Value chain and ecosystem concepts are the used as the backbone to establish the connections between the main players and then the main factors are determined to analyze the convergence between space and internet industries

The factors used for analyses are based on the information from research papers and recommendations from industry experts that were interviewed as part of the research methodology. These factors are analyzed using tools like linear regression, technology readiness level (TRL), demand readiness level (DRL) and market readiness level (MRL). These tools helped establish the trends that provide the indication of convergence.

Convergence is looked at from two difference perspectives; one purely from increasing revenue point of view and the other that looks further into the rate of this increase.
First part creates the connections between space and internet by using revenue as the means and second part uses the foundation created in the first part and prepares a foundation for further investigation, which can be quite useful towards the final aim of improving business growth within the industries involved by utilizing this convergence, which in turn also substantiates the existence of convergence between space and internet sectors.

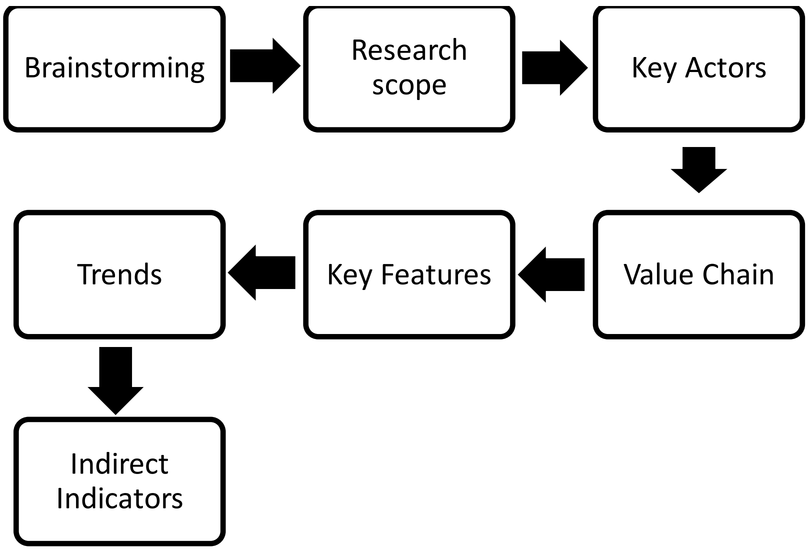
2 Research Methodology

2.1 Type of investigation

The research question investigated in this study is classified as an exploratory research question. And the study conducted is classified as descriptive. It based on the past and dynamics of future to analyze the trend of different factors which may have an impact on the development of and relationship between the internet and space industry.
The aim of this study is to help create the foundation for a further study into the topic. Research design and data used in this study opens up more questions that needs to be answered and concepts that needs to be further developed.

The methodology used for this study is summarized in the schematic below, starting with brainstorming to understand the scope of the topic and then develop further to investigate existing trends that could then be seen as indicators, strong or weak, of the convergence between space and internet industries.

Figure 1: Schematic of the research methodology



Throughout this process, a combination of primary and secondary sources were utilized that helped create the connection between various concepts and to recognize the links between key factors. This helped to further develop the scope of the research.

2.2 Data collection method

This study uses a range of different sources including books, formal reports, thesis, articles and interviews and discussions with experts in the industry to observe and reflect on the information related to the topic. These inputs and processes provided various theories and tools that helped with a deeper understanding of the convergence between internet and space industry. Even though the convergence is not a concept that can be easily measured, yet within this report, attempts was made, using a combination of qualitative and quantitative data, to create a foundation for this concept.

2.3 Source of Methodology

2.3.1 Primary sources

In order to get a deeper and practical understanding of research topic, various formal and informal interviews were conducted with experts from within space and telecommunication industry including a telephonic interview with representatives from Northern Sky Research and face to face interview with CNES delegates. Other experts from space and telecommunication companies like Euroconsult and Sigfox were also informally interviewed. Key topics discussed in the interviews are summarized in the appendix.

These primary sources helped provide some crucial theories that directed this research study towards the approach defined in this report.

2.3.2 Secondary sources

Reports from conferences and organizations

Conferences and industry reports like 3rd International Internet Conference, EU Commission, ENTO, ITU, etc. from companies within space, internet and telecommunication sector, were researched for the purpose of this study. These reports helped provide a direction for the research study from an unbiased, global perspective.

Information from research reference

This research report also uses concepts or comments from PhD or Master thesis and reports from consulting companies like Deloitte and other organizations like KPCB. These sources helped provide a macro understanding of the current dynamics of internet and space industries.

Figures from educational reference

In addition, the study refers to some handbook and books to get the basic model or concept to help with analysis and decision making. Books like 《Exploring Strategy》[1] and other similar educational sources provided theoretical concepts and instructions to help with the analysis of research topic.

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[1] Exploring Strategy, 10th Edition, Gerry Johnson, Richard Whittington, Kevan Scholes, Duncan Angwin, Patrick Regner, Pearson Edition

2.4 Contribution of study

This research study attempts, with the help of aforementioned resources, to conduct an analysis to help build a better understanding of the trends of convergence. In addition, the study aims to create the groundwork for future research into this area by giving the reader a new direction to explore further.

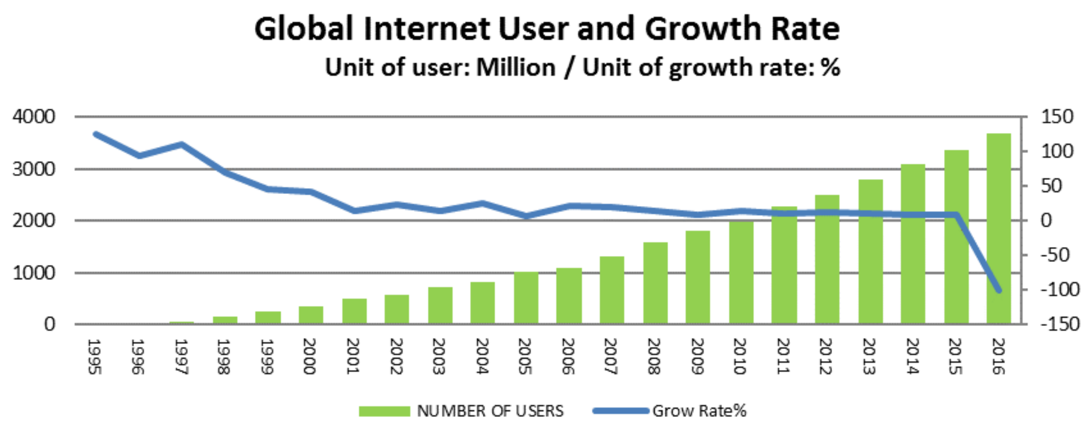
This study, even though keeping an unbiased approach is more inclined towards investigating the developments within space industry, leaving the terrestrial telecommunication developments open for further investigation for comparison. This also forms a major part of the limitations of this research study.

3 Background

3.1 Internet

In his theory, Marshall McLuhan, a Canadian professor and philosopher, particularly famous for his media theory, predicted the concepts of global village and World Wide Web which were invented 30 years later. In 1964, he said the world will be interconnected by an electronic nervous system, it will become more and more popular and to transfer to the kind of culture[2]. As described in **Erreur ! Source du renvoi introuvable.**, the global internet users has proven Marshall's prediction. Even though access to the internet is not equally popular or achievable everywhere in the world, **Erreur ! Source du renvoi introuvable.** is a good indication of the growing trend of internet over the past 20 years.

Figure 2: Global Internet User and Growth Rate[3]



[2] McLuhan, Marshall. 1964. "McLuhan Understanding Media The Extensions of Man London and New York." Basieexpsispittedu, 43. doi:10.2307/2711172.

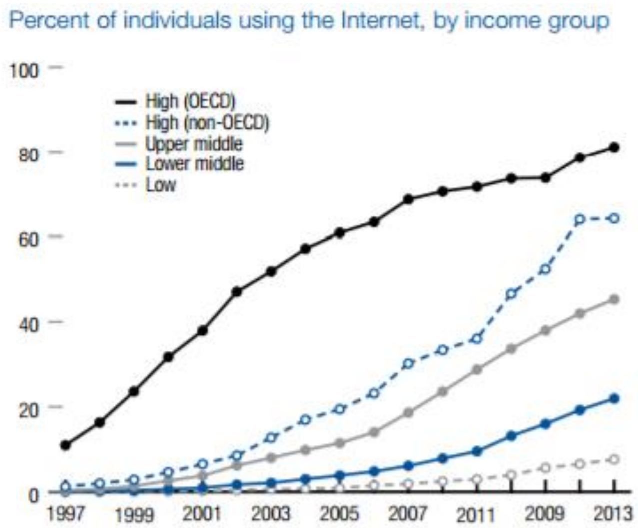
[3] Miniwatts Marketing Group. 2014. "Internet Growth Statistics - the Global Village Online." Global Village Online.

Within last 20 years, the number of global internet users has increased from 16 million to 3675 million, around 300 folds compared with the figure in 1995. And the growth rate is pretty high in the first 5 years with a fairly stagnant growth for the next 15 years till 2015 and a steep decrease in 2016. This can be explained by the lack of users in developing markets. More than half of the world population is connected to internet, which counts for the upper limit of internet development in the urban area. While there's still the other half of the population that is not connected which is also a potential market and main driven for internet and telecommunication companies.

3.1.1 Internet penetration

Looking at the number of global internet users, the identification of internet penetration in different group of countries is not quite apparent. In 2015, global information report World Economic Forum[4], classified the percentage of internet penetration by income groups. From high income to low income group of countries, there seems to be a big gap in the penetration. But at the same time, it shows the high potential market for upper middle level income group which relates to the similar trend for developing, emerging and developing countries as shown in **Erreur ! Source du renvoi introuvable.**

Figure 3: Percent of individuals using the internet by income group[4]



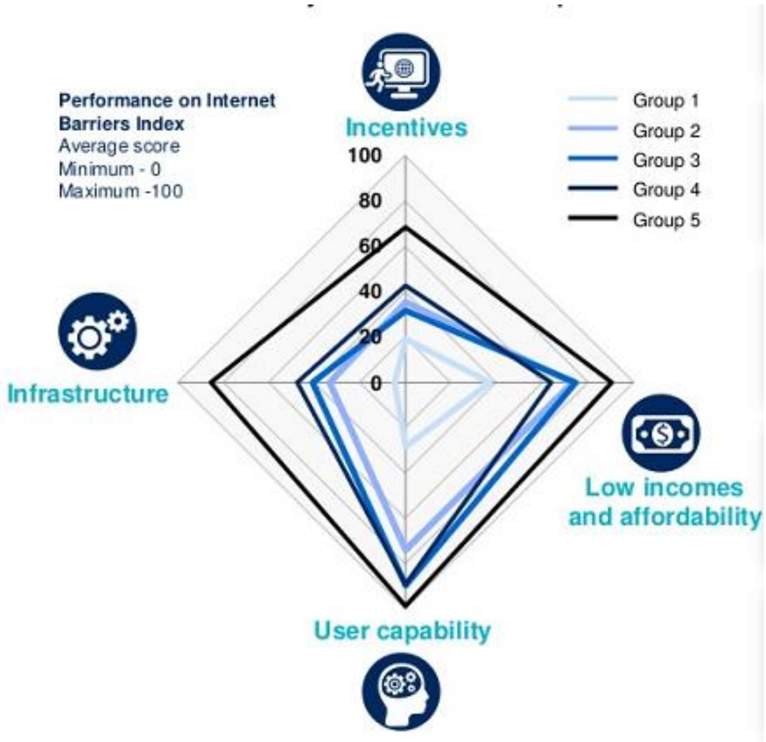
As for high income countries, the penetration rate is almost up to the top limit. It also appears that the potential market may gradually transfer to emerging and developing countries.

[4] Dutta, Soumitra, Thierry Geiger, and Bruno Lanvin. 2015. *The Global Information Technology Report 2015*.

3.1.2 The market segment of internet market

In their report, Kleiner Perkins Caufield Byers[5] divide the countries into 5 different groups based on the internet barriers facing these groups. 0 to 100 means scale is used with 0 being the worst and 100 being the best. After giving the score of each group, KPCB identified the characteristics of each group as it illustrated in **Erreur ! Source du renvoi introuvable.**

Figure 4 : Performance of 5 groups of countries facing internet barriers



<u>Group 1</u>

This group always has a high barrier facing internet and the offline population are younger generation and rural with low literary. The total number of users is around 548 million in 2014 with only 18% internet penetration rate. These are the countries like Bangladesh, Ethiopia, etc.

<u>Group 2</u>

This group seems to have relatively middle to high level barriers due to a lack of incentives and infrastructure. Around 1438 million people are within this phase with a very low internet penetration rate, which is only 20% in 2014. Countries like Egypt, Indonesia Thailand fall in this group.

[5] Meeker, Mary. 2016b. "KPCB-- Performance of 5 Groups of Countries Facing Internet Barriers." http://www.kpcb.com/blog/2016-internet-trends-report.

Group 3

These countries also have a middle level towards barriers with rural areas still suffering from a lack of incentives. This offline population in this group of countries takes up 753 million in 2014 with the half of the internet penetration. Countries like China and Vietnam fall in this category.

Group 4

Barriers to internet for this group are similar to group 3 with additional challenges in the form of low incomes and affordability. Offline population reaches to 244 million with more than half of internet penetration in 2014.

Group 5

It is much easier to get access to internet for countries in this group. Offline population are still highly literate, which constitutes about 147 million but with a high internet penetration around 84%[6].

Based on the data from Union Internationale des Télécommunications (hereafter ITU)[7] , in 2016, still around 60% of the global population should be online. Within this figure, around 75% of population is from developing country, constituting 4 billon people and 90% of least developing countries which counts for 851 million people still needing to connect to internet.

3.2 Space industry

Space industry, as clear from recent developments, is going through a period of reinvention. A lot of focus is being on the concept of "New Space", with the technology advancing faster than ever in different areas of the industry, including re-use of launch vehicles, use of electric propulsion and smaller (micro and nano) satellites, all aiming at bringing the costs down. These are only a few examples of how the industry is making efforts in making space more affordable and subsequently, more accessible to general public, both in developed and developing countries[8].

Currently, the space economy extends about 36,000 Km from the surface of the Earth and includes a combination of critical services like satellite communications, global positioning satellites and imaging satellites, all on which the global economy depends[9].

[6] Meeker, Mary. 2016b. "KPCB-- Performance of 5 Groups of Countries Facing Internet Barriers." http://www.kpcb.com/blog/2016-internet-trends-report.

[7] ITU. 2014. "ITU Releases 2014 ICT Figures.pdf." http://www.sia.org/annual-state-of-the-satellite-industry-reports/2014-sia-state-of-satellite-industry-report/.

[8] (https://www.spacefoundation.org/sites/default/files/downloads/The_Space_Report_2016_OVERVIEW.pdf)

[9] https://www.nasa.gov/sites/default/files/files/Emerging_Space_Report.pdf

The next era of space exploration will see governments pushing technological development and the American private sector using these technologies as they expand their economic activities to new worlds. The next exploration such as visits to asteroids and Mars, have reached a certain level of complexity. The NASA budgets have been reduced since many years but the desire to explore so far and to develop the space access for commercial reason, has pushed American entrepreneurs to spend hundreds of millions of dollars to develop technologies. Since 2003, commercial human spaceflight has received $2.5 billion in private investment. United States is transitioning from a spacefaring nation to a nation of spacefarers.[10]

The space technology combined to communication networks has changed the ways of monitoring infrastructure and providing services. In Belgium, underground sensors have been replaced by geo-fencing and communication. The global demand for space data and applications drives recent investments in space industry.

Despite the decline from $329 billion in 2014 to $323 billion in 2015, the space industry grew in 2015 due to strong U.S dollar. Commercial space products and services including telecommunications, broadcasting, and Earth observation constituted the largest sector, growing by 3.7% to reach $126.33 billion in 2015. Commercial infrastructure and support industries including the manufacture of spacecraft, in-space platforms, and ground equipment, as well as launch services, independent research and development, and insurance totalled $120.88 billion in 2015, a 5.2% decrease.

The development of a new generation of satellites with a mass of 10 kilograms (22 pounds) or less, nanosatellites constituted 48% of the 262 spacecraft launched in 2015. Looking at the past decade, the rise of nanosatellites in 2013 has proven that the number of launched during the past three years is approximately double the average rate for the previous seven years. Unfortunately, this number is less than 1% of the total mass sent in orbit in 2015. But the telecommunications satellites launched to geosynchronous orbit made up 41% of the total mass, with an average mass of approximately 4,500 kilograms (9,920 pounds) per satellite. These satellites form the backbone for satellite communications and broadcasting services that generate more than $100 billion each year.

[10] https://www.nasa.gov/sites/default/files/files/Emerging_Space_Report.pdf

3.3 Convergence

According to Basolea et al., (2015)[11], convergence refers to a transformation process that blurs boundaries by unifying value propositions, technologies, or markets. He further identifies several types of convergence with suggestion to focus on knowledge, technology and industry approaches. The concepts involved in these types of convergence is explained below.

3.3.1 Knowledge convergence

It is the combination of knowledge bases and the erosion of boundaries that define and isolate industry-specific knowledge. Knowledge convergence is generally motivated by an industry actor's identification of new opportunities lying at the edge of its industry border and awareness of the potential of combining own knowledge with external one, thereby leading to novel and potentially innovative activities.

3.3.2 Technological convergence

Technological convergence is closely linked to knowledge convergence and is defined as the combination of previously distinct technologies into a common product. Technological convergence leads to new value-creating opportunities and product and service offerings. There are many examples of technological convergence in the ICT industry, one of the most well-known example could be the bundling of a mobile phone and digital camera into a camera phone.

3.3.3 Industrial convergence

When technologies converge and applications from distinct domains are combined, they infringe on existing value-creating territories of underlying sectors and industries. This leads to collision of business models and gradual blurring, or redefinition, of market boundaries. This phenomenon is called industry convergence. Industry convergence often leads to a new cross-industry segment that widens markets, lowers barriers to entry and increases competition. Moreover, industry convergence can lead to reconfiguration of the value chain through the addition or elimination of activities, consolidation through mergers and acquisitions, as well as a complete shakeout of players from the ecosystem. Industry convergence is particularly prevalent in the ICT context. Traditionally separate market segments, such as broadband, cable, and telephony for instance, are now deeply intertwined, providing integrated, bundled digital products and services to consumers.

3.3.4 Service convergence

Fundamental technological developments including digitalization, computerization and packet-switch establish the groundwork of service convergence. With this regard, digital contents are mandatory all over the ICT platforms (broadcasting, internet and mobile communication). Computerization supports the operation and convergence of the ICT systems and the IP protocol ensures the interoperability of services.

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[11] Basolea R.; Parkb H.; Barnettc B. (2015) Coopetition and Convergence in the ICT ecosystem. Telecommunications Policy. Volume 39, Issue 7, Pages 537-552

Under these circumstances, service providers from different sectors and backgrounds, including telecom operators, rejuvenated cable operators, ISPs, customer brands etc., all regard the integrated service offerings as the promising revenue source.

Service convergence in a sense results from intense competition and players seek for competitive advantages in form of merge, alliance, or forming strong supply networks in response to the market pressure. Different converged service offerings in fact embody various competitive strategies: overall cost leadership; differentiation; focus; or any combination of them. The services are in numerous but they can be summarized as the rudiment ICT services including voice, broadband access including wire and wireless, broadcasting and the internet services such as portals, searching engine, on-line B2C and web sites. In general, broadband infrastructures stimulate the demand for multimedia services and contents and emerging new technologies expand the service portfolio.

3.3.5 Market convergence

Based on the traditional market segmentation, customers of telecommunication services are classified into four main groups: Residential in dense population area, Residential in sparse population area, Business as SME and Business as Big Corporate. Currently, in the context of ICT services, residential customers prefer the core ICT services such as voice, broadband access, and TV, whereas business customers require broadband access and specific ICT managed network services.

Considering the ICT ecosystem approach, convergence in content and service involves all sectors and players. On the other hand, for the main ICT services, the market convergence is more remarkable between players in the interface, network and transport layers where the telecommunication operators have a central role.

3.3.6 Regulation convergence

Regulation is a broad subject including public ownership, legislation, and market incentives. Generally, there are five objectives of regulation; efficiency, industrial policy, funding, social welfare, and state security. The regulation of ICT services plays an important role in the development of information society. From the regulation point of view, the liberalization of the telecommunication industry is a key factor for the development of the ICT environment. Also, it is important to highlight that the different types of convergence has imposed challenges on the current regulation such as technology neutrality.

3.4 ICT ecosystem

The Information and Communication Technologies (ICT) concept combines information system, software applications and telecommunication networks in order to provide the infrastructure to support a lot of activities in the modern society[12]. ICT services are changing

[12] Razani M. (2012) Information, Communication, and Space Technology. CRC Press – Taylor & Francis Group – USA.

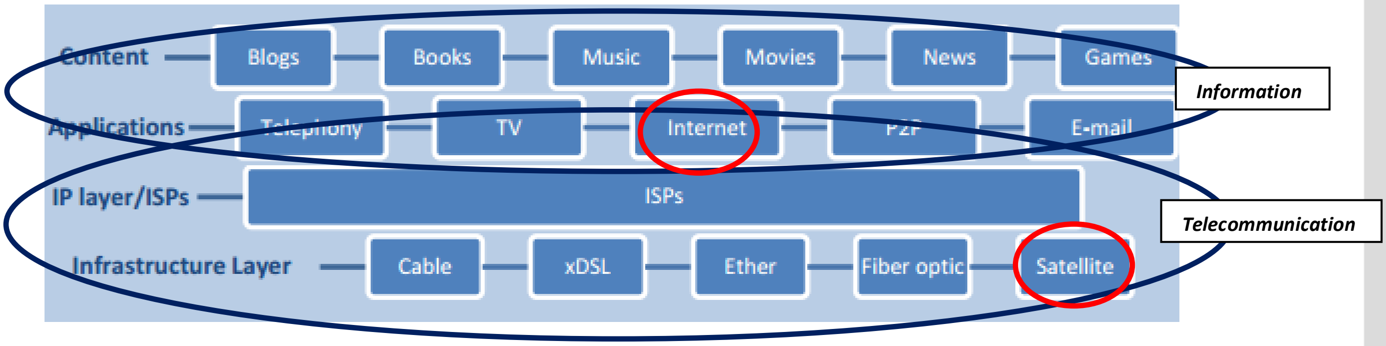
people's life style and the way businesses operate. It brings people closer, provides an easy information access and enables businesses to operate more efficiently. Moreover, it plays a pivotal role in the globalization concept.

The concept of 'ecosystem' used in this thesis shows the relationship between internet, telecommunication and space industry. Movements from each actor influence the all other actors within the overall ecosystem.

Figure 5 below summarizes the concept of ICT ecosystem as the platform for the main players being investigated in this research paper.

Table x

Figure 5: ICT Ecosystem[13]



3.4.1 Telecommunication

Telecommunication industry has experienced and it is always experiencing significant revolutions which lead to intense changes in the market structure and accelerates the emergence of new services. Looking at the evolution of telecommunication industry, besides the disruptive technology innovations such as digitalization and computerization, it has experienced two major milestones, which are liberalization and internet. These two milestones fundamentally changed the industry in terms of market environment and technology paradigm[14]. Indeed, the radical internet changes, in combination with other factors, has led to the move from telecommunication to ICT services

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[13] OPTA (2006) Vision and annual plan 2007.
Retrieved from http://www.opta.nl/en/news/allpublications/publication/?id=2101

[14] Ming X. (2008) Value Chain and Business Model Analysis of ICT Services in Context of Next Generation Network. Center for Information and Communication Technologies at Technical University of Denmark.

Fransman (2002)[15] divides the evolution of the telecom industry into three stages as Old Telecom, New Telecom and Info-communications Industry. The first was featured as a regulated and vertical integrated sector. The second was characterized by the liberalization campaign in many countries in the mid-1980s. The third is the telecom industry that never stops in terms of technology, service offerings, business model and regulations. It is in this third stage that the telecommunication industry has experience radical technological changes that go beyond the telecommunication industry and combines the information technologies to implement ICT services.

Telecommunication operators play a vital role in the ICT ecosystem. ICT players are evolving their competences and adjusting their strategies in order to face the challenges and seize opportunities in the competitive service environment. As such, 3rd party developers for content and application services play an important role in the ICT services, principally, the giants of the internet industry like Google, Apple, Facebook, Amazon and Microsoft. Their focus is no longer limited to terrestrial options, but also towards any complementary plans that will help enlarge their capacity, quickly and cost efficiently. This has brought about a keen interest in space options, which at this stage are seen as complementary solutions.

3.4.2 Space industry

Space industry is original player within the ICT ecosystem. But along with the evolution of whole ICT system, space industry is not only providing technology to telecommunication industry but also a supporter for information services through the huge data processer.

Nowadays, people need more customer tailored service which is a big challenge for internet industry, but an opportunity for space industry. The limitation of the capacity issue of the telecommunication industry is becoming more and more obvious. The trend for internet industry to find space alternatives to get more access has emerged. Meanwhile, with the cost of satellite decreasing, more and more companies can now afford to evolve as the new-comers under this ecosystem. These trends seem to also highlight the formation of a bridge between space and internet sector.

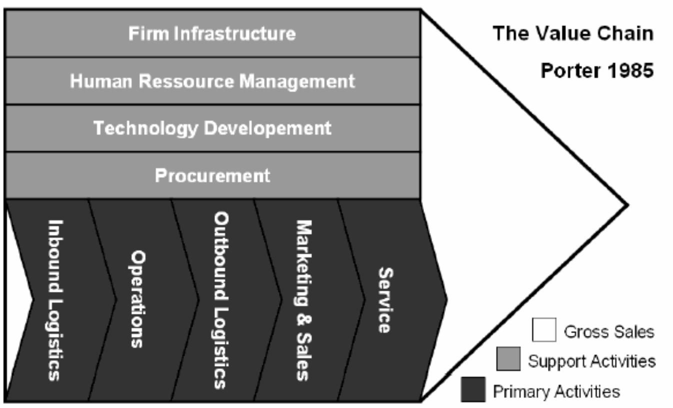
The dynamic movements of all the old players and new comers and the connections between them marks the real evolution of ICT ecosystem. With the increasing demand and growing market, there is a need for innovation, not just in technology but more importantly in disruptive business models.

[15] Fransman M. (2002) Telecoms in the Internet Age, From Boom to Bust to Oxford University Press.

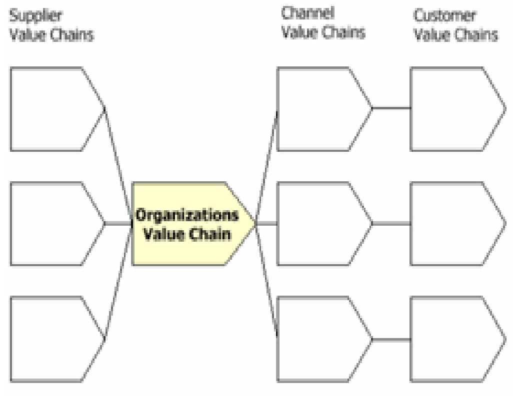
4 Value chain

The approach of this research paper is based on the concept of value chain. *"Michael Porter puts forward that a value chain is made up of a chain of activities"* as shown in **Erreur ! Source du renvoi introuvable.** where a product is produced within one organization. There is a certain value gained through each activity along the chain of product development activities as shown in the figure. These value-adding activities are categorized into primary activities and support activities.

Figure 6: The generic value chain (a) [16] ***and the Value Network Model (b)***[17]***.***



(a)



(b)

"The value chain analysis describes those activities a business organization performs and relates them to the company's competitive position."

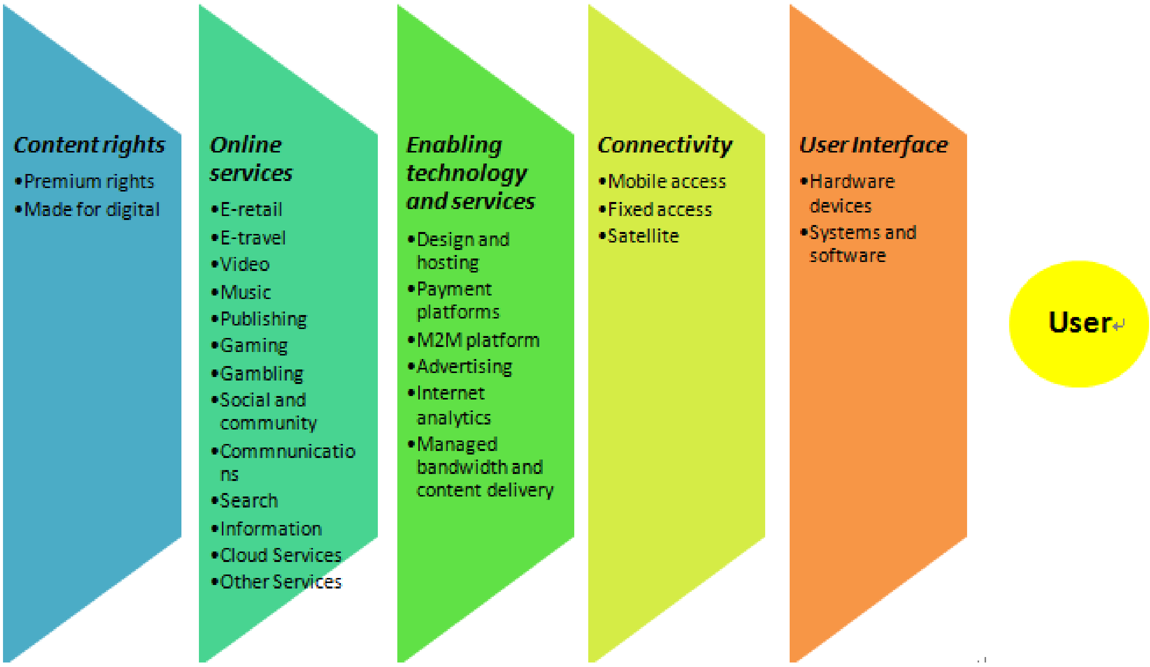
In this study, not all the activities of the market players including internet actors, ground equipment, launch industry, internet access, telecom operators, satellite manufacturers, software vendors, service or content providers, Internet service brand, and etc. are discussed. The scope of this report limits the use of value chain analysis to investigate the common link between space and internet industries. As such, the value chain of internet, space as well as ICT are discussed below.

[16] Porter M. (1985) Competitive Advantage: Creating and Sustaining Superior Performance. Originally published; New York: Free Press; London: Collier Macmillan.

[17] Ming X. (2008) Value Chain and Business Model Analysis of ICT Services in Context of Next Generation Network. Center for Information and Communication Technologies at Technical University of Denmark.

4.1 Internet Industry Value chain

Figure 7: Schematic of Internet value chain.



The internet value chain is quite complex and involves multiple players and activities. In order to understand the internet value chain, figure 7 breaks it down into five key markets; content rights, online services, enabling technologies and services, connectivity and user interface (including applications and devices).

Figure 7 also summarize the main characteristics of each key market that could be developed by different actors or players. It is important to highlight that many of these players operates in two or more segments in order to take more control over quality of services for the end user, but also to take full advantage of assets such as technology, brands, partnerships and alliances.

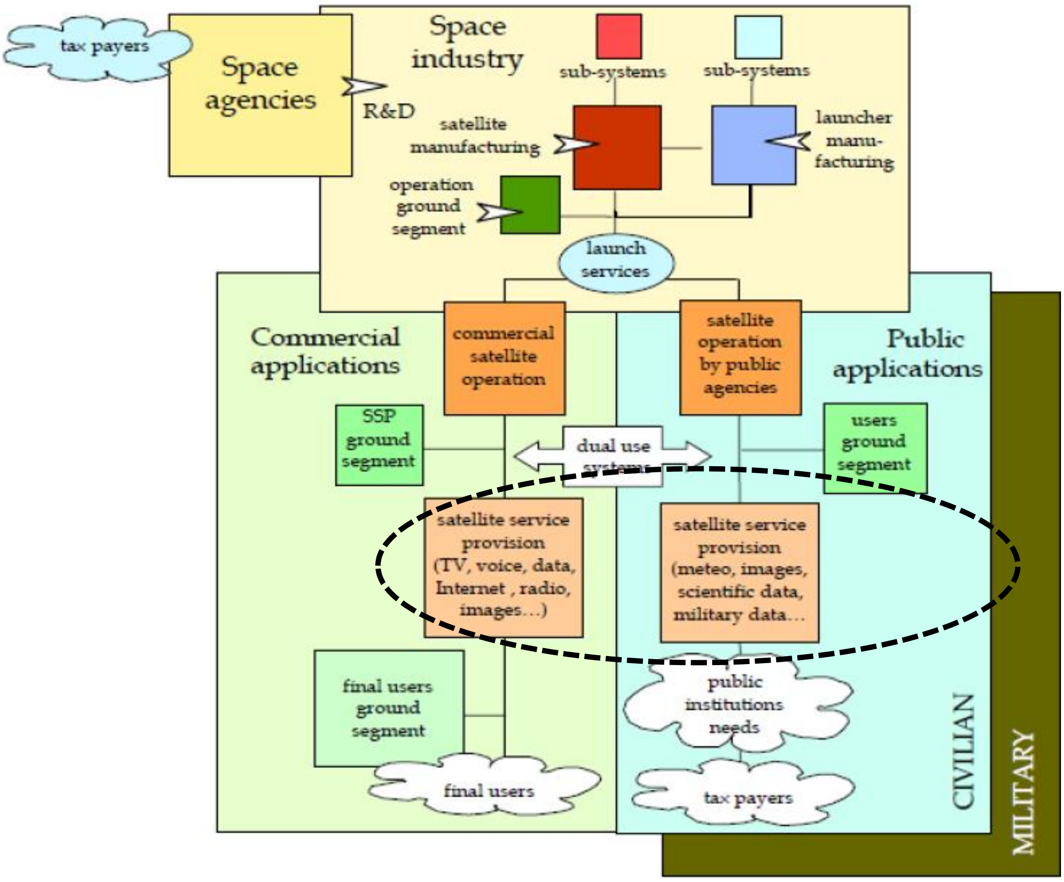
As a result, the growth in the internet value chain is impressive, but not all firms are benefiting. Those that focus on their traditional market can see value shift quicker to those firms that have grown and acquired aggressively in multiple segments and geographies, combining different offerings to create a powerful market position.

This trend may reverse over the long run, or be challenged by regulators, but for now it means that a cautious strategy of "focus" is actually more risky than it may seem.

4.2 Space value chain

The Space value chain comprises of some segments and categories that are global and others that are more local. Figure 8 summarizes the space value chain below.

Figure 8 : The space economy simplified value chain (Euroconsult)[18].



This value chain can be divided in four main categories; satellite manufacturing and launch industry, satellite operators, ground segment and service provider and network operators. Each of these main value chain activities is described in brief below.**Erreur ! Source du renvoi introuvable.**

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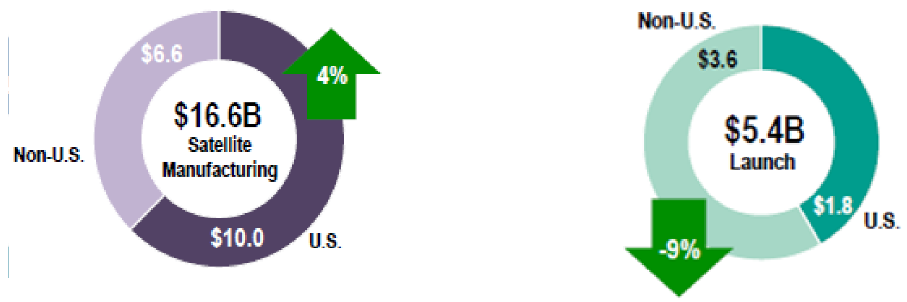
[18] Pacôme Révillon, Euroconsult. (2016). Economic aspects of the space sector

4.2.1 Satellite manufacturing and Launch industry

The satellite manufacturing sector remains a relatively small sector. According to the literature, worldwide space manufacturing revenues have increased since 2008 and 2009 (from $10.5B to $13.5B) as per the OECD[19] report for reaching a peak of $16.6B in 2015.

The Launch industry represents only $5.4B in 2015 which the lowest sector in terms of revenues in this value chain. 12 companies compete worldwide in this segment such as Airbus Defense and Space, Thales Alenia Space and Arianespace, etc.

Figure 9: Total revenue of the satellite manufacturer and Launch industry in 2015



4.2.2 Satellite Operators

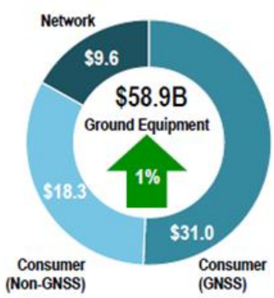
Satellite operators are responsible for the planning and cost of the construction and launch of satellite into space. They own and manage a constellation of satellites and determine coverage and geographic areas. Satellite operators lease this bandwidth to service providers, government entities, television broadcasters, enterprises and sometimes direct to the end consumer. In this segment, 50 companies worldwide compete. The total revenue of this segment included in the satellite services is around $13B as of 2015.

4.2.3 Ground segment

About 100 companies around the world manufacture products such as pure antenna manufacturers and satellite equipment manufacturers that produce indoor or outdoor ground equipment including antennas, LNBs, BUCs, hubs, routers, software and network management systems.
The total revenue of this segment has a reach a value of $58.9B in 2015 which is the most important segments after the satellites operators.

[19] The Space Economy at a Glance 2011 By OECD.

Figure 10: Total revenue of the ground equipment in 2015.

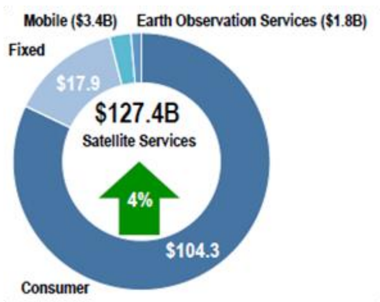


4.2.4 Service Providers / Network Operators /Satellites services

Service providers, sometimes known as network operators, are telecommunication companies or specialized satellite service companies who sell a full-service package to the end customer.

About 1000 companies around the world provide fixed and mobile satellite communications for instance. They lease capacity from satellite operators, purchase and operate the network equipment and the antenna, and are responsible for the installation and maintenance of the network.

Figure 11: Total revenue of the satellites operators in 2015



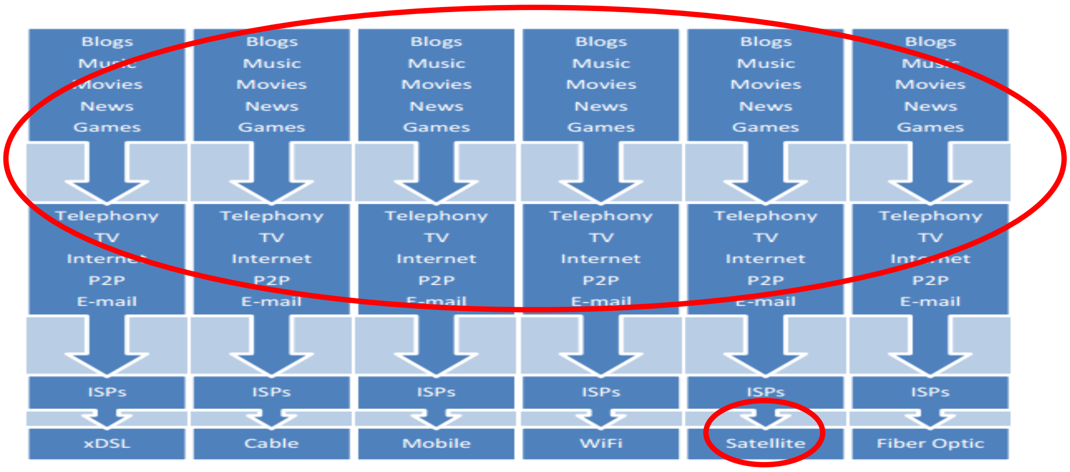
The end-customers are the enterprises, organizations and consumers who use satellite communication services. Governments or large corporate customers may operate as their own service provider by managing the equipment directly and leasing bandwidth from satellite operators. Individuals and smaller enterprises typically work with service providers who manage the equipment and connections. In many occasions, high-speed connectivity is required for a lot of variety of applications such as VoIP, Email, Video and Internet.

4.3 ICT value chain[20]

The relationship between the players in the ICT ecosystem is complex and diverse; and not a single player can satisfy the diversified customer demands in a fast-changing circumstance. The value network of ITC services consists of all the stakeholders cooperating to deliver products or services to customers. In former times, most of the telecom services were controlled by a single player, the telecom operator. After the liberalization and internet phenomenon, the telecom environment enables the competitive scenario for new services and application developers and it drives on competition, cooperation and interaction between ecosystem roles. Thus, taking into account the reference TCP/IP Model, the main stakeholders in the ICT ecosystem could be summarized as system manufactures, telecommunication operators (infrastructure and operation), system integrators, Internet and services providers, and 3rd party developers for services, application and content.

Erreur ! Source du renvoi introuvable. shows this open and dynamic ecosystem where user requirements and technology are the two drivers of ICT industry, where any potential market actor that has resources can contribute to the ICT service provision. The successful output of this ecosystem relies on the co-evolution of all actors. Most relevant features of each player are detailed below.

Figure 12: Vertical radiography of the ICT ecosystem: ICT value chain[21]



[20] Fransman M. (2010) The New ICT Ecosystem: Implications for Policy and Regulation. Published in the United States of America by Cambridge University Press, New York

[21] OPTA (2006) Vision and annual plan 2007.
Retrieved from http://www.opta.nl/en/news/allpublications/publication/?id=2101

Note: The vertical radiograpy of the ICT ecosystem is only a particular representation to understand the ICT value chain concept. In real scenario, the next generation idea or provide multiple service over one network which means one of the telecom targets.

4.3.1 System Manufacturer: Network equipment and User terminal producers

System manufacturers focused on network equipment and user terminal producers, hardware and its related software. They act as the technology and equipment suppliers in the existing value chain. Regarding network equipment, besides equipment sales, some manufacturers also are involved in operator's day-to-day network operation by managed services bundled with their equipment. In this regard, the valued added of system manufacturer is to provide platforms. More importantly for the service-oriented market, the terminal is becoming smarter in order to implement value-added services on the terminal.

4.3.2 Telecommunication Operators

Telecom operators are generally those organizations that operate communication networks and offer telephony, data communication, TV and some simple value-added services. All telecom operators excluding Mobile Virtual Network Operators (MVNO) have their own network infrastructures. Telecom operators have a strategic position in the value network of ICT services industry. The main value-adding activities in the ICT services industry could be the deployment of network infrastructure, operation and maintenance of networks, communication service development, supporting software development, customer care and marketing.

Telecom operators can be sorted into the incumbents and new entrant operators. In the former category, operators had the advantages of market domination, economies of scale and scope and brand recognition. For the latter category, operators have the opportunity to deploy or apply latest technologies to offer most advanced services. The new entrants usually focus on the high-usage parts of the major cities to address the most profitable market segment with relatively small investment. Due to the coverage range of network infrastructures, some operators only provide access services whereas others, mainly the incumbents, operate within the whole infrastructure set.

4.3.3 System Integrators

System integrators develop hardware and software products in order to bring together all the elements involved in ICT services and to ensure the proper functioning. System integrator activities may include designing or building a customized architecture or application, integrating it with new or existing hardware, packaged and custom software, and creation of communications infrastructure. This segment of actors play a functional role in the basic of opening the service provisions to 3rd-parties. They may even impose limitation on the service interoperability with other platforms.[22]

4.3.4 Content and Applications Service provider

Content and applications service providers are located at the upper end of the network chain and they include providers focusing primarily on information and media services, content, entertainment and applications services. Content and available application services rather than network technology are seen as the key drivers of the further growth of broadband. With the advent of broadband technologies, internet has become a fast distribution channel of multimedia content. With this regard, telecom operators become the new channel competitors against broadcast network operators and as such the bargaining power of content provider is increasing.

The application/service providers do not own network infrastructures but they produce innovative services (VoIP and Web Service). Moreover, they are responsible for increase in traffic within the telecommunication networks. There are several types of Internet service brand such as portals, searching engine, on-line B2C and web sites. Without doubt, the most famous are GAFAM. These brands have built up big customer base. The strength of these firms lies in the profound understanding of users' demand and service innovation capability.

4.4 Common link

After analysing the value chains of space industry and internet industry, it is quite clear that the common link between the two is telecommunication. ICT value chain further maintain this link by creating a common platform for interaction between the actors of both industries. Further analysis into value chains limits the common link to broadband within overall telecommunication industry.

As such, in order to analyze convergence, the main focus of this study will remain on development of broadband satellites and the connection to both industries.

5 Problem definition

Previous sections of the report have discussed briefly how internet and space industries come together in the ICT ecosystem. There is further investigation into the value chains of space and internet industries as well as ICT, to establish the common linkage between the industries in questions. This section aims to further define the boundaries and scope of this study.

Five different kinds of convergence as defined in the previous sections is noticeable in different forms within different sections and segments of industries. Based on Xie (2008) and considering the technology, service, market and regulatory aspects of convergence already established, the main parameters of the ICT ecosystem are summarized in Table 1 below.

Table 1 : Main convergences factors

	Convergence factors *Technology*	*Economy*		*Legal*
ICT Players		**Service**	**Market**	
Application	**Digitalization, computerization, packet-switch: IP**	Digital Content	Broadband focus	Liberalization
		Rudiment ICT service (Voice, broadband access and TV)	- Internet services	Spectrum allocation
Transport Network	Interoperability throughout the ICT Systems	Internet Services (portals, searching engine, on-line B2C and web sites)	- Rudiment service	Antitrust law
			- External market	Neutrality law
			- Internal market	Open sky policy
Interface				

The table above helps to identify the main factors that can be used to investigate the convergence of space and internet industries. These are:

- **Economy**, that covers the services provided by the ICT players and brings together different markets with main focus on broadband.

- **Technology**, that looks into interoperability of the industries through development of the technologies

- **Legal**, that looks into various regulations that can have a huge impact on the functionality of the industries, especially in terms of convergence between the industries.

Work so far in the report has helped to recognize a common ecosystem, ICT, which accommodates the main players of this study; internet industry, space industry and telecommunication services. The concept and ecosystem in addition to the value chain also helped establish the common link between space and internet, in the form of telecommunication. Within telecommunication, the main area of convergence and thereby, of interest for this study is broadband.

This study, therefore, focuses mainly on the growth and development of broadband satellites. In next few chapter, the role, contribution and impact of broadband satellites within telecommunication industry is analyzed in depth.

However, in order to do that, emphasis must first be put on the current identified limitation of broadband satellites as these limitations play an important role in identifying the effects of the three predetermined convergence factors, namely economic, technological and legal, on the evolution of this segment within telecommunication industry, which can be seen as an indirect gauge of convergence between internet and space industries. Following are just few of the major limitations facing the satellite industry currently.

- Low relative latency due to the distance
- Lack of ground infrastructure to support non GEO satellites
- High capital cost (CAPEX) including manufacturing and launching costs
- High operating cost (OPEX) including the cost of capacity, etc.
- Limited frequency spectrum poses challenge to the growing demand
- Frequency interferences between satellites

The following section attempts to analyze the impact of the convergence factors on these limitations, which in turn impact the growth and usage of broadband satellites.

6 Analysis

This section aims to investigate the presence of convergence between internet and space industries based on the foundation built in the previous sections.
To reiterate the main aspects which will be used in this investigation are three factors of convergence:

1. Economic
2. Technological
3. Legal

These indicators are based on recommendations from interviews and research conducted to be the most influential factors for both space and internet industry and will be the basis of the analysis into the relationship between the two industries.
This chapter is organized such that each of these factors is studied in depth in relation to their influence on both internet and space industries. These influences, once established, result in exploration of the main trends in both industries that are further developed to indicate presence of converge.

6.1 Assumptions and limitation

The current limitations of broadband satellites are frequently referred in this section to show the effects of all three convergence factor on the limitations. The approach used for this analysis is based on the main assumption reduction in the existing limitations of broadband satellite will result in the growth of this segment within the telecommunication industry. This growth, in turn, is perceived as an indication, however strong or weak, of convergence between the two sectors.

In addition, the main concepts and developments discussed in this analysis are more satellite industry focused. As such, similar developments within the terrestrial alternatives and their impact on the overall evolution of telecommunication industry is not included in the scope of this study.

6.2 Economy

One of the biggest drivers for the growing interest towards satellite based internet, other than the known limitations of terrestrial broadband in terms of accessibility is the awareness of the positive impact of internet on economic development. This section looks into the relationships between internet and satellite from economic standpoint.

In the context of this report, economy has been looked at from a global GDP as well as macro level revenue growth, which further point to reduction is capital and operating costs, which is also the main limitation of broadband satellites at present.

The logic followed in this section is summarized very modestly by the following equation:

Economy → GDP → Internet → Satellite Internet (Space)

This sections starts with making a link between internet and GDP, specifically the impact of internet on GDP growth. This relation is further exploited in the link between GDP and ARPU, which is another approach to looking at telecommunication. Reduction in capital and operating costs for broadband satellite is then analyzed. Further analysis compares percentage growth of broadband revenue via satellite relative to the overall telecommunication revenue.

6.2.1 Internet and GDP

A research conducted by (Ericsson 2013) [23] beautifully summarizes the effects of increased broadband penetration on the various aspects of economy, and the cycle of development is leads to, by increasing innovation and further improving the broadband technology.

[23] Ericsson, Arthur D Little and Chalmers University of Technology. 2013. *SOCIOECONOMIC effects ofbroadband speed.* September. Accès le April 2017. https://www.ericsson.com/res/thecompany/docs/corporate-responsibility/2013/ericsson-broadband-final-071013.pdf.

Figure 13: Schematic of effects stemming from increased broadband speed (Ericsson 2013)[20]

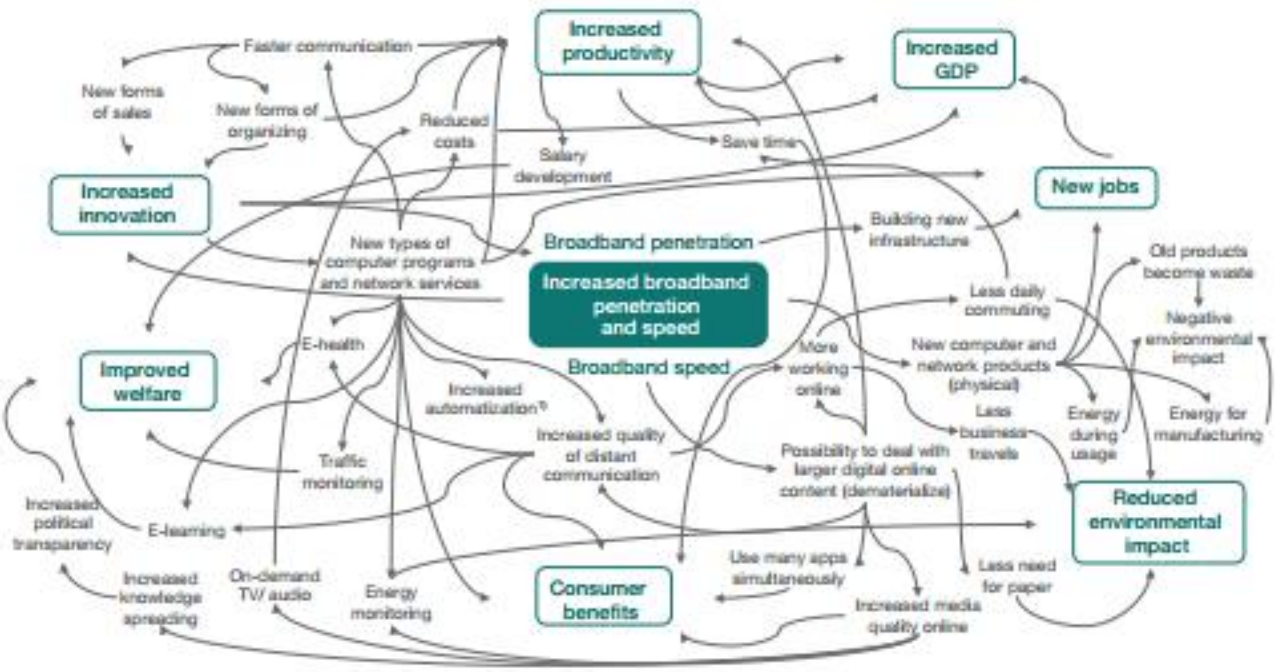


Figure 13 shows the links between increased broadband penetration and speed to socio-economic factors like increase in number of jobs due to better infrastructure and increased productivity that leads to the growth in GDP. There are additional benefits to welfare and environment that tie back to the growth in GDP.

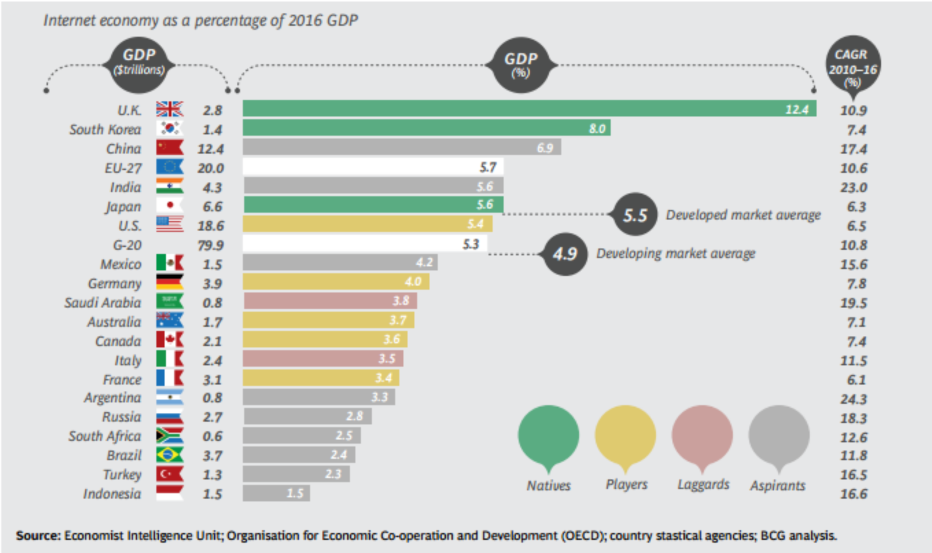
Furthermore, according to research conducted by (Phillippa Biggs 2016)[24], a 20% increase in ICT investment can lift a country's GDP by one percentage point. This makes national broadband networks extremely important to governments around the world to gain a strategic advantage. The same is also evident from the study conducted by the Boston consulting group[25]. The results, even though based on data from 2012, show surprising results with contribution of internet to GDP being 4.1% for G-20 countries, with a forecast of an increase to 5.3% by 2016 as shown in figure 14 which is very much in line with the current situation.

24

Phillippa Biggs, et al. 2016. *The state of broadband 2016: Broadband catalyzing sustainable development .* September. Accès le May 30, 2017. http://unesdoc.unesco.org/images/0024/002459/245905e.pdf.

25 Group, The Boston Consulting. 2012. *The Internet economy in the G-20.* March. Accès le March 28, 2017. https://www.bcg.com/documents/file100409.pdf.

Figure 14: Internet Economy as a percentage of GDP in the G-20 countries in 2016 (David Dean 2012)[22]



6.2.2 GDP and Average revenue per user (ARPU)

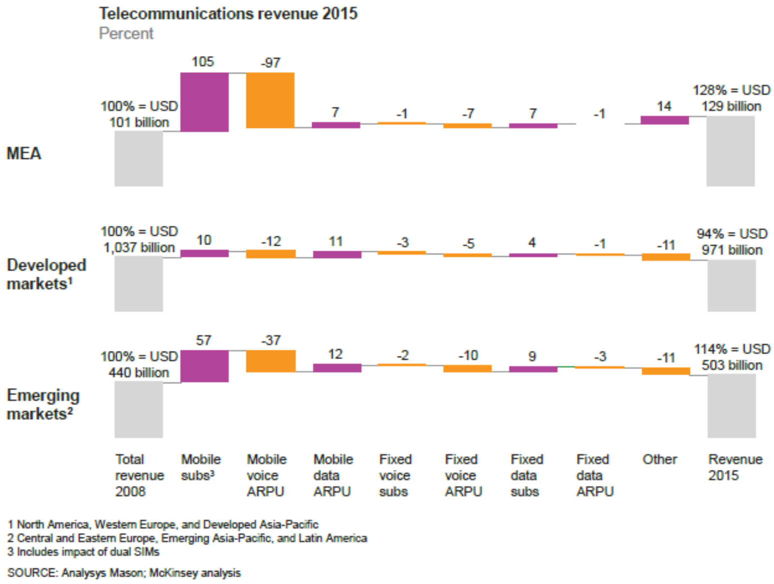
Now that the link between internet and GDP has been established and demonstrated using various studies conducted, it's essential to now look at relation between GDP and ARPU. This follows from an article from Norther Sky Research (Butani 2015)[26] that points to ARPU as one of the most significant aspect being aimed at to making satellite internet affordable.

Figure 15 below from a Mckensie & Company report[27] further shows the telecommunication revenue split for developed and emerging markets. As evident, there is a clear difference in the current ARPU's for both markets.

[26] Butani, Prashant. 2015. *GEO-HTS here today..but is LEO-HTS the future?* Report, NSR

[27] Daniel Boniecki, et al. 2016. *Telecommunications industry at cliff's edge* . Report, Mckinsey & Company.

Figure 15: Telecommunication revenues split in 2015 for developed and emerging markets *(Daniel Boniecki 2016)*[28]



To further add to the challenges faced by satellite internet sector, due to the increasing competition, there has been a rapid and continuing decrease in the ARPUs for each of these markets. In order to be able to compete with terrestrial options, there is a frantic need for major technological advancements in broadband satellite to be able to achieve the goals set by the ideas similar to those of satellite constellations for global coverage. This is discussed further in the technology section of the analysis.

6.2.3 Cost of capacity, OPEX and CAPEX

Clearly, the capacity of satellites is increasing drastically. Additional effect of this is decreasing cost of capacity, as shown in figure 16, which is essential to survive in this competitive sector (VanderMeulen 2015)[29].

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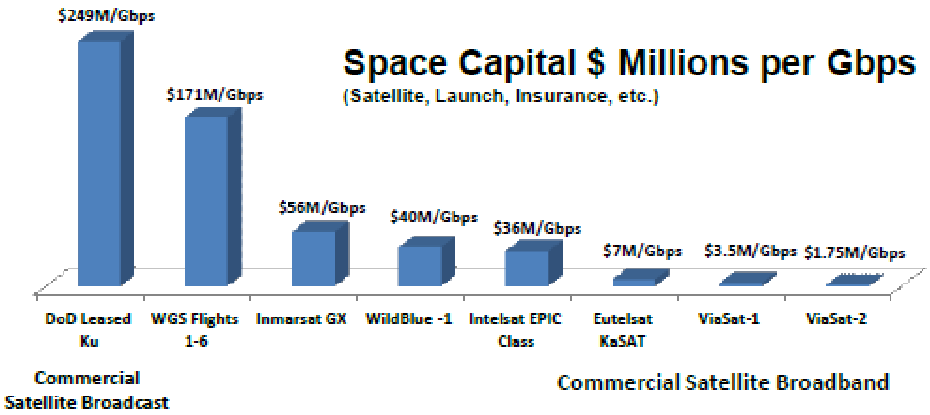
[28] Daniel Boniecki, et al. 2016. *Telecommunications industry at cliff's edge .* Report, Mckinsey & Company.

[29] VanderMeulen, Richard. 2015. *High capacity satellite communication.* Thesis, Space Symposium

Figure 16 : Reducing trend of the cost to generate capacity with new generations of broadband satellites



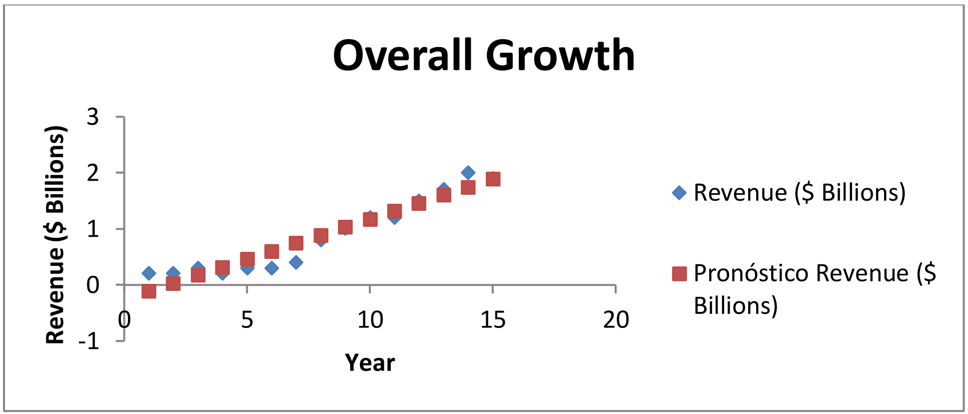
The question remains, however, if the technological developments and reduction in capital (CAPEX) and operating costs (OPEX) of satellite internet are and will be enough to compete with similar developments in already more cost-wise 'superior' terrestrial potentials.

Above stated is one of the examples of development in terms of OPEX but equally critical is the reduction in CAPEX which has, in fact, made the idea of satellite constellations thinkable and maybe even achievable. A major element for the reduction in CAPEX is yet again, the development in satellite technology. Owing to the recent developments in this field, capital expenses for satellite broadband is now cheaper than for terrestrial options, especially when comparing laying cables and fibre optics in oceans and rural and less accessible regions, according to CNES delegates.

6.2.4 Increasing revenue from broadband satellites

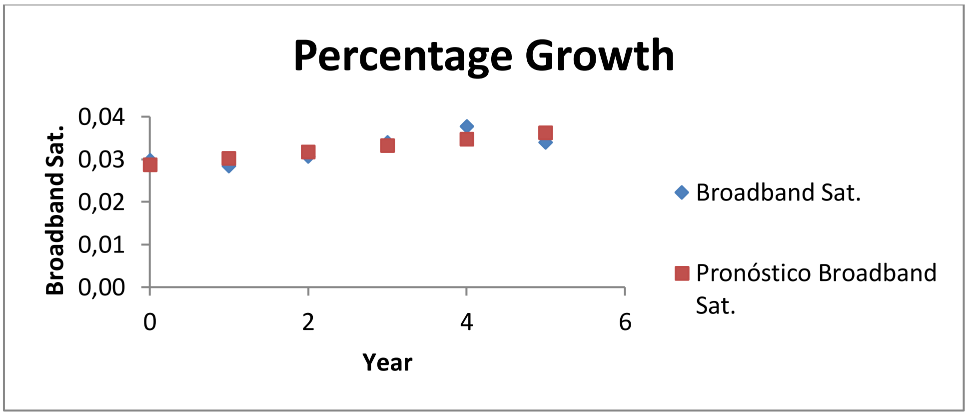
The keen interest in the broadband satellite industry is evident from the significant increase in the number of telecom satellites over last 10 or so years. Specific to satellites that serve the internet sector, linear regression of the increase in revenue over the years is shown in figure 17 with details of the analysis in the appendix.

Figure 17 : Increasing revenue in broadband satellite industry



The above figure shows the increasing revenue of the industry, however, the telecommunication industry revenues are growing as well and a much higher rate. In order to look at convergence, it is worthwhile and relevant to look at the percentage growth of revenue from broadband satellite within overall telecommunication industry. Figure () is shows the linear regression of this growth.

Figure 18 : Percentage of Broadband satellite within overall telecommunication industry



As small as this percentage increase, it is still a clear indication of the growth of satellite industry within telecommunication, and by relation, internet industry.

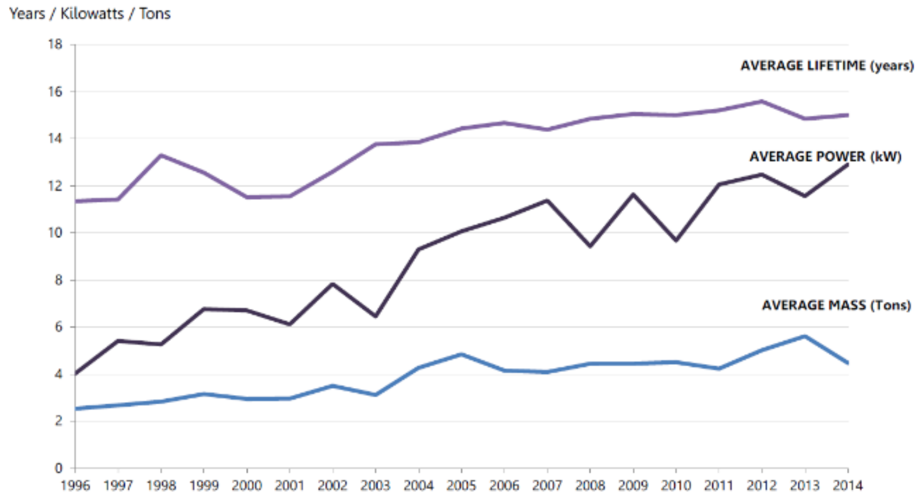
6.2.5 Resulting Convergence

Space still counts for a very small part within the telecommunication industry, in terms of revenue, even smaller is the share of broadband satellites. However, the above chart is a good indication of an increase is this share. The revenues used for this assessment are from 2010 to 2015 from (SIA 2016)[30] however, **this growth can still be seen as a relatively strong indicator of convergence between space and internet industries.**

6.3 Technology

As mentioned in the previous section, there has been there has been a vast development in technology within the space industry, from the weight of satellites, to the increased power and capacity as well as average lifetime. This is demonstrated in the figure 19 below.[31]

Figure 19 : Evolution of the GEO communication satellites



Source: Euroconsult (2014b).

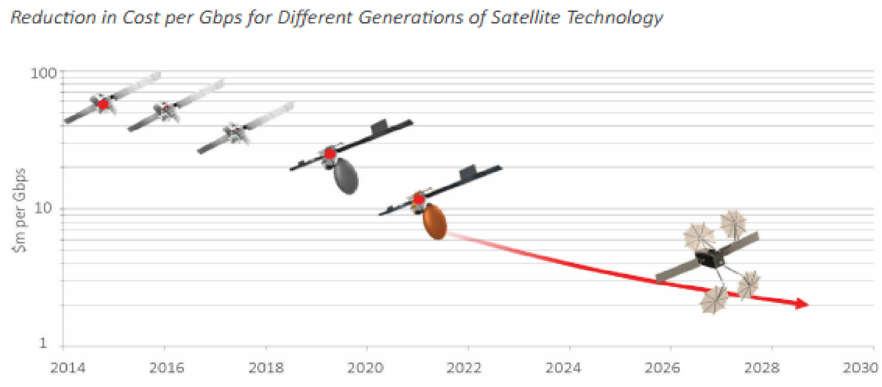
With these ongoing developments in various technologies, there has been a substantial cost decrease per Gbps in broadband satellites. Based on this trend, broadband commission has forecasted the decrease in cost per Gbps by roughly a factor of 20 by 2030 as shown in figure 20[32]

[30] SIA. 2016. *State of satellte industry.* Report, Tauri Group.

[31] Lal, Bhavya, Emily J Sylak-glassman, Michael C Mineiro, Lucas M Pratt, and Abigail R Azari. 2015. "Global Trends in Space Volume 2 : Trends by Subsector and Factors That Could Disrupt Them" 2.

[32] ITU, and UNESCO. 2016. *The State of Broadband 2016: Broadband Catalyzing Sustainable Development*. doi:10.1017/CBO9781107415324.004

Figure 20 : Impact of the development of satellite technology on cost per Gbps



Following the recommendations from CNES delegates, this report looks at three of the most significant technological developments that have and, going forward, will continue to have disruptive impact on the industry. These are:

- Miniaturizing,
- Electric propulsion,
- Inflatable antennas.

Following sub-sections will analyze these technologies based on their technology readiness level (TRL), demand readiness level (DRL) as well as market readiness level (MRL). These concepts are introduced in the sub section below prior to their application for analysis.

6.3.1 TRL, DRL and MRL Concept introduction

Technology readiness level (TRL) is a type of measurements system used to assess the maturity level of a specific technology. [33] To understand these levels, the technology is evaluated against a set of parameters and assigned a grade that corresponds to that parameter. There are nine levels, with 1 being the lowest and corresponding to the basic research in order to progress the technology. 9 is the highest level and links to certification and sales authorization.

Proposed by Florin Paun in 2010[34], Demand Readiness Level (DRL) is a new measure to assess the maturity of evolving demand towards a particular technology.

The table below shows the parameters, that this report intends to use for analysis. As illustrated in Table **Erreur ! Source du renvoi introuvable.**

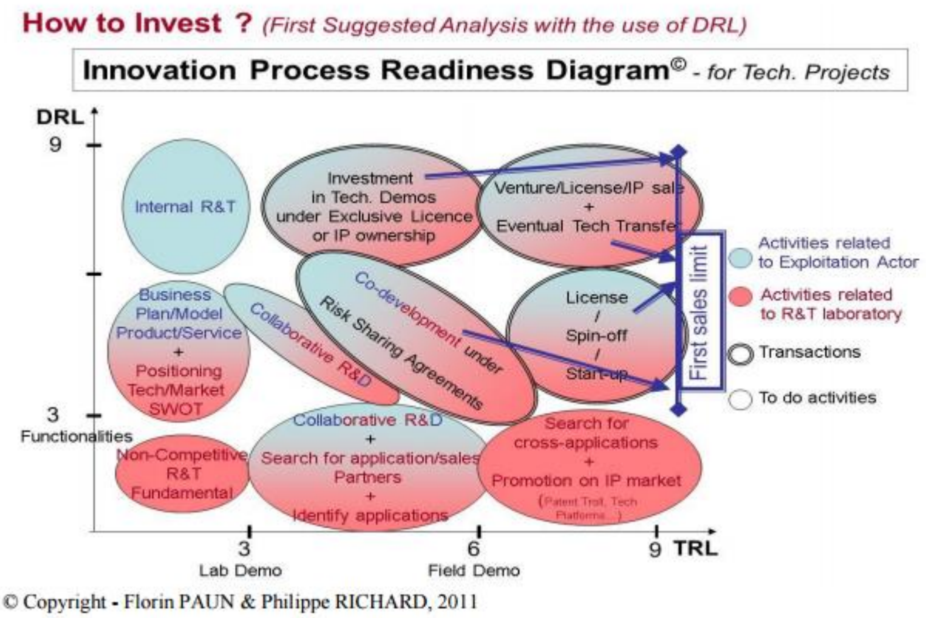
[33] NASA. https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html
[34] Paun, Florin. 2010. *Demand readiness Level.* SAL.

Table 2: DRL and description paired with TRL

DRL	DRL Description	TRL Description	TRL
1	Occurrence of feeling "something is missing"	Market Certification and Sales Authorization	9
2	Identification of specific need	Product Industrialization	8
3	Identification of the expected functionalities for a new product/service	Industrial Prototype	7
4	Quantification of expected functionalities	Field demonstration of whole system	6
5	Identification of system capabilities	Technology Development	5
6	Translation of the expected functionalities into needed capabilities to build the response	Laboratory Demonstration	4
7	Definition of the necessary and sufficient competencies and resources	Research to prove feasibility	3
8	Identification of the experts possessing the competencies	Applied Research	2
9	Building the adapted answer to the expressed need in the market	Fundamental Research	1

Innovation process readiness diagram (as it shown in figure 21) as put forward by shows the growth of technologies in terms of both, technological advancement as well as demand pull. DRL is an important tool used by investors to understand the need for a particular technology.

Figure 21 : Innovation Process Readiness Diagram



-

Table of description of TRL and DRL (shown in **Erreur ! Source du renvoi introuvable.**) also shows the parameters used for assessment for DRL. The lowest grade of 1 corresponds to occurrence of needing a new technology and grade 9, the highest relates to being able to build a solution to this 'need'.

While TRL and DRL cover the technological maturity and the demand for the technologies, Market Readiness Level (MRL) is based strongly on Florin Paun's DRL theory but include a very critical consideration of "fit". The solutions that a technology provides must fit in its designated environment. As this is a fairly new concept, this report focuses on use of MRL specifically to relate to the technology "fit" to the convergence, which is the environment for the basis of this research. Hence, there is notably a lot of discussion about satellite internet and the ideas of satellite constellations to provide global coverage in this section.

Table 3 : Combine market readiness levels (Hjorth 2016)[35]

Level	Demand Readiness	Integration Readiness	Market Readiness
1	Occurrence of feeling "something is missing"	An interface (i.e., physical connection) between technologies has been identified with sufficient detail to allow characterization of the relationship.	An acceptance that viable improvements can be made
2	Identification of specific need	There is some level of specificity to characterize the interaction (i.e., ability to influence) between technologies through their interface.	Ability to highlight where the improvement can be made
3	Identification of the expected functionalities for a new product/service	There is compatibility (i.e., common language) between technologies to orderly and efficiently integrate and interact.	Being able to identify what the system should do
4	Quantification of expected functionalities	There is sufficient detail in the quality and assurance of the integration between technologies.	Putting numbers on what is expected in terms of a solution, financially and technically
5	Identification of system capabilities	There is sufficient control between technologies necessary to establish, manage and terminate the integration.	Ability to define how the system should operate and integrate
6	Translation of the expected functionalities into needed capabilities to build the response	The integrating technologies can accept, translate and structure information for its intended application.	Identify on a component level what the system should be comprised of
7	Definition of the necessary and sufficient competencies and resources	The integration of technologies has been verified and validated with sufficient detail to be actionable.	An understanding of who should be planning, designing and implementing the solution
8	Identification of the experts possessing the competencies		Having contact with the people, internally or externally, who will design and create the solution
9	Building the adapted answer to the expressed need in the market		Solution is being created to solve a defined problem

6.3.2 Miniaturization

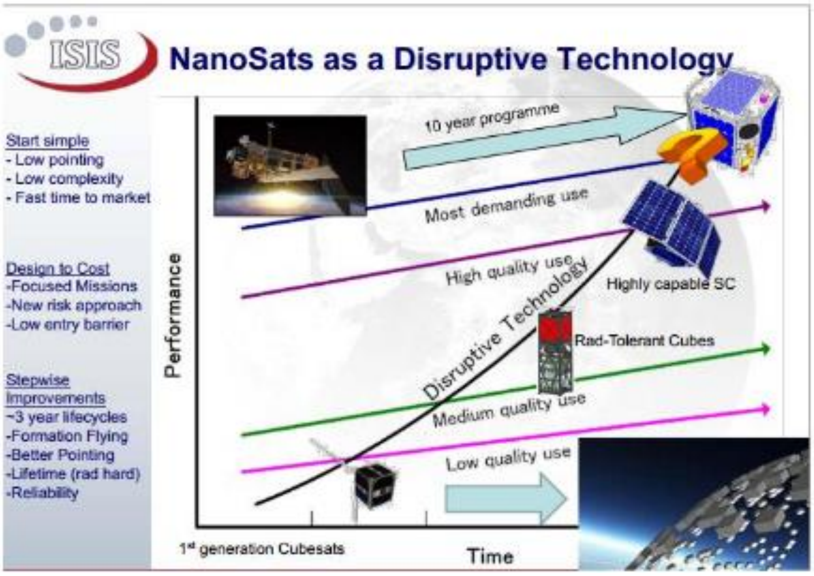
There has been an increasing emphasis on development of smaller satellites, which not only make the launch activities significantly cheaper but are able to provide relatively sophisticated services, which further indicate increasingly significant capacities available in future.[36]

[35] Hjorth, Sune Solberg. 2016. «How to access market readiness for innovative solution.»

[36] Space business & law. 2014. "Satellite Miniaturization".http://chaire-sirius.eu/wp-content/uploads/2015/07/Note-SIRIUS-Satellite-Miniaturization.pdf.23.

Figure 22 shows the development in performance of the nano- and cube-sats over years. [37]

Figure 22 : Technology growth in performance and time

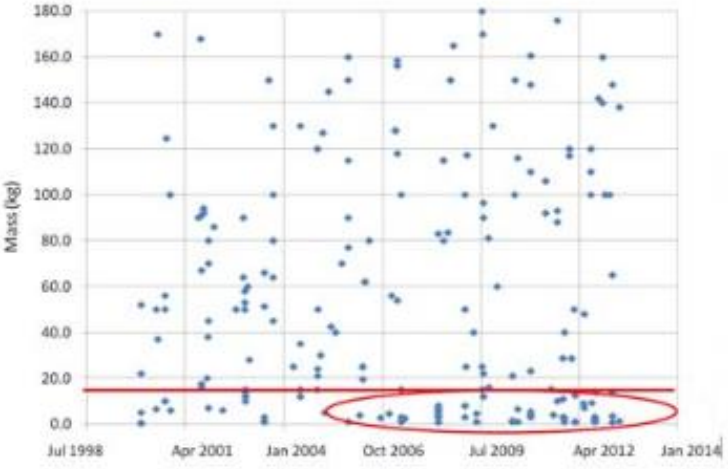


Over the years, the technology has developed enough to overcome some significant disadvantages it offered in early years in terms of quality and lifespan. Owing to these developments, number of smaller satellites have grown suggestively over the last 20 years. A study conducted by NASA [38] compares the mass of the spacecrafts over years as shown in figure 23.

[37] P.Basu. 2014. "Disruptive innovation".https://www.linkedin.com/pulse/20140929163209-70331470-strategic-response-to-disruptive-innovations-in-the-space.

[38] AMES Research Center,Moffett Field, California. 2014. "Small Spacecraft Technology State of the Art," no. February: 1–197. doi:NASA/TP–2014–216648. https://www.nasa.gov/sites/default/files/atoms/files/small_spacecraft_technology_state_of_the_art_2015_tagged.pdf

Figure 23 : Launch dates vs mass of the small spacecrafts



6.3.2.1 TRL assessment

NASA also conducted TRL analysis of various cubesats as shown in table 4. [39]

Table 4 : Integrated cubesat platforms.

Product	Manufacturer	Status	Radiation testing
Endeavour	Tyvak Nano-Satellite Systems Inc	TRL 8	10 krad
GOMX	GomSpace ApS	TRL 9	10 krad
XB1	Blue Canyon Technologies LLC	TRL 8	
Complete CubeSat Kits	Pumpkin Inc	N/A (no single configuration)	LEO parts heritage
Nukak	Sequoia Space	Unknown	Unknown

Most of the satellites have a status of 8 or higher. Based on this information and from all other available research in this area, it can be confidently stated that 'miniature' satellites are in "Product industrialization" stage within the TRL criteria, which corresponds to Grade 8 on TRL scale.

TRL score: 8

6.3.2.2 Demand Readiness Level

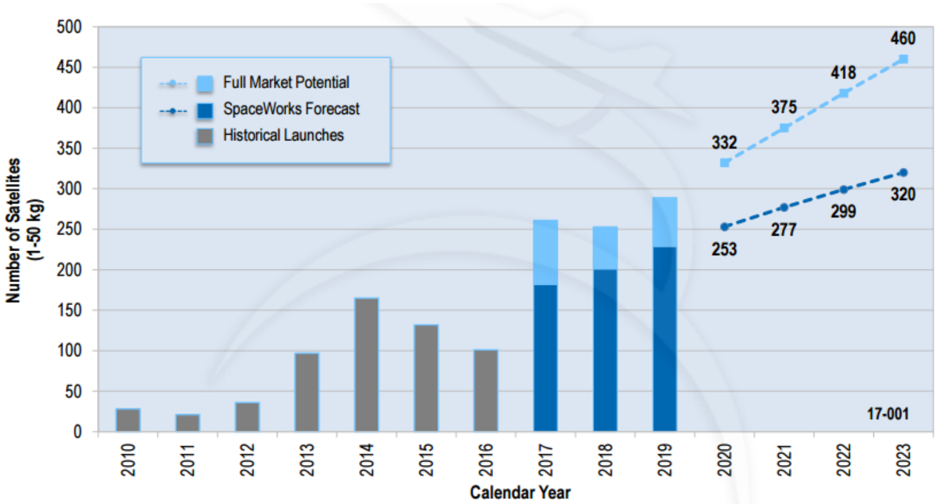
Based on the spaceworks study [40], number of smaller satellites, of mass less than 50 Kg increased from roughly 25 to around 160 from 2010 to 2014. There was an intriguing decline

[39] Shimmin, Rogan. 2015. *Small spacecraft technology state of art.* NASA.

[40] Bill Doncaster, Caleb Williams, Jordan Shulman. 2017. "2017 Nano/Microsatellite Market Forecast," 20. https://www.nasa.gov/sites/default/files/atoms/files/small_spacecraft_technology_state_of_the_art_2015_tagged.pdf.

in this number from 2014 to 2016 however, mostly due to delay in launches. This is shown in figure 24.

Figure 24 : Projections based on announced and future plans of developers and programs indicate nearly 2400 nano/microsatellites will require a launch from 2017 to 2023.



Nonetheless, there is an expected rise in this number again from 2017 and the study, which is based on announced plans and future programs, suggests that there will be a demand of as many as 2,400 nano- and micro-satellites over next 6 years. Based on this data, the demand for small satellites (less than 50Kg) identifies with two features within the criteria: "identification of the experts possessing the competencies" as well as "building the adapted answer to the expressed need in the market". With that in mind, for the purpose of this report, the DRL grade provided is 8/9.

DRL Score: 8/9

6.3.2.3 Market Readiness Level

Even with all the technological maturity and demand, there is yet a need to analyse the market readiness, specifically in terms of using small satellites for the purpose of providing internet, which is the basis of the business model of the newcomers like OneWeb, etc. According to NSR interview, there is a need for the right balance of quality, capability and price in order to be competitive. As briefly seen in the economic part of the report, even though these smaller satellites are a lot cheaper that their first generation counterparts, there is still a big question about them being cheap ENOUGH.

There are further challenges that go along with the idea of satellite constellations for the purpose of global internet provision, including latency and efficient usage of available capacity.

Similar deductions are made in article posted by Blaine Curcio and Prashant Butani [41], which states that Sub-Saharan Africa lacks sufficient ARPU to justify a concentrated consumer broadband via satellite.

In addition to this, there is another big challenge associated with the idea of small-satellite constellations and that is the ground infrastructure. The technology in terms of ground infrastructure to support the model of satellite constellations is not advanced enough at this stage and has a high cost associated with its development.

Taking into consideration these potential challenges, the market readiness of the concept of small satellites to provide global internet coverage is currently undergoing "putting numbers on what is expected in terms of solution, financially and technically", which corresponds to Grade 4 in the MRL scale, making the current MRL score for this technology a Grade 3 (being able to identify what the system should do).

MRL Score: 3

6.3.3 Electric propulsion

6.3.3.1 Technology readiness analysis

Electric propulsion (EP) is being considered a revolutionary technology in the development of next generation of satellites, due to its enhanced propulsive performance compared to the conventional chemical thrusters. EP requires very little mass to accelerate a spacecraft, making the overall system a lot more mass efficient. Need for better performance and more cost efficient has increased the popularity of electric propulsion. [42]

NASA conducted TRL analysis of various kinds of electric propulsion systems (refer appendix), the most technologically advanced, based solely on this data is Pulsed plasma and vacuum arc propulsion system.

[41] Curcio, By Blaine, and Prashant Butani. 2017. "Not for the Faint- Hearted — Opportunities on the Last True Frontier Continent,". no. October 2015: 1–10. .http://interactive.satellitetoday.com/not-for-the-faint-hearted-opportunities-on-the-last-true-frontier-continent/

[42] Esa. http://www.esa.int/Our_Activities/Space_Engineering_Technology/What_is_Electric_propulsion

Table 5 : Pulsed plasma and vacuum arc propulsion systems

Product	Manufac-turer	Thrust	Power	Specific Impulse	Propellant	Status
PPTCUP	Mars Space and Clyde Space	40 μN	2 W	655 s	PTFE	TRL 6
NanoSat PPT	Mars Space and Clyde Space	90 μN	5 W	640 s	PTFE	TRL 5
μCAT	GWU and USNA	1 to 50 μN	2 to 14 W	2500-3000 s	Titanium	TRL 7
BmP-220	Busek	20 μN-s Impulse bit	1.5 W	536 s	PTFE	TRL 5
MPACS	Busek	80 μN-s Impulse bit	10 W	827 s	PTFE	TRL 8

Based on this information and the current status of most EP technologies, the best fit in terms of TRL category would be "industrial prototype", which would put this technology at a Grade 7.

TRL Score: 7

6.3.3.2 Demand Readiness Analysis

Even with the ongoing technological improvements, the demand for these technologies has not been significant until recently. This change was triggered after Boeing signed a contract with ABS and Eutelsat for four all electric satellites following an even in 2010 that demonstrated the extent of electric power thruster when one of their satellites suffered an anomaly with its main electric propulsion system. With the benefit of reduction in mass of propellant, satellites can now carry a significantly bigger payload. This is another big driver for increased interest towards electric propulsion. One of the main challenges of it, on the other hand is the increased amount of time required to reach final orbit, which can and in most cases is countered by the above mentioned benefits. [43]

Accordingly, the demand readiness level of electric propulsion can be recognized as currently being in the phase of "translation of the expected functionalities into needed capabilities to build the response". Therefore, the DRL score translates to Grade 6.

DRL Score: 6

6.3.3.3 Market Readiness analysis

In order to evaluate the market readiness for electric propulsion systems, it is important to understand the advantages it brings to broadband sector specifically. That is, if this technology

[43] Federal Aviation Administration. 2015. "2015 Commercial Space Transportation Forecasts,". 44.https://www.faa.gov/about/office_org/headquarters_offices/ast/media/Commercial_Space_Transportation_Forecasts_2015.pdf.

is a good "fit" for the purpose of this investigation towards the relationship between space and internet sectors.

With the increase performance and benefits of being able to add additional payload or additional satellites is quite relevant in enabling the presence of satellite constellations to provide global internet coverage. From the economic section of the report, it is quite apparent, one of the biggest challenge in the past of success of this concept is the costs, both OPEX and CAPEX. Further development in the technology of electric propulsion directly helps to reduce those costs. As such this technology could correspond to grade 7, "an understanding of who should be planning, designing and implementing the solution".

MRL Score: 7

6.3.4 Inflatable Antennas

This section looks at fundamentally the same technology and similar used, just in two different environments. And that one difference creates a massive difference in the availability and application of it. With the new developments in the technology of satellites with smaller sized, cheaper, more efficient satellites, there exists a constraint in terms of communication range. Inflatable antennas on cube-sats are a solution to this problem. This is the main technology focused on in this section.

The other challenges with the ongoing development of satellite constellations, as mentioned in the previous section is the maturity of ground equipment. And again, inflatable antennas on ground can be a potential solution to this problem.

6.3.4.1 Technology Readiness Level (TRL) assessment

According to the study conducted[44]**,** researchers at MIT have designed and tested an inflatable antenna that can fold into a compact space and inflate when in orbit. This antenna amplifies the radio signals, which could enable Cube-sats to transmit data back to Earth at a much higher rate than currently possible.

Study conducted by NASA, assessed the TRL of a number of inflatable antenna options. Even with the latest developments in technology, this particular area seems to be developing relatively slowly. The readiness of this technology and concept seems to be at about the same level now as it was back in 2006, when the study was conducted, with a move from "laboratory demonstration" to "technology development", giving it a TRL grade of 5.

Similar is the development of ground inflatable antennas. With the exception of GATR, who have successfully developed inflatable satellite antennas, there isn't any other significant progress in this area. However, GATR development in itself is quite noteworthy and opens up a lot of opportunities in terms of accessing satellite internet in remote locations. According to the article[45]**,** GATR signed a

[44] Chu, Jennifer. 2017. "Inflatable Antennae Could Give CubeSats Greater Reach," 1–4. http://news.mit.edu/2013/inflatable-antennae-could-give-cubesats-greater-reach-0906.

[45] Félix A. Miranda*, James A. Nessel, Robert R. Romanofsky and Rober J. Acosta. 2006. "A REVIEW OF ANTENNA TECHNOLOGIES FOR FUTURE NASA A Review of Antenna Technologies for Future NASA Exploration Missions," 33 .https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110000847.pdf

memorandum of understanding with OneWeb to develop electronically scanned array antennas for the operator's global aviation broadband service. This falls in between the categories of "technology development" and "field demonstration of the whole system", grading this technology between 5 and 6.

TRL Score: 5

6.3.4.2 Demand readiness Assessment

There is a clear demand for both in-ground as well as in-space inflatable antennas. As the satellites go smaller in size, which seems to be the clear trend, there will be a need for antennas that could inflate in space so as to respect the size and mass constraints of the smaller satellites.

Similarly, the ground inflatable antennas, as already demonstrated by the growing need of GATR inflatable antennas, due to its light weight and compact rolled up size, can be used in the most remote areas of the world.

As such, the demand readiness of these technologies falls under the category "Translation of the expected functionalities into needed capabilities to build the response", giving this technology a market readiness score of 6.

DRL Grade: 6

6.3.4.3 Market Readiness assessment

Again, for the assessment of market readiness, it's important to note the relevance of these technologies in space telecommunication sector, and more precisely, the internet sector. As previously discussed, these two technologies are quite possibly the missing links that can make the dream of satellite constellations to prove internet access globally.

As cube-sats are a big part of this concept, it makes the availability of inflatable space antennas quite advantageous. Similarly, as discussed in the previous sections, the ground inflatable antennas, being relatively cheap and easily accessible can solve one of the biggest challenges facing this concept. [46]

Taking the relevant advantages into account, the market readiness level for these technologies a grade 5, "ability to define how the system should operate and integrate". [47]

6.3.5 Resulting Convergence

[46] Chu, Jennifer. 2017. "Inflatable Antennae Could Give CubeSats Greater Reach," 3.
[47] Torruella, By Anika. 2017. "Next Generation Technology Signals the Future of Antenna Innovation," no. July 2015: 1–16. http://interactive.satellitetoday.com/next-generation-technology-signals-the-future-of-antenna-innovation/

As expressed in problem definition, satellite industry is facing numerous challenges against terrestrial counterparts. The technologies mentioned in this section are the key to resolving these challenges. At a very high level, the technologies discussed above can reduce the limitations as below.

- Miniaturization helps with lowering the capital cost of satellite broadband,
- Electric propulsion helps with lowering the operating cost of satellite broadband
- Inflatable antennas are a solution to resolving the terrestrial infrastructure problem also related to the capital cost.

As mentioned in the problem description, the assumption for this study is that reduction in limitations results in growth of application of broadband satellites, thereby increasing the revenue share within telecommunication.

6.4 Legal

With the rapid technological developments within telecommunication industry, especially involving satellite broadband, there are bound to face regulatory and legal challenges that haven't developed quite at the same pace as the technologies.
Satellites are now considered a global communication technology. Its functionality depends on international governance of radio spectrum at its core, with its ability to reach and connect millions of people across borders at any given time. As such, any political decision at national or regional level can have a drastic impact on not only space but overall internet industry. [48]

This section briefly touches on some of the key regulations and laws that influence this industry, and can have significant impact on the future of this sector. [49]

6.4.1 Spectrum allocation and band interference

Radio frequency spectrum is a significant component in space activities. Most satellites use a portion of RF spectrum to communicate with ground or other satellites. RF is a limited resource and as such RF congestion from growing number of satellites needs to be handled by a regulatory framework. International Telecommunication Union (ITU) is responsible for the management of RF spectrum at an international level. Table 6 shows the frequency bands used by satellites for various applications. [50]

[48] Helseth, Ania. n.d. "SATELLITES & SPECTRUM The Right Wavelength," 6. https://www.esoa.net/Resources/Satellites-and-Spectrum-Publication.pdf.

[49] Friedrich, Robert B. 1995. "Regulatory and Antitrust Implications of Emerging Competition in Local Access Telecommunications : How Congress and the FCC Can Encourage Competition and Technological Progress in Telecommunications" 80 (3): 50.

[50] Helseth, Ania. n.d. "SATELLITES & SPECTRUM The Right Wavelength," 5.

Table 6 : Spectrum allocation

S-DAB	1.467 GHz to 1.492 GHz	Satellite Audio Broadcasting to fixed & mobile units
L-Band	1.518 GHz to 1.675 GHz	Civilian Mobile-Satellite Services (two-way)
S-Band	1.97 GHz to 2.69 GHz	Satellite television & radio broadcasting to mobiles + two-way mobile services
C-Band	3.4 GHz to 7.025 GHz	Fixed-Satellite television & data services (including broadcasting)
Ku-Band	10.7 GHz to 14.5 GHz	Fixed-Satellite television & data services (including broadcasting)
Ka-Band	17.3 GHz to 30 GHz	Fixed-Satellite television & data services (including broadcasting)

Fig.4 Frequency bands used by Satellites[2]

Ka band satellite has now become one of today's fastest-growing technologies because of the growing demand for capacity and increase in technologies supporting the use of more bandwidth-intensive services.

Interference is another big challenge facing telecommunication satellites. Not only can there be unintentional interference created in GEO orbit due to the close proximity of satellites, most of which use similar frequencies, there is a growing issue of interference of satellites in LEO and MEO with those sharing the same Ku bandwidth in GEO. [51] Figure 25 displays how these interferences that could occur. Natural events like heavy rain or snow can also cause interference for certain frequencies.[52]

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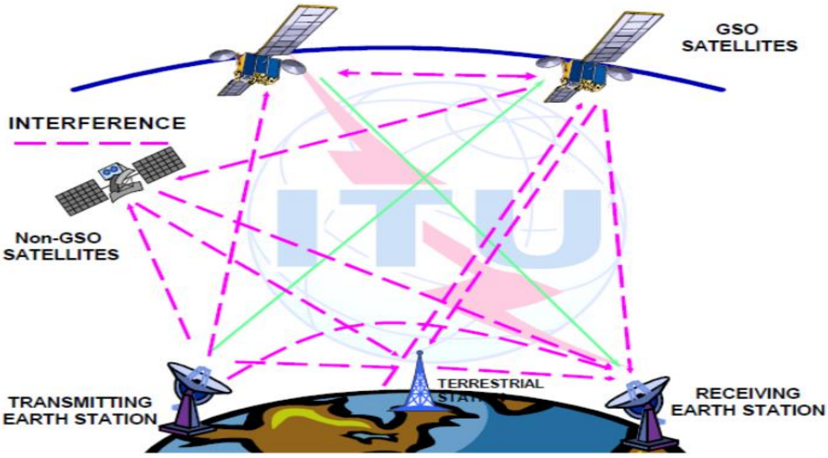
51 Weeden, Brian. 2013. "Radio Frequency Spectrum, Interference and Satellites Fact Sheet," 17. https://swfound.org/media/108538/swf_rfi_fact_sheet_2013.pdf

52 ITSO. n.d. "B2: Basics of Satellite Communications: Policy and Regulation," 1–33. http://www.itso.int/images/stories/Capacity-Building/Addis-Ababa-2015/B-II_Basics_of_Satellite_Communications_Policy_and_Regulation.pdf

Figure 25 : Frequency interferences



With the increasing demand for high speed wireless networks, there is an exploration into concept of shared spectrum, which, aside from the benefits of efficient use of a naturally restricted resource, can be extremely challenging to manage. [53]

Some of the actions being undertaken and further investigated by satellite operators to resolve this issue are:

- Same frequency being used between different orbital positions
- Re-use of same frequencies by different spot beams of one satellite
- Capacity leasing to third party operators
- Trading of orbital positions

These actions help satellite operators increase the total capacity without increasing the allocated bandwidth. In addition, more harmonized frequencies for planned satellite systems are under construction at present. There are also further negotiations currently underway regarding allocation of additional spectrum in line with the increasing capacity.[54]

6.4.2 Anti-trust laws

The main idea that the anti-trust laws are created on, is to encourage competition and in doing so, discourage monopolistic situation. However, in some cases, as quite notable within telecommunication industry, the way in which some of the anti-trust regulations are enforced can actually restrict the competition, that ironically, these laws are created to protect.
Due to the fast pace technology progress and highly competitive nature of the telecommunication industry, anti-trust laws can be quite in-efficient in achieving best level of competition in the market.

[53] Weeden, Brian. 2013. "Radio Frequency Spectrum, Interference and Satellites Fact Sheet," 10.
[54] Helseth, Ania. n.d. "SATELLITES & SPECTRUM The Right Wavelength," 4.

Local access markets are often ignored from the assessment of competition in the industry, which can sometimes provide incorrect indication of the realistic status.

There is a big difference in the environment, technology and overall industry from when the anti-trust laws were first created to present. There is a definite need for the regulatory schemes to be streamlined to accommodate not only the technological but financial growth of the sector. It is quite clear that telecommunication industry is highly time sensitive and must be regulated as such.

6.4.3 Neutrality and "Open Skies" policy

6.4.3.1 Network Neutrality

Network Neutrality is one of the most suitable regulation that exists in telecommunication industry. In simple terms, it allows broadband users to subscribe to any service or content without any interference from the broadband providers. This regulation has been put in place to avoid infrastructure based providers getting an unfair competitive advantage over the ones without the infrastructure. This is done by means of additional fees that is charged to the infrastructure based providers to keep the environment fair and impartially competitive. (Nelson 2015)[55]

6.4.3.2 Technology Neutrality

In addition to network neutrality, technology neutrality is used as a competition principle that prevents unnecessary discrimination against any technology or communication system. It enables sharing the same frequency bands without preference to any single technology over the other. There needs to be some control over technology, however, to avoid interferences resulting from sharing, which could potentially harm the quality of the service delivered to the end user.

Another aspect of technological neutrality is "equity", which states that the same rules should apply to all licenses, regardless the person, company or industry is represented.

Due care is required to make sure that licensing requirements do not become barriers to free trade, but accomplish legitimate regulatory objectives. If practiced proficiently, technological neutrality can result in healthy competition, increased demand and higher cost savings. [56]

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[55] Nelson, Ekow. 2015. *Five telling years, four future scenarios.* Telco.

[56] ITU. 2012. "Regulation of Global Broadband Satellite Communications," 56. http://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_RegulationBroadbandSatellite.pdf.

6.4.3.3 *Service Neutrality*

Service neutrality allows satellite operators to choose the services they want to offer in any frequency band. This is quite helpful as the satellite industry provides diverse range of application in the same frequency bands.
It hold particular importance for the idea of satellite constellations due the geographical diversity that needs to be served. [57]

6.4.3.4 *Open skies policy*

There are two main considerations to promote an open, competitive market. First and foremost, it is vital that the regulation are set such that there is no discrimination in favour of existing service provider. There should also not be a limitation to the number of service providers that are permitted to provide satellite and communication services to the final user.
Second consideration, is what is referred to as "open skies" policy. Under this policy, there is no discrimination in terms of market access between domestic and non-domestic satellite and telecommunication service providers. This allows satellite operators to not be limited to the countries that have corporate presence in to provide service.
This is quite an essential policy that has a big impact on the future of satellite internet and especially the concept of satellite constellations to provide global internet coverage. [58]

6.4.4 Resulting Convergence

Referring back to the current limitations or future challenges of satellite industry, it is clear that spectrum allocation, interferences, network neutrality and other regulations mentioned above can have a huge impact on the growth of this industry.
This report looks at this section very briefly as the legal regulations require an in depth analysis and impact on all aspects of the environment, which are out of scope of this report.

With specific attention to broadband satellites only, it can be stated that liberalization of regulations with caution to interference as discussed above can resolve one of the biggest challenges facing the industry. This could result in growth of the broadband satellite sector within telecommunication industry.

With that in mind, this particular factor provides a weak indicator for convergence, with recommendations to the reader is to delve into this aspect further to examine the impacts on the industry.

[57] Helseth, Ania. n.d. "SATELLITES & SPECTRUM The Right Wavelength," 3.
[58] ITSO. n.d. "B2: Basics of Satellite Communications: Policy and Regulation," 20.

7 Discussion

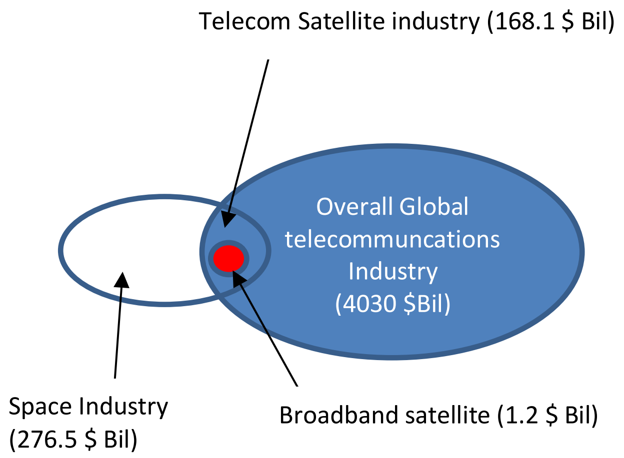
7.1 Established indicators

From the analysis, the convergence has been established via three main factors; economic, technological and legal. As stated above, economic factor has provided a strong indicator for the convergence in form of percentage revenue increase of the satellite broadband industry within telecommunication.

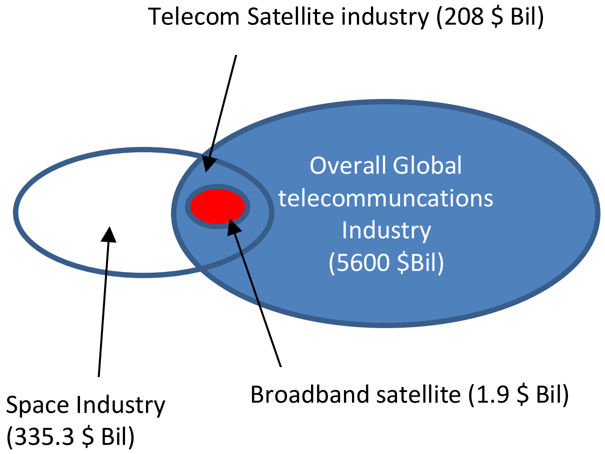
Other indicators analyzed through technological and legal factors emphasize this convergence further and all together provide a strong indication of this convergence, even though, by themselves, they are relatively weak.

Figure 26 below simplifies the analysis in terms of comparison of the share of revenue of telecommunication, space, satellite and broadband satellite industries in 2010 and the latest available information of 2015.

Figure 26 : Revenue comparison of space and telecommunication industry



Revenues in 2015



With these converging trends and limitations of the study established, this report looks further into the influence of this convergence on businesses and future revenue growth, with the same converging factors as the basis. This is also another view towards convergence that needs to be investigated further. The aim of this section is to introduce this work as foundation for further study, with the convergence indicators proposed already.

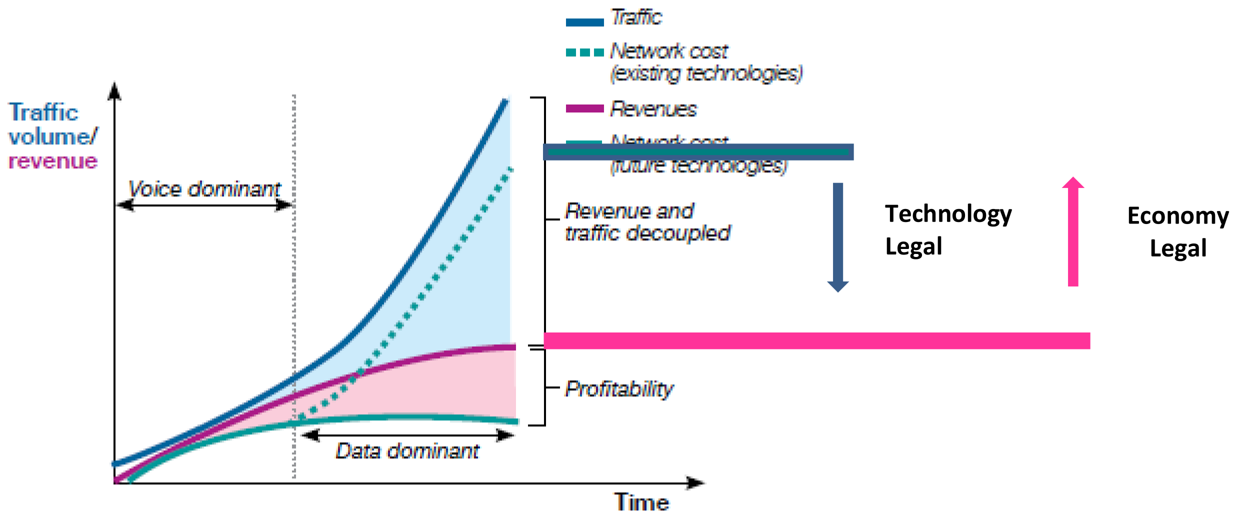
7.2 Foundation for further investigation into convergence

After the advent of internet, one of the brightest spots in the ICT industry is the phenomenal growth of broadband services and the growth of data connectivity service. At the beginning, the flat tariffs model applied by telecom operators seemed to be the correct charging model. However, with flat tariffs, costs no longer match revenues for delivering an ever-increasing amount of data over a network designed to support lightweight download, web browsing and e-mails.

Essentially revenue and traffic volumes are disconnected as telecom industry becomes more data connectivity-centric. Historically, traffic and revenue have tracked along the same path. After the advent of internet, however, they have diverged. This disassociation is known as the decoupling of traffic and revenue (figure 27). [59]

[59] Nelson, Ekow, and Rob den Dam Van. 2015. "Telco 2015-IBM Institute for Business Value Telco," 5. http://www-05.ibm.com/cz/gbs/study/pdf/GBE03304USEN.PDF

Figure 27 : Revenue and traffic are disassociated in an increasingly data-dominant world



Source: IBM Institute for Business Value (2015)

In order to contextualize the decoupling of traffic and revenue concept in terms of satellite and internet industry, traffic volumes is mainly linked with the top innovations (internet industry) and the revenue and network costs linked with the actors involved in connectivity service (telecom and network operators).

As it is discussed in the previous section, three factors such as technology, economy and legal are identified as key drivers in the convergence between satellite and internet industry. However, at the same time, it is interesting to note the strategic positions among actors in the ICT ecosystem. In a general overview, on the one hand, the internet industry takes advantage of the traffic growth but on the other hand, legacy telecom service providers are struggling to reduce the network cost and the revenue and traffic are decoupled.

Taking into account the position of the satellite industry regarding to the decoupling of traffic and revenue situation, it is necessary to address the drivers of convergence over the revenue and cost networks lines in order to increase the participation of the satellite industry in the data dominant world.

Referring to figure 27, according to the technological convergence factors established in the previous section, future technologies and their respective convergence will decrease the cost of the network (CAPEX) and operation and maintenance (OPEX). Regarding the revenue line of telecom and connectivity service providers, they are struggling to monetize the OTT innovations or traffic volume. New business model or new ways of charging the traffic volume are of great significance to overcome the weak flat rate model. Furthermore, the legal driver (for example, the liberalization of telecom market) will increase the possibility to provide new services and to participate in the content, application services and management data.

In general, the growing role of the internet in the economy and society has enhanced the process of convergence among the ICT participants. Today, innovative offers and new business models in the communications sector are stemmed from convergence in network technologies, services, terminal equipment and regulations. A clear example, the combination of digitalization of content, Internet protocol, and the adoption of high speed broadband are bringing previously distinct communication networks and services together in one network.

In the current idea, the satellites are mostly used to broadcasting, connectivity in remote areas or extreme situations and as back up telecom systems. However, the data dominant world requires full-time broadband access to users, tendency that uncovers gaps in the primary or terrestrial networks. Today broadband must be available everywhere, there is new wave of demand for satellite connectivity and terrestrial carriers have begun addressing this demand through the development of converged networks. The new generation network is a key example in the search of convergence in the core and access terrestrial, wireless and satellite communications technology. Moreover, only with satellite communications this idea can stretch broadband around the globe and serve every customer need, which is the ultimate next generation goal.

7.3 Recommendation for further investigation

According to the established scope and limitations of this research, the reader is advised to investigate further two main aspects presented in this report. These are:

- Relationship between space and telecommunication to understand the revenue growth of each sector
- Relationship between the increasing number of users and the increasing revenue

As mentioned above, the decoupling of revenue and traffic is a major concern for business in the industry. As such, further analysis into this area is of great importance in order for businesses in the industry to take advantage of the future developments in the industry, which is not the case at present. It is quite clear that both internet and space play a vital role in this area.

8 Conclusion

The study conducted in this research was aimed at investigating the existing relationships between actors within space and telecommunication industries. The approach used for this report used value chain as the basis to develop these relationships. Telecommunication was established as the link between these industries. Ecosystem concept proposed in this report further helped to identify the dynamics of the actors involved in the two industries, thereby further emphasizing the connection in form of telecommunication.

Deeper investigation into the telecommunication system and space value chain defined the scope of the study further by helping move the focus towards broadband satellites.

Convergence factors were then established as economic, technological and legal that were investigated in depth. The analyses focused on the growing trends in each of these factors relating to space and telecommunication industry. Investigation into economic factors revealed the increasing proportion of revenue from broadband satellites within telecommunication industry, which proved to be the strongest indicator of convergence in this study.

Technological developments and evolution of regulatory requirements further helps to understand their impact on the growth of satellite industry, with specific interest towards broadband satellites. Growth in technology and discussions around liberalization of some significant legal regulations, especially in terms of spectrum allocation are seen to reduce the current challenges facing the satellite industry. Elimination or reduction of these challenges is assumed for the purpose of this study as an indication of growth of the sector, by default.

The report goes one step further by using the convergence between internet and space and the convergence factors to investigate the impact on businesses in the industry. One of the biggest challenges that the businesses are facing comes in the form of decoupling of traffic and revenue. A foundation has been created by linking the convergence factors to this decoupling effect, however further analysis is essential to conclude this relationship, as recommended in the report.

9 References

Alpheus Bingham, Dwayne Spradlin. 2011. “The Long Tail of Expertise - Alpheus Bingham, Dwayne Spradlin - Google Livres.pdf.”

AMES Research Center,Moffett Field, California. 2014. “Small Spacecraft Technology State of the Art,” no. February: 1–197. doi:NASA/TP–2014–216648.

Basolea R.; Parkb H.; Barnettc B. (2015) Coopetition and Convergence in the ICT ecosystem. Telecommunications Policy. Volume 39, Issue 7, Pages 537-552

Butani, Prashant. 2015. GEO-HTS here today..but is LEO-HTS the future? Report, NSR

Bill Doncaster, Caleb Williams, Jordan Shulman. 2017. “2017 Nano/Microsatellite Market Forecast,” 20. https://www.nasa.gov/sites/default/files/atoms/files/small_spacecraft_technology_state_of_the_art_2015_tagged.pdf.

Campbell, Dan, and Sherlock Campbell. 2008. “Introduction to Regression and Data Analysis.” Analysis, 3. http://statlab.stat.yale.edu/workshops/IntroRegression/StatLab-IntroRegressionFa08.pdf.

Chu, Jennifer. 2017. “Inflatable Antennae Could Give CubeSats Greater Reach,” 1–4. http://news.mit.edu/2013/inflatable-antennae-could-give-cubesats-greater-reach-0906.

Commission, European. 2017. “Connectivity for a European Gigabit Society.” https://ec.europa.eu/digital-single-market/en/connectivity-european-gigabit-society.

Curcio, By Blaine, and Prashant Butani. 2017. “Not for the Faint- Hearted — Opportunities on the Last True Frontier Continent,” no. October 2015: 1–10. http://interactive.satellitetoday.com/next-generation-technology-signals-the-future-of-antenna-innovation/.

Daniel Boniecki, et al. 2016. Telecommunications industry at cliff's edge . Report, Mckinsey & Company.

Dr Adam Gorden. 2008. “Scenario-Building-Workshop-How-to-Build-and-Use-Scenarios-1-638.pdf.” https://fr.slideshare.net/adgo/scenario-building-workshop-how-to-build-and-use-scenarios?next_slideshow=1.

Dutta, Soumitra, Thierry Geiger, and Bruno Lanvin. 2015. The Global Information Technology Report 2015.

Ericsson, Arthur D Little and Chalmers University of Technology. 2013. SOCIOECONOMIC effects ofbroadband speed. September. Accès le April 2017. https://www.ericsson.com/res/thecompany/docs/corporate-responsibility/2013/ericsson-broadband-final-071013.pdf

Federal Aviation Administration. 2015. “2015 Commercial Space Transportation Forecasts,” no. April.

Félix A. Miranda*, James A. Nessel, Robert R. Romanofsky and Rober J. Acosta. 2006. “A REVIEW OF ANTENNA TECHNOLOGIES FOR FUTURE NASA A Review of Antenna Technologies for Future NASA Exploration Missions,” 33.

Fransman M. (2002) Telecoms in the Internet Age, From Boom to Bust to Oxford University Press.

Friedrich, Robert B. 1995. “Regulatory and Antitrust Implications of Emerging Competition in Local Access Telecommunications : How Congress and the FCC Can Encourage Competition and Technological Progress in Telecommunications” 80 (3): 50.

Gerry Johnson, Richard Whittington, Kevan Scholes, Duncan Angwin, Patrick Regner. “Exploring Strategy.” 10th Edition, , Pearson Edition

Group, The Boston Consulting. 2012. The Internet economy in the G-20.March. Accès le March 28, 2017. https://www.bcg.com/documents/file100409.pdf.

Helseth, Ania. n.d. “SATELLITES & SPECTRUM The Right Wavelength,” 6. https://www.esoa.net/Resources/Satellites-and-Spectrum-Publication.pdf.

ITSO. n.d. “B2: Basics of Satellite Communications: Policy and Regulation,” 1–33.

ITU. 2012. "Regulation of Global Broadband Satellite Communications," 56. http://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_RegulationBroadbandSatellite.pdf.
———. 2014. "ITU Releases 2014 ICT Figures.pdf." http://www.sia.org/annual-state-of-the-satellite-industry-reports/2014-sia-state-of-satellite-industry-report/.
ITU, and UNESCO. 2014. The State of Broadband 2016: Broadband Catalyzing Sustainable Development. doi:10.1017/CBO9781107415324.004.
Lal, Bhavya, Emily J Sylak-glassman, Michael C Mineiro, Lucas M Pratt, and Abigail R Azari. 2015. "Global Trends in Space Volume 2 : Trends by Subsector and Factors That Could Disrupt Them" 2.
McLuhan, Marshall. 1964. "McLuhan Understanding Media The Extensions of Man London and New York." Basieexpsispittedu, 43. doi:10.2307/2711172.
Meeker, Mary. 2016a. "KPCB-- Global Smart Phone User Growth." http://www.kpcb.com/blog/2016-internet-trends-report.
———. 2016b. "KPCB-- Performance of 5 Groups of Countries Facing Internet Barriers." http://www.kpcb.com/blog/2016-internet-trends-report.
———. 2016c. "KPCB--Global Internet Market Leader.pdf."
Miniwatts Marketing Group. 2014. "Internet Growth Statistics - the Global Village Online." Global Village Online.
Moore, James F. 2006. "Business Ecosystems and the View from the Firm" 51 (1): 2–4. doi:10.1525/sp.2007.54.1.23.
National Aeronautics and Space Administration. n.d. "Emerging Space," 42. https://www.nasa.gov/sites/default/files/files/Emerging_Space_Report.pdf.
Nelson, Ekow, and Rob den Dam Van. 2015. "Telco 2015-IBM Institute for Business Value Telco," 5.
Paun, Florin. 2011. "' Demand Readiness Level ' (DRL), a New Tool to Hybridize Market Pull and Technology Push Approaches" 2011: 2–5.
Pacôme Révillon, Euroconsult. (2016). Economic aspects of the space sector
Razani M. (2012) Information, Communication, and Space Technology. CRC Press – Taylor & Francis Group – USA
Phillippa Biggs, et al. 2016. The state of broadband 2016: Broadband catalyzing sustainable development .September. Accès le May 30, 2017. http://unesdoc.unesco.org/images/0024/002459/245905e.pdf.
Porter M. (1985) Competitive Advantage: Creating and Sustaining Superior Performance. Originally published; New York: Free Press; London: Collier Macmillan.
space business & law. 2014. "Satellite Miniaturization," 23. https://www.nasa.gov/sites/default/files/atoms/files/small_spacecraft_technology_state_of_the_art_2015_tagged.pdf.
Space foundation. 2016. "The Authoritative Guide to Global Space Activity," 7. https://www.spacefoundation.org/sites/default/files/downloads/The_Space_Report_2016_OVERVIEW.pdf.
The Space Economy at a Glance 2011 By OECD.

Torruella, By Anika. 2017. “Next Generation Technology Signals the Future of Antenna Innovation,” no. July 2015: 1–16.
Weeden, Brian. 2013. “Radio Frequency Spectrum, Interference and Satellites Fact Sheet,” 17.
XIE, MING. 2008. “Value Chain and Business Model Analysis of ICT Services in Context of Next Generation Network,” no. May: 63–76.

Butani, Prashant. 2015. *GEO-HTS here today..but is LEO-HTS the future?* Report, NSR.
Daniel Boniecki, et al. 2016. *Telecommunications industry at cliff's edge .* Report, Mckinsey & Company.
David Dean, et al. 2012. *The Internet economy in the G-20.* March. Accès le March 28, 2017. https://www.bcg.com/documents/file100409.pdf.
Ericsson, Arthur D Little and Chalmers University of Technology. 2013. *SOCIOECONOMIC effects of broadband speed.* September. Accès le April 2017. https://www.ericsson.com/res/thecompany/docs/corporate-responsibility/2013/ericsson-broadband-final-071013.pdf.
Hjorth, Sune Solberg. 2016. «How to access market readiness for innovative solution.»
Nelson, Ekow. 2015. *Five telling years, four future scenarios.* Telco.
Paun, Florin. 2010. *Demand readiness Level.* SAL.
Phillippa Biggs, et al. 2016. *The state of broadband 2016: Broadband catalyzing sustainable development .* September. Accès le May 30, 2017. http://unesdoc.unesco.org/images/0024/002459/245905e.pdf.
Shimmin, Rogan. 2015. *Small spacecraft technology state of art.* NASA.
SIA. 2016. *State of satellte industry.* Report, Tauri Group.
VanderMeulen, Richard. 2015. *High capacity satellite communication.* Thesis, Space Symposium.

Appendix

Regression

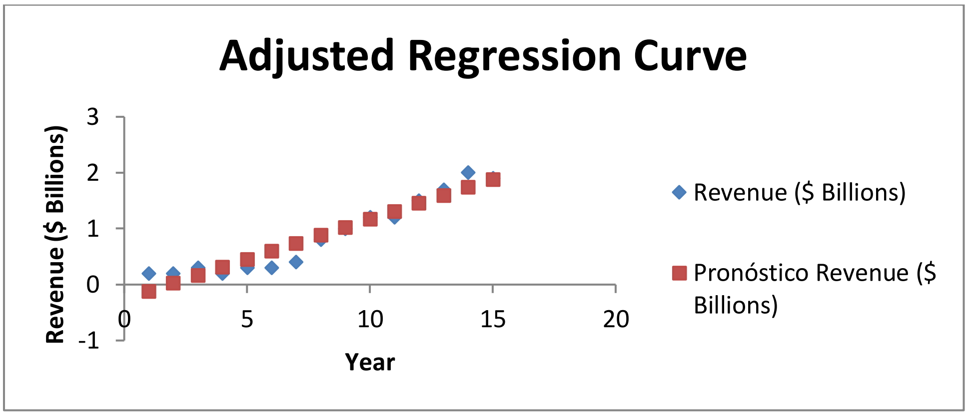
Regression is a statistical technique to research the linear relationship between two or more variables. It is used for prediction. The simplest form is covering two variables (independent variable X and dependent variable Y). As it shown in the equation below

$$Y = \beta_0 + \beta_1 X + u$$

The magnitude and direction of that relation are given by the slope parameter (β1), and the status of the dependent variable when the independent variable is absent is given by the intercept parameter (β0). An error term (u) captures the amount of variation not predicted by the slope and intercept terms. [60](Campbell and Campbell 2008)

[60] Campbell, Dan, and Sherlock Campbell. 2008. "Introduction to Regression and Data Analysis." *Analysis*, 3. http://statlab.stat.yale.edu/workshops/IntroRegression/StatLab-IntroRegressionFa08.pdf.

1) Revenue of (Internet or Telecommunication) satellites from 2000 to 2015



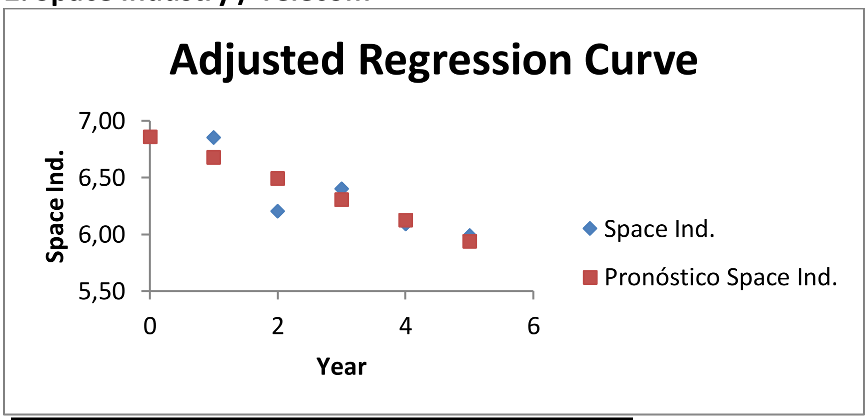
Estadísticas de la regresión	
Coeficiente de correlación múltiple	***0.959721184***
Coeficiente de determinación R^2	***0.921064751***
R^2 ajustado	***0.914992809***
Error típico	***0.194088458***
Observaciones	***15***

Note: R^2 adjusted of 0.9 shows a strong correlation between the la independent variable (year) and the dependent variable (revenue). It means that 90% of the variability in the revenues telecom satellites can be explained by this linear relationship.

	Coeficientes	*Error típico*	*Estadístico t*	*Probabilidad*	*Inferior 95%*	*Superior 95%*	*Inferior 95.0%*	*Superior 95.0%*
Intercepción	-0.262857143	0.105459549	-2.492492586	0.026967785	-0.490688646	-0.03502564	-0.490688646	-0.03502564
Year	0.142857143	0.011599004	12.31632854	1.52858E-08	0.117799018	0.167915267	0.117799018	0.167915267

The equation: Y = -0.26 + 0.14*X

2. Space Industry / Telecom



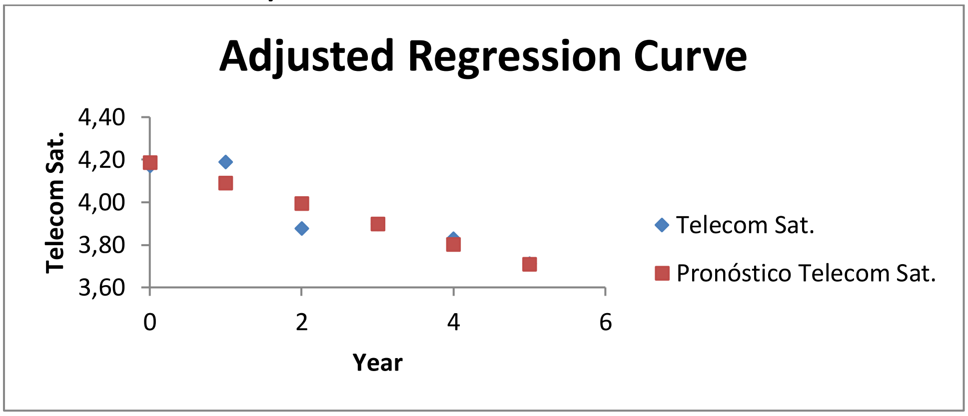
Estadísticas de la regresión

Coeficiente de correlación múltiple	*0.90852334*
Coeficiente de determinación R^2	*0.82541466*
R^2 ajustado	*0.78176832*
Error típico	*0.17771622*
Observaciones	*6*

Note: R^2 adjusted of 0.78 shows a correlation between the la independent variable (year) and the dependent variable (proportion of space industry regarding telecommunication industry). It means that 78% of the variability in the revenues of the proportion of space industry regarding telecommunication industry can be explained by this linear relationship.

	Coeficientes	*Error típico*	*Estadístico t*	*Probabilidad*	*Inferior 95%*	*Superior 95%*	*Inferior 95.0%*	*Superior 95.0%*
Intercepción	6.86098172	0.12862156	53.3423927	7.3934E-07	6.50387102	7.21809242	6.50387102	7.21809242
Year	-0.18474396	0.0424823	-4.34872747	0.01216923	-0.30269374	-0.06679418	-0.30269374	-0.06679418

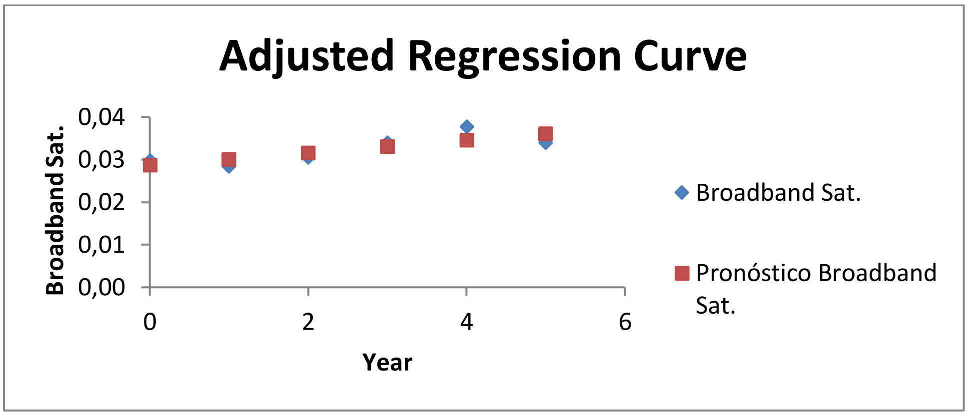
3. Telecom satellite / Telecom



Estadísticas de la regresión	
Coeficiente de correlación múltiple	0.93013495
Coeficiente de determinación R^2	0.86515103
R^2 ajustado	0.83143878
Error típico	0.07894748
Observaciones	6

	Coeficientes	*Error típico*	*Estadístico t*	*Probabilidad*	*Inferior 95%*	*Superior 95%*	*Inferior 95.0%*	*Superior 95.0%*
Intercepción	4.18646253	0.05713799	73.2693347	2.0793E-07	4.02782204	4.34510302	4.02782204	4.34510302
Year	-0.09560297	0.01887206	-5.0658478	0.00715118	-0.1480002	-0.04320574	-0.1480002	-0.04320574

4. Broadband satellite / Telecom



Estadísticas de la regresión	
Coeficiente de correlación múltiple	0.8082588
Coeficiente de determinación R^2	0.65328229
R^2 ajustado	0.56660286
Error típico	0.00227474
Observaciones	6

	Coeficientes	*Error típico*	*Estadístico t*	*Probabilidad*	*Inferior 95%*	*Superior 95%*	*Inferior 95.0%*	*Superior 95.0%*
Intercepción	0.02867166	0.00164634	17.4154454	6.3816E-05	0.0241007	0.03324262	0.0241007	0.03324262
Year	0.001492811	0.00054377	2.74531654	0.05162238	-1.6927E-05	0.00300255	-1.6927E-05	0.00300255

NSR Interview—2nd Mar, 2017

1. What do you think about the convergence of the space and telecom industry?
   Not convergence. It's a complementary relationship. Satellites fit in where ground equipment (fiber etc) doesn't reach or is extremely expensive

2. Do you see any physical indicators of this convergence?
   Costs of satellites have come down and power reduced. But there are big challenges with high costs. Satellite internet costs much expensive compared to fiber. Number of satellites would have to increase a lot in number in constellations to be able to compete with the costs from fiber optic.
   Need to look at justification of the market demand to make sure investment makes sense.

3. We are trying to look at this from three standpoints: technological, financial and strategic. Do you propose any other?
   Legal aspects need to be considered.
   Need to consider interference from other satellites. So power of the satellites might need to be reduced when these satellites are passing through the beams near equator. This means that the expected throughput from the satellites will be less than currently expected.

   Ground systems are not very well established. Handover and tracking from the ground antenna will be a constraint.

4. What would your approach to indicate this convergence be?
   Elasticity of demand in different broadband markets. How much is the price elastic in these markets. Article shows convergence cross over points where satellite and terrestrial broadband crosses over.

5. We are looking into the value chain of both industries to see the 'physical' convergence to establish further indicators. Any recommendations about where we should focus our attention to within the value chain?
   Ground segment should be the main segment. There is enough technology in space to get enough satellites launched. We should look at the downstream value chain. How the ground system need to be updated to accommodate the upstream value chain
   Also focus on sales channels. How are the services being delivered.
   Also look at regulatory requirements.

6. How do you think the project made by GAFAM companies to expand their global telecommunication service? How about the company like OneWeb or space X? And China Satellite (low orbit broadband tele satellite)? Do you think it exist the market?
   GAFAM can only increase their business by penetrating into the market further. Hence there is a trend in this direction.

7. What do you think the main difficulties to establish satellite constellation? Does establish satellite constellation in LEO is the main trend in space industry?
   Main reasons for LEO: latency will be lower and cost of delivery to LEO is cheaper – at the space segment because launching on LEO is cheaper. And smaller antenna and payloads required.

http://www.nsr.com/news-resources/the-bottom-line/leo-constellation-models-actdont-react/

8. Above article mentions growing investments in LEO. Could the investor's interest in LEO, expecting higher returns be seen as a convergence?
   New technology coming up for ground systems updates – which is attracting investors interest as they see high rates of returns. They expect economies of scale to help with higher returns. It's a matter of perfecting the services.
   Constellation plan usually first targets mobility – that's where the most money is. And then the market for consumer broadband is achieved.

9. Is there data available showing investments in GEO and LEO over last 20 years?
   Satbeams database can give us this information. We should look at that for communication satellites.

http://www.nsr.com/news-resources/the-bottom-line/is-the-sky-falling-for-capacity-pricing/(v. important)

10. This article states that broadband costs are declining by 60% worldwide – are we talking about economies of scale here?

11. Question 6, 7 and 8 – could be a little contradictory. If the broadband costs are reducing, there might be low rise or not at all in revenue – doesn't explain investor's interest then?

12. Global IP traffic has boomed since the inception of the Internet. According to Cisco, global IP traffic grew at a 29% rate from 2010 to 2015. Despite the satellite industry having done fairly well in the same period, growing capacity at 11.8% CAGR, it is obvious the satellite industry is continuously losing ground in favor of other technologies and today, a mere 0.15% of the global IP traffic crosses the global satellite network. However, looking forward, as ground networks struggle to extend further

their footprints and satellite connectivity becomes affordable, NSR expects this share to slowly grow in the coming years.
Need to confirm with team before we ask the question. Would be a good idea to see (on same chart) how the IP traffic and satellite industry did.

13. NSR forecasts in its *VBSM14 report* that over 8.9 million new fixed broadband subscribers and sites will be added in the next 10 years, thus creating large opportunities for revenue growth despite the pressure on pricing.
What is this forecast based on?
Mostly linear regression done on past year – we can get more information from Luke. Prateep can get us in touch his colleague for more information.

CNES interview

1. Challenge of space:

- Technology
    - Small satellite with higher capacity
    - Saturation of space (2/3 satellite may useless because over the sea)
    - Competitor (low cost model)
    - Most of the innovative idea are under institutional thinking (TRL is very mature)
    - Price sensitive of customer
    - Latency

2. Opportunity for space:
    - Can be one of the solution : Customer need tailored service→ need a huge data base to support→ internet company need more access→ providing more access through constellation
    - Multi sources to earn money: (transition→ commercial space)
    - Original one/ provide service to telecommunication and internet (service is more profitable) / direct work with internet (shorten the value chain)
    - More industries and companies start to pay attention to satellite constellation/ even invest on this topic

- Cost reduction→ cheaper than ground (satellite become normal object)
- Wide band→ wide cover (remote area/ ship/ plane)
- LEO: less latency with low power
- Customer is not that demanding one live broadcasting, they need self control , see what they want to see at any time (latency is not a big problem any more)