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# THE RISE OF THE GLOBAL INTERNET SATELLITE MEGA-CONSTELLATION SECTOR

## opportunities and challenges for a sustainable transition


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## Abstract

Studies indicate that bringing reliable internet access to low-income countries can boost GDP and is necessary for aiding in the United Nations Sustainable Development Goals (SDGs). In recent years, private companies (e.g., SpaceX, Amazon, and OneWeb) are building Low-earth orbit (LEO) satellite mega-constellations to bring high-speed internet access to remote areas where conventional methods are difficult to install. However, these constellations would require thousands of satellites, causing congestion, which could threaten the safety of LEO. Currently, there are many different actors in the sector, each with their own interests. Given the orbital sustainability challenges, there is a debate whether the sector is under-regulated. A sustainable transition would require juggling the development of the sector to bridge the digital divide while simultaneously maintaining earth's orbital viability. Therefore, this study aims to understand the factors that have shaped the rapid development of the internet satellite mega-constellation sector to identify opportunities and challenges for a sustainable transition.

Recent studies define a transition as being purposeful and intended, with actors coordinating their work to reach a common goal. This study adopts an institutional logics approach to identify Actors' values, goals, and visions in this sectors' emerging socio-technical regime (i.e., the guiding principles). More specifically, this study applied a socio-technical configuration analysis (STCA) which used discourses from newspapers and government documents to map actors' value orientations across three time phases. By applying the value-based proximity approach actors' value orientations can be aggregated into field logics which give an indication as to the preferences of sectoral development by the corresponding actors.

The results identified the core actors shaping the sector, the dominant field logics, and three potential trajectories for the sectors' development. Currently, the sector is experiencing opposing clusters of interests. Actors of the Market Field Logic value profit and benefit from the sector remaining under-regulated, while the Ecology Market Field Logic contains actors who are interested in correcting orbital sustainability challenges. Additionally, the Community Market Field Logic is defined by actors' mobilizing their discourses to bridge the digital divide. The sectors development trajectories will be dependent on which field logic gains (or maintains) dominance over time. Overall, the results of this study indicate that the infiltration of profit values throughout all field logics will cause increasing conflict for a quick transition to a Space sector which considers orbital and social sustainability.

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# Table of Contents

# List of Tables



# List of Figures



# List of Abbreviations

| | |
|---|---|
| GDP | Gross domestic product |
| ICT | Information and communication technologies |
| ITU | International Telecommunications Union |
| LEO | Low-earth orbit |
| MLP | Multi-level perspective |
| SDG | Sustainable Development Goal |
| STCA | Socio-Technical Configuration Analysis |

# 1. Introduction

A study by the International Telecommunications Union (ITU) on the economic impact of broadband penetration found that, in middle income countries, an increase of 10% in mobile broadband penetration yields an increase of 1.8% in gross domestic product (GDP). For low-income countries, this same increase in broadband penetration would result in a 2% increase in GDP (ITU, 2014; ITU Publications, 2019). Access to information and communication technologies (ICT), more specifically, the internet, can aid in achieving the United Nations Sustainable Development Goals (SDGs) (Broadband Commission for Sustainable Development, 2019; Graham, 2015). This is done through the delivery of government services, job creation, and financial inclusion. Nearly half of the world's population does not yet have access to the internet, 90% of which live in the developing world (ITU, 2014; Di Pippo, 2019). Increasing digitalization and the global COVID-19 pandemic brought attention toward the urgent need for stable connectivity in our every-day lives. Since the last few years, private companies are constructing *satellite mega-constellations*[1] in Low-earth orbit (LEO) in an attempt to provide connectivity in remote areas where building cell towers or installing a fiber network is not feasible (McKinsey, 2020a; The Economist, 2016). These developments were driven by the fact that the Space sector entered an era known as *New Space*, whereby an increase in spacefaring nations and private companies has led to rapid technological innovations (Mazzucato & Robinson, 2017; Riberio Gomes et al., 2013). Mega-constellations offer a potentially promising solution to bridging the digital divide. Once a mega-constellation is fully developed, the satellites work together in a system so that at anytime, anywhere on earth, a satellite is reachable, providing connectivity. These constellations offer faster communications and provide a higher bandwidth per user than communications satellites placed in Geostationary orbit[2] (McKinsey, 2020a; The Economist, 2016).

However, creating reliable coverage would require constellations of thousands of satellites to orbit in LEO simultaneously. At the moment, there are no international regulations to monitor the activities of these satellites. An improperly managed industry could quickly lead to severe orbital sustainability concerns due to increasing congestion in LEO. Increasing congestion in earth's orbit would contribute significantly to the accumulation of Space debris, which could disrupt all satellite related services on earth in the future due to collisions of the debris. In 2020 more than 2,500 satellites were orbiting earth in LEO with numbers expected to increase to about 50,000 within ten years (if all current satellite constellation proposals become a reality) (Daehnick et al., 2020). Scientists increasingly warned that the excessive number of satellites could cause the realization of the 'Kessler syndrome' – a phenomenon where too many objects in LEO would make specific orbital ranges impossible to use in the future (Adilov et al., 2018). Additionally,

[1] Systems of thousands of satellites (Boley and Byers, 2021).

[2] Traditionally communications satellites are placed in a higher orbit than low-earth orbit called the Geostationary, or Geosynchronous Equatorial Orbit (GEO). These satellites move at the same angular velocity as the earth and orbit a path parallel to earth's rotation, appearing fixed in the sky. They cannot provide service above or below approximately +/- 70 degrees latitude (Iridium, 2018). LEO satellites orbit at a distance of 500 to 2,000 kilometers from earth's surface compared to the 36,000 km that conventional satellites orbit at (McKinsey, 2020a; The Economist, 2016).

satellites have a lifespan of about 5-7 years after which they are left in orbit with no function, polluting Space.[3] Furthermore, these satellites are bright, disrupting our view of the night sky, and can interfere with frequencies used by radio astronomers to study distant objects (Kanaya & Bandai, 2019; Tyson et al., 2020).

At the moment there are many different actors in the sector, each with different interests. While some actors are pushing for the development of mega-constellations due to their ability to provide remote connectivity, others are concerned about the capacity of satellites that LEO could realistically hold before the orbit becomes too congested, causing Space objects to collide. When collisions occur, they disrupt operational satellites which provide services like weather monitoring, global positioning systems, and telecommunications that are critical in our everyday lives (Adilov et al., 2018). Given the orbital sustainability challenges, there is a debate whether the sector is under-regulated. Additionally, it is unclear how actors building, or planning to build, mega-constellations will create business models that effectively aid in societal development goals. A sustainable transition would require juggling the development of the sector to bridge the digital divide while simultaneously maintaining earth's orbital viability. The sector is currently experiencing massive growth. However, since this sector is only emerging due to events that have taken place in recent years (see section *3.1.2. Historical Developments*), there are no clear institutions in place which guide its' development. This thesis therefore aims to understand the factors that have shaped the rapid development of the internet satellite mega-constellation sector to identify opportunities and challenges for a sustainable transition.

It is important to understand that technology co-evolves with social and institutional elements, also understood as 'socio-technical transitions' (Geels & Kemp, 2007; Fuenfschilling & Truffer, 2014). In particular, the socio-technical transitions lens shows how technological innovations and changes in institutional context conditions interrelate (Geels & Kemp, 2007), thereby allowing to better understand the drivers and strategies of multiple actors of the sector in this study. Transitions are a result of deep changes in the socio-technical system, governed by the prevalent regime, understood as the guiding principles, leading to changes from one configuration to another one (Rip & Kemp 1998).

More specifically, Fuenfschilling & Truffer (2014) propose analyzing socio-technical regimes using insights from institutional theory, in particular institutional logics. The concept of Institutional logics explains that actors tend to subscribe to one or a limited number of ideal type institutions, being: family, community, religion, professions, the state, the corporation, and the market (Fuenfschilling and Truffer, 2014). The combination of these basic logics of actors give rise to field logics (see *section 2.2*) which describe the coherent bundles of rules, goals, and visions that actors are subscribing to. A socio-technical regime is generally made up of several complementing or competing field logics which drive its' development. The dominant field logics of a socio-technical regime therefore reflect actors' adherence towards different values, which indicate the actors' strategic preferences and development visions. To understand the factors

[3] Although scientists are working on removal strategies for Space debris, none have been actualized, much less have become a standard (Virgili & Krag, 2009; Leomanni et al., 2020).

under which the mega-constellation sector is emerging, it is important to analyze different value orientations (i.e., different interests) of actors and identify the field logics which will promote varying development trajectories. The overarching research question for this thesis is therefore:

*How does the emerging socio-technical regime of the global internet satellite mega-constellation sector look and in what direction might the sector develop in the future?*

To answer this overarching research question, it is broken down into corresponding sub questions for a deeper perspective:

1. *How have the conflicting interests, i.e., different field logics, in the satellite mega-constellation sector evolved over time?*
2. *Who have been the most prominent actors in influencing the sector's development?*
3. *How does the emerging socio-technical regime shape the direction of different development trajectories of the sector?*

This study will deepen the understanding of the formative socio-technical regime surrounding the emerging global internet satellite mega-constellation sector to gauge potential development trajectories and hence identify policy implications in terms of opportunities and challenges that could potentially support a sustainable transition for this increasingly privatized but under-regulated sector. Socio-Technical Configuration Analysis (STCA) will be used to construct the network of actors in the global LEO satellite mega-constellation sector based on their respective field logics (i.e. similarities in value orientations) over time (Heiberg & Truffer, 2021). More specifically, the analysis will identify core development trends since 1997 (when LEO mega-constellations were first proposed but which did not come to realization), with more focus on the last decade. The research will build onto the growing research that explores sustainable Space development. Additionally, it is among the early studies that utilize STCA to map different value orientations among actors in the sector, identifying where similar or conflicting interests may potentially arise. This can inform future policy to aid in a sustainable transition.

## 2. Theoretical Framework

The research draws on frameworks of transition studies, more specifically the concept of socio-technical regimes. This section will introduce this theory and then lead into an explanation of the institutional logics approach. Institutional logics can help us better understand the general drivers and how specific field logics influence actor strategies to shape sectoral development. Furthermore, proximity between actors can be measured through their value orientations. Lastly, an explanation is given as to how all these concepts integrate with one another, establishing their importance for the research.

## 2.1 Socio-Technical Transitions

Sociologists argued that policy makers, scientists, and users establish networks with mutual dependencies, contributing to overall development of technological trajectories, thus extending the term *technological transition* to *socio-technical transition* to include the social and institutional complexities (Bijker, 1995; Geels & Kemp, 2007). Geels & Kemp (2007) define *socio-technical systems as* "a cluster of elements, involving technology, science, regulation, user practices, markets, cultural meaning, infrastructure, production and supply networks" (p. 442). Therefore, the *Socio-technical regime* is understood as the core 'rules' or guiding principles which account for the stability of the socio-technical system (Geels & Kemp, 2007). The lens of the socio-technical regime goes beyond a technological focus by also considering institutional structures and user practices in addition to technology (Fuenfschilling & Binz, 2018; Markard et al., 2012).

The transitions literature, in particular the multi-level perspective (MLP), describes the loosening of the socio-technical regime, which creates windows of opportunity for niche-innovations to breakthrough (Geels & Schot, 2007). However, the perspective is often criticized for placing too much emphasis on technological niches that provoke regime changes (Geels & Schot, 2007). It is unclear how to apply the MLP's empirical levels. A regime shift at one level may actually be an incremental change for a wider socio-technical system (Berkhout et al. 2004). Most importantly, it lacks operationalization and has a weak conceptualization of agency (Fuenfschilling & Truffer, 2014).

Over time, *transitions studies* has been elaborated upon and referred to as "large-scale societal changes", deemed necessary to solve sustainability related challenges (Loorbach et al., 2017, p. 600). However, Recent studies reviewing the state of transitions research have pointed to the need for broader dimensions for analysis. A *transition* should be "purposeful and intended" (Markard et al., 2012, p. 957), with actors coordinating their work to reach a common goal. This perspective can especially inspire sectors that are only emerging, and which might still develop in a more or less sustainable direction. Identifying the opportunities and challenges for a transition towards a sustainable future as early as possible becomes critical.

## 2.2 Institutional logics and socio-technical regimes

Institutional theory elaborates the idea that organizations operate in economic and institutional environments, competing for legitimacy within the socio-technical regime. "Legitimacy may influence reputations, license-to-operate, access to capital and governmental support (Geels, 2020, p. 8)." Viewing transitions through an institutional lens leads to a deeper understanding of transition dynamics (Fuenfschilling & Truffer, 2014). It emphasizes that actors (companies, organizations, government, etc.) on the field are not definitive, they change over time, competing for central positions (Fuenfschilling & Truffer, 2014). Institutional logics is the idea that cultural elements (values, beliefs, norms, etc.) shape the practices of actors' everyday activities. Actors tend to subscribe to one or a limited number of ideal type institutions, being: family, community,

religion, profession, the state, the corporation, and the market (Fuenfschilling & Truffer, 2014; Thornton et al., 1999).

It is possible for several institutional logics to coexist and compete within an organizational field forming specific *field logics* - the guiding principles that set the rules of the game, they steer attention toward specific problems and solutions (Fuenfschilling & Truffer, 2014). The degree of institutionalization of a field logic in an organization field may therefore influence the direction of a transition to a higher or lower degree (Fuenfschilling & Truffer, 2016). The more certain actors are subscribing to the dominant field logics at a certain moment, the more they will support incremental changes in the transition of the regime. Typically these are also the more resourceful and prestigious actors in the respective field (Fuenfschilling & Truffer, 2016). Actors subscribing to more peripheral field logics are typically pushing for more radical trajectories, or transitions, but will at the same time have more problems in raising resources and material investments, thus making it difficult to influence the direction of sectoral development in their favor (Fuenfschilling & Truffer, 2014) .

New configurations may challenge the prevailing regime by getting more institutionalized over time. This typically proceeds over different steps of maturation: habitualisation, objectification, and sedimentation - when a new technology has diffused, become taken-for-granted, and supported by vested interests. When the norms and principles of the regime have been shaped into material structures (i.e., policies, supporting technologies, financial investments), this is typically a sign that the highest level of institutionalization (sedimentation) has been achieved (Fuenfschilling & Binz, 2018).

To better illustrate how institutional logics shape sectoral development, a study of the Australian urban water sector revealed a dominant field logic “Hydraulic Logic” which values security of supply, national welfare, and social equity. However, since the 1970s the sector experienced the rise of other institutional logics. They found that the “Hydraulic Logic” was now being challenged by the “Water Market Logic” which values economic efficiency and is in direct conflict with the “Water Sensitive Logic”, whose main guiding principle is creating environmental stability (Fuenfschilling & Truffer, 2014, 2016). These co-existing field logics can co-influence future development of water infrastructure and policy. Therefore, it is important to understand how closely related these co-existing field logics are and how they might influence each other.

The value-based proximity approach was introduced by Heiberg and Truffer (2021) to get a better understanding of how closely related actors are in terms of shared institutional logics. *Value-based proximity* is defined by *“how similar two actors are in terms of the different basic logics they adhere to”* (Heiberg & Truffer, 2021, p.7). Measuring proximity through values can determine where harmonies or conflicts are shaping development within a socio-technical field. This approach traces actors’ value orientations which leads to an understanding of how their values influence their strategies and preferences. Thus, the results can lead to better informed policy recommendations which guide the transition to a more sustainable sector.

To explain transition dynamics, drawing a boundary of a socio-technical regime can best be explained at the sectoral level. While most studies on socio-technical regimes have been done at the national level (Boschma et al., 2017; Geels 2011), Fuenfschilling and Binz (2018) point out that socio-technical regimes exist beyond their immediate national contexts. This is because socio-technical systems often develop institutional rationalities that diffuse via international networks. Therefore, a global socio-technical regime can be defined as "*the dominant institutional rationality in a socio-technical system, which depicts a structural pattern between actors, institutions and technologies that has reached validity beyond specific territorial contexts, and which is diffused through internationalized networks"* (Fuenfschilling & Binz, 2018, p. 739). It is therefore unlikely to have a global socio-technical regime for a newly emerging sector.

## 2.3 An Integrative perspective for the Global LEO Mega-constellation Sector

This study will adopt the suggestion of Fuenfschilling & Truffer (2014), who proposed analyzing in closer detail socio-technical regimes with insights from institutional theory. Utilizing the value-proximity approach by Heiberg and Truffer (2021) can provide information about how similar or opposed actors are in their value orientations, or field logics, which can identify the conflicting interests among the diverse set of actors in the internet mega-constellation sector. This theoretical approach is promising for gaining a better understanding as to which values are being considered most in this emerging sector and identify potential trajectories for the sector's development.

More specifically this research identifies how the socio-technical regime of the global Low-earth orbit internet satellite mega-constellation sector is forming and how it might develop in the future. By applying a value-based proximity approach it is possible to analyze the different institutional logics of actors, which provides further insights on how value orientations (also understood as value dispositions) co-exist in the emerging regime. These value orientations can then aid in the identification of strategies used by different actors in the sector under analysis. The adoption of a global perspective is used because services provided by satellites are meant to provide connectivity to all parts of the world and a congested orbit would impact all nations (Taverney, 2020). The discourses have therefore been generated through internationalized networks. Additionally, there is a need for transitions to be studied from a global perspective rather than the traditional single nationally bounded case study (Fuenfschilling & Binz, 2018; Heiberg et al., 2020).

It is likely that varying field logics are present, or at least emerging, in the internet satellite mega-constellation sector. The business strategies between the communications companies Telesat and OneWeb are used here as an example. It can be observed that Telesat, a satellite communications provider that was founded in 1969, recently launched its LEO mega-constellation, lightspeed, with the intention to deliver unsurpassed performance (Telesat, 2020). In contrast, OneWeb was founded in 2012 on a mission to bridge the digital divide and provide internet to some of the world's most remote schools (OneWeb, n.d.). It can therefore be expected that the profit-oriented 'Market' logic as strongly guiding Telesat whereas OneWeb

demonstrates more of a Community logic which aims to bring its services to the developing world. These examples served as a starting point to identify the higher-level field logics currently shaping the sector. Uncovering the actors in the sector and their respective values, interests, and strategies in the sector could drive an understanding of the development of the sector. Overall, this conceptual approach will therefore allow to improve our current understanding on the factors (e.g., value orientations and preferences) currently shaping the development of the emerging global internet mega-constellation sector, be able to gauge whether the sector will develop in a sustainable direction, and derive relevant policy implications for a sustainable transition based on the analysis.

# 3. Methodology

This section will elaborate on the methodological approach used for this research. First, research design will be presented and the case selection will be substantiated. Next, a detailed overview of the data collection process will be given. Thereafter, the method of analysis will be explained. To conclude, approaches for research validity and reliability are presented.

## 3.1 Research Design

This is a combination of an exploratory and explanatory study. It is exploratory as it is a newly emerging sector with more or less sustainable trajectories in the future. Data was collected from a publicly available dataset and analyzed using STCA, a qualitative and quantitative approach, used to explore whether clear value orientations or field logics can be identified. The study is also partly explanatory in the sense that it explains the factors involved in the shaping of the sector's development. This research is a single case study of the global LEO satellite mega-constellation sector, as it is a new sector, and its socio-technical regime is still only emerging. Instead of a direct comparison of multiple cases, the study approaches the topic by taking into consideration different relevant multinational companies and international organizations that overall influence the development of the sector.

The scope of the research for this thesis was conducted in the time period of 1997 through March 31, 2021 (see *3.1.2* for justification), on a global scale. More specifically, the study was broken down into three time periods: 1997 – 2013, 2014 – 2017, and 2018 through the first quarter of 2021. The discourse analysis began in 1997 as this was the period when the first mega-constellations were proposed but did not come to realization. In 2014 the idea of LEA mega-constellations re-emerged as companies began to announce their massive plans, and the New Space era (rapid commercialization of the Space sector) was in full swing. Finally, from 2018 onwards the mega-constellation plans began to be actualized (more details to follow in *section 3.1.2*). Overall, this time period gives a comprehensive representation of the factors to the rise of the internet satellite mega-constellation sector as we know it today.

### 3.1.1 A Global Perspective

The scope of the study included all relevant actors and their institutional logics who have an interest (or stake) in this sector which were represented in the articles analyzed to capture as many of the complexities as possible of the emerging sector. This includes (but is not limited to), LEO mega-constellation operators, governments, multi-national organizations, Space agencies, rocket launch companies, and accessory companies (e.g., satellite antennas, software companies, etc.). These actors evolve during the discourse analysis (described in *section 3.3 data analysis*) and were included because they are the core actors shaping the development and influencing the trajectory of the sector. Additionally, regulations are primarily at the national level despite the fact that all nations share Space as a global commons resource. While the United Nations Office for Outer Space Affairs (UNOOSA) keeps a record of all objects launched into outer Space (UNOOSA, 2020), and ITU allocates orbit paths and radio frequencies (ITU, 2021), there are no global mandates on mega-constellations. Meanwhile, operators must get approval by their national communications regulators (Ritchie & Seal, 2020). This justifies the need to view the sector at the international level and include the perspectives for all Nation States that appear in the discourses analyzed.

### 3.1.2 Historical Developments

The phases were determined based on major events that outline the rapid growth of the industry and data availability. Segmentation which takes events into consideration allows for a more thorough analysis of sectoral development. This is because it helps to explain the changing development trends and allows for a comprehensive analysis of the factors that drive the overall development of the sector across each phase. An overview of the major events per time phase are as follows:

Phase I (1997 – 2013)

During the 1990s and early 2000s the first LEO satellite internet mega-constellations were proposed. Around 1997 Motorola proposed Celestri, a constellation comprising of 63 operational satellites intended to offer global, low-latency broadband internet services. However, in 1998 Motorola dropped the project in favor of investing in a rival constellation, Teledesic (Bloomberg News, 1998). After not being able to deliver on their business plan the company officially abandoned its' plans in 2002 (Press, 2020). The costs for forming these mega-constellations were too great and demand was limited leading to more companies declaring bankruptcy during this time (e.g., Iridium and Globalstar) (Gertner, 2016; McKinsey 2020b), and the internet satellite mega-constellation industry did not see much activity until a decade later.

On September 28, 2008 SpaceX[4] successfully launched its Falcon 1, the first privately developed liquid fuel rocket to earth's orbit (NASA, 2008). To many, this is considered the beginning of the New Space era (Jarvis, 2020). This event marks a transition period away from "old space", whereby Space activities are funded by governmental and institutional bodies (Robinson & Mazzucato, 2019).

Towards the end of this phase, in 2012, U.S. government organizations (NASA and the Department of Defense) announced their plans to partner with the private sector in order to piggyback their instruments off the launch of private companies (Moskowitz, 2012). This move allows government to mitigate tax dollar spending by leveraging their private industry partners.

Although the idea of satellite mega-constellations did not take off in phase I, including this in the analysis could serve as a core background understanding as to why the sector gained market traction in phases II and III. It allows for an understanding as to the factors within the New Space industry which helped shape the current emerging socio-technical regime.

Phase II (2014 – 2017)

Since 2014, SpaceX, OneWeb, Telesat, and Amazon have been among a handful of companies to announce their intent to build mega-constellations in LEO. It is during this phase that these actors were seeking for regulatory approval to put their plans into motion. This re-emergence of the idea is attributed to the increased demand for broadband, the advancement of satellite technologies, and innovative business models that thrive off connectivity which has increased the ability for companies to invest (McKinsey, 2020b). These aforementioned companies alone have plans to launch more than 46,000 satellites into LEO in the coming years (Boley & Byers, 2021). To put this number into perspective, a study from 2019 states that about 9,000 objects have been sent to Space in the past 60 years (Sheetz & Petrova, 2019).

Additionally, March 31, 2017, marked the successful launch of the first ever reused rocket booster, the Falcon 9 (Drake, 2017). This historical move of reusability could massively lower the barriers to entry into Space, lowering the often-prohibitive costs to Space activities. Meaning, this technology would make the deployment of satellite mega-constellations more realistic due to the decrease in cost.

Phase III (2018 – Q1 2021)

Data collection (see *Section 3.3, Data Collection*) showed a sharp increase of available data starting in 2018. This is likely due to the press surrounding the first launches of their respective satellite mega-constellations by SpaceX and OneWeb (Jarvis, 2020). In 2019, nine companies in

[4] This was the first success of private rocket launching for the company who owns the world's largest mega-constellation currently operating in LEO, making them an actor that could be highly influential in directing the regime

the United States were licensed by the FCC to launch mega-constellations. These include SpaceX, Amazon, Telesat, and LeoSat (O'Callaghan, 2019). Mega-constellation plans range in size from Telesat's 298 satellites, which are expected to launch in 2023, to SpaceX's massive constellation of 42,000 satellites (Telesat, 2021; Cao, 2019).

Following the Covid-19 pandemic starting in January 2020, the need for stable internet has accelerated due to the influx of users now relying on broadband access for a range of activities from education, work, to tele-health appointments (Lovelace Jr., 2020). SpaceX was granted nearly $900 million U.S. dollars through the Rural Digital Opportunity Fund[5] which is a U.S. Federal program developed in response to the pandemic to provide internet to rural parts of the country (Templin, 2021).

Since September 2021 SpaceX has launched 1,791 of its Starlink satellites into orbit and OneWeb has launched 322 of their satellites (Harwood, 2021). These numbers continue to grow and there are other companies launching satellites as well. SpaceX CEO, Gwynne Shotwell, has said that the company cooperates well with OneWeb regarding collision avoidance, but she does worry about the sustainability of the orbit: *"I am not worried about the number of organizations that are interested in doing this. I'm interested and concerned about their sustainability when it comes to the space environment"* (Harwood, 2021). Due to the continual lack in regulation of this industry it is unclear how emerging companies and nations will manage orbital sustainability challenges. Therefore, this study is useful in gaining a perspective as to which actors are currently operating in this sector and what their views are regarding the growth and governance of the industry.

## 3.2 Data Collection

This study collected data from LexisNexis, an English database which provides publicly available legal, governmental, and business documents from journals, newspapers, and magazines, as well as relevant industry reports. This research focused on newspaper articles and government documents to trace the discourses made by different core actors.

LexisNexis returns relevant documents based on a search string query. To select the best search string for this case, over thirty search strings were trialed to get an indication of the amount of data available. For this research, it was important to find a search string which returns a sample of articles that give a comprehensive picture of the sector yet be specific enough that the number of articles could be analyzed in the given amount of time for the research. By including key terms such as "New Space", "constellation", and "internet", the query remains broad enough to include a sampling of articles from varying viewpoints, allowing the dominant logics of the sector to emerge inductively during the data analysis. *Table 1* provides a sampling of search string queries that were performed to collect data for this research along with an *Evaluation* as to why or why not the *search string* was used. A sampling of the articles was read in order to provide the

[5] For more information: https://www.fcc.gov/auction/904. No information was found as to whether any other U.S. companies with plans for a LEO mega-constellation received funding through this grant.

*Evaluation.* LexisNexis also gives an overview of Industry and People when conducting a search which was helpful for determining the relevance of articles returned from a search string query.

*Table 1: Sampling of LexisNexis search string queries*

| Trial | Search String | Results | Time Trend | Evaluation |
|---|---|---|---|---|
| 1 | atleast2(satellite w/p internet AND space AND constellation) | 2515 |  | Nice development over time but far too many articles and too broad |
| 3 | atleast4(satellite w/p internet AND space AND constellation) | 345 |  | Not enough articles after manual filtration of irrelevant articles |
| 4 | atleast3(satellite w/p internet AND telecommunication AND space) | 1499 |  | Far too many articles |
| 5 | atleast4(satellite w/p internet AND telecommunication AND space) | 742 |  | Great development over time but sampling of articles showed that many were irrelevant |
| 6 | Satellite AND (New Space) AND atleast4(internet) | 627 |  | Great development over time but sampling of articles showed that many were irrelevant |
| 7 | atleast2(Satellite AND New Space AND internet) | 301 |  | Not enough articles. Very steep incline in data and then immediate decline |
| 8 | Satellite AND (New Space) AND (internet) AND ALLCAPS(LEO) | 246 |  | Not enough articles |

| | | | | |
|---|---|---|---|---|
| 9 | Satellite AND (New Space) AND atleast3(internet) AND (low earth orbit) | 278 |  | Not enough articles. Very steep incline and then immediate decline |
| 10 | Satellite AND (New Space) AND atleast2(internet) AND constellation | 398 |  | Reasonable number of articles, development over time, initial sampling of articles included the correct discourses |

*Trial 10* was selected for this research. The search string provided a feasible number of articles for coding, had good development over time, and the initial sampling of articles showed relevant content. While some other searches appear to be richer from the time trend (e.g., Trial 5 & 6 in table 1), when the articles were sampled, there were many that did not contain the relevant content for this study. For example, they would contain information about traditional telecommunications rather than the New Space sector and satellite mega-constellations or focus on satellites in GEO rather than LEO. Because of the recent developments in the sector, it is not unusual for time trends to display a sharp increase around the year 2014.

After excluding irrelevant articles and duplicates, 60% of the articles were analyzed. The final data set used is depicted in *Figure 1* below:

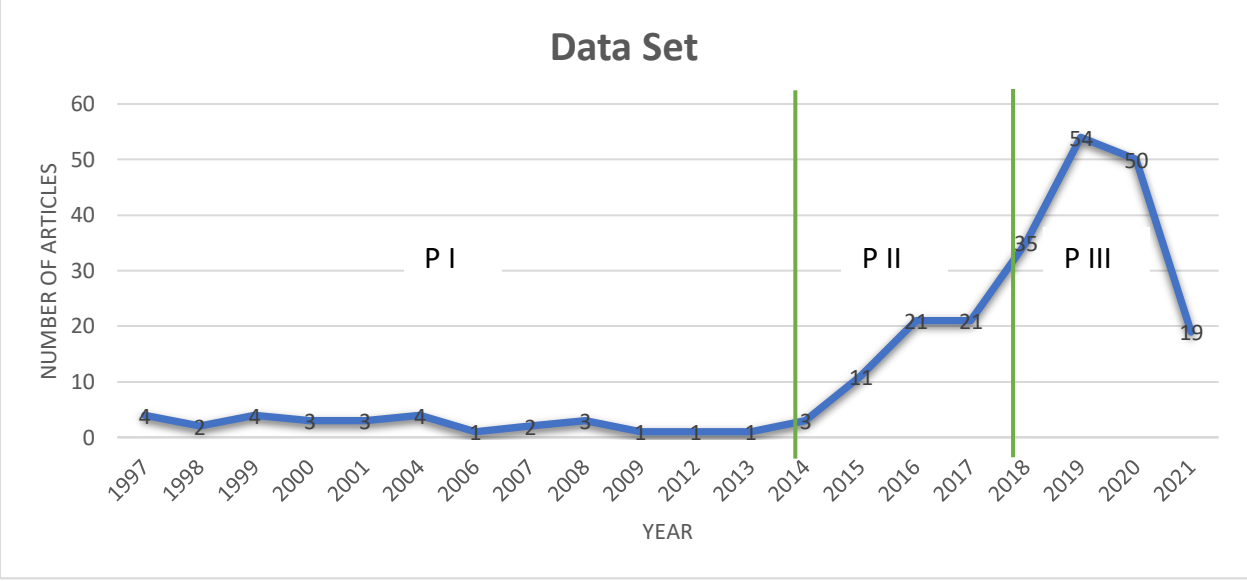


*Figure 1: Number of articles analyzed by year*

The data for the year 2021 drops significantly because only the first quarter of the year 2021 was included due to the timing of when this research was being conducted. *Table 2* provides a more detailed breakdown of the types of articles evaluated.

*Table 2: Number of articles analyzed by document type and time phase*

| Phase | Newspaper | Government | Total |
|---|---|---|---|
| I | 22 | 7 | 29 |
| II | 42 | 14 | 56 |
| III | 132 | 26 | 158 |
| | | | |
| Total | 196 | 47 | 243 |

In conclusion, 243 articles were analyzed, with 19% of the total being comprised of Government documents and the remainder coming from newspaper sources. These government documents mainly consisted of transcripts from committee meetings discussing policy, as well as transcripts from industry testimonies. 81% of government documents came from the United States with the remainder from the European Union (5 documents), The United Kingdom (1 document), and China (1 document). Government documents make up 25% of the total documents reviewed for phases I and II, compared to 16% of the total documents in phase III.

## 3.3 Data Analysis

Socio-technical Configuration Analysis (STCA) builds on the coding of large sets of texts, such as newspapers and professional magazines (Heiberg et al., 2020). This semi-quantitative relational methodology involves the coding of actors' statements, in the context of specific discourses that mirror or accompany the formation of a regime over a spatial scale and time.

In this research, the institutional logics concept from transition studies is used as a basis for analyzing value dispositions of different actors. Coding first started in a deductive manner. The ideal type institutions, being: *family, community, religion, professions, the state, the corporation*, and *the market* (Fuenfschilling & Truffer, 2014; Thornton et al., 1999;2012), are used as a foundation for the coding scheme. *Family* and *Religion* were found to be irrelevant for the purpose of this study. Additionally, some *Corporation* discourses were found but were often paired with *Market* ideals and thus were aggregated to the *Market Logic*. The basis of strategy for the Corporation logic is to increase size and diversification of the firm. It was found that many companies aim to do this while also increasing their efficiency profit which is the Market basis of strategy. Since this study looked at one technology, corporations tended to favor a strategy based on profit. Therefore, Market logic was coded over the Corporation Logic. The remaining four

groups, as listed in *Table 3*, were used as starting points to categorize and develop a coding scheme tailored to this research:

*Table 3: Institutional logics of societal sectors*

| Categories | Community | State | Market | Profession |
|---|---|---|---|---|
| Root Metaphor | Common boundary | State as redistribution mechanism | Transaction | Profession as relational network |
| Sources of Legitimacy | Unity of will, belief in trust and reciprocity | Democratic participation | Share price | Personal expertise |
| Sources of Authority | Commitment to community values and ideology | Bureaucratic domination | Shareholder activism | Professional association |
| Sources of Identity | Emotional connection, Ego-satisfaction, and reputation | Social and economic class | Faceless | Association with quality of craft, personal reputation |
| Basis of Norms | Group membership | Citizenship in nation | Self-Interest | Membership in guild and association |
| Basis of Attention | Personal investment in group | Status of Interest group | Status in market | Status in profession |
| Basis of Strategy | Increase status and honor of members and practices | Increase community good | Increase efficiency profit | Increase personal reputation |
| Information Control Mechanisms | Visibility of actions | Backroom politics | Industry analysts | Celebrity professionals |
| Economic System | Cooperative capitalism | Welfare capitalism | Market capitalism | Personal capitalism |

Adapted from: Fuenfschilling and Truffer (2014); Thornton et al. (1999;2012)

Further development of the coding scheme for this study was then informed by the empirical evidence of the case. NVivo, a qualitative content analysis software was used for the coding process. Selected texts were coded in a bottom-up process based on actors and their attributing value orientations. As more articles were coded, more specific facets of value orientations emerged, such as (but not limited to), *Societal Development* (Community Logic), *National Economic Gains* (State Logic), and *Science & Innovation* (Profession Logic). Additionally, the Community Logic has been broken into Community and Ecology Logics. This is to account for the differences in sustainability regarding the social side (*Societal Development* value) and a planetary approach (*Governing Orbital Sustainability* value). While informed by the theoretical

concepts, adjustments to the coding scheme were then made inductively and deductively throughout the coding process based on the data. This step was done repetitively which involved back-and-forth re-evaluation, expansion, and aggregation of the institutional logics (and preferences and strategies, see *Appendix B*) before reaching the final coding scheme. The final simplified coding scheme for logics and corresponding values used in this study is presented in the following table[6]:

*Table 4: coding scheme (full version in appendix A)*

| Logic | Value | Description |
|---|---|---|
| Ecology | Governing Orbital Sustainability | Concerns and governance ideas regarding the orbital boundaries of Space. This includes regulation of spectrum frequencies and physical orbiting paths. |
| Community | Societal Development | Utilizing LEO satellites to bridge the digital divide, increase socio-economic status, etc. |
| Market | Profit | Use of constellations with the intent to profit from the technology. |
| Profession | Science & Innovation | Importance of science & innovation. |
| State | International Cooperation | Cooperation between different nations regarding the sector. |
| | Diplomatic Tool | Utilizing New Space activities to increase or maintain national power. |
| | National Economic Gains | New Space activities used to fuel a nations' economy. |
| | Space as a Common Resource | Idea that all nations should have access to Space. Democratization of Space access and Space governance. |

The coding process distinguished actors by discursive statements (statements made by an actor) and substantive statements (general statements referring to/involving an actor). Due to the types of articles under review, the results utilizing discursive statements were not as rich as those using substantive statements. This was due to the fact that many newspaper articles do not clearly state the actors who are making statements. Therefore, this analysis utilized substantive statements to derive the networks presented in the results. *Table 5* provides a sample of how coding was executed. Actor coding was performed with as much specificity as possible. This is most relevant in the case of different United States governmental organizations. The specific organization was always coded when possible due to their specific policy realms (i.e., *House Committee on Science, Space, and Tech, US Executive Branch, US Department of Defense,* and *US Department of Commerce*), it is only when the statement was unclear regarding which

[6] See Appendix A for an expanded version of the coding scheme and details on the number of times coded.

governmental organization that the statement was coded as the U.S. Government (appearing as '*US*' in the networks; *Figures 3,4,5*). The networks also include actor groups for some professions. These are: *Investors, Market Researchers, Scientists*, and *Space Policy Experts*. These were used when it was clear that an actor belonged in that group.

Only obvious statements were coded to eliminate biased assumptions. If a logic value, preference, or strategy could not be clearly determined then those elements were not coded. Additionally, elements could be co-coded. Co-coding is when a statement displays more than one logic therefore all would be coded and accounted for.

*Table 5: Examples of coding for actor-logic affiliations*

| Text Sample | Statement by | Subject | Value |
|---|---|---|---|
| "Whether we are in the public or private sector, we are working together toward the same goal: promoting American innovation and investment in the New Space Age. And the launch of this facility is a major step forward for our nation's commercial space sector." | Chairman Pai of the FCC | Federal Communications Commission (FCC) | National Economic Gains |
| "This is a long-term project that envisions serving tens of millions of people who lack basic access to broadband internet. We look forward to partnering on this initiative with companies that share this common vision." | Amazon | Amazon | Societal Development |
| "The Department's Office of Space Commerce is actively working with private sector and Congressional stakeholders to streamline regulations governing the satellite launch process. | Deputy Secretary Karen Dunn Kelley of the U.S. Department of Commerce | US Department of Commerce | Governing Orbital Sustainability |

After coding was completed, data was translated into unweighted two-mode affiliation matrix in NVivo between actors (rows) and logics (columns). In this matrix a 0 in the cell represents an actor who did not adhere to a corresponding logic, and a 1 indicates that the actor does adhere to the logic. This matrix was then exported and run through an R-script to identify value-based proximity as a one-mode actor network (Heiberg & Truffer, 2021). Links between actors represent shared logic affiliations. Following the method of Heiberg and Truffer (2021), the Jaccard index is then used to calculate similarity among actors. The Jaccard index is calculated by dividing the number of common properties by the total number of properties (Niwattanakul et al., 2013).

$$J = \frac{|A \cap B|}{|A \cup B|}$$

J is 1 if two actors share the exact same value orientation profile and gets closer to 0 the more dissimilar actors' assigned values are. This was then imported into *Visone* to create a visual representation of the results in a network form. Thus, the closer two actors are to one another in the network, the stronger their value-based proximity (i.e., similarities in value orientation) (Heiberg & Truffer, 2021). *Figure 2* explains how logic affiliations will appear in the one-mode configuration.

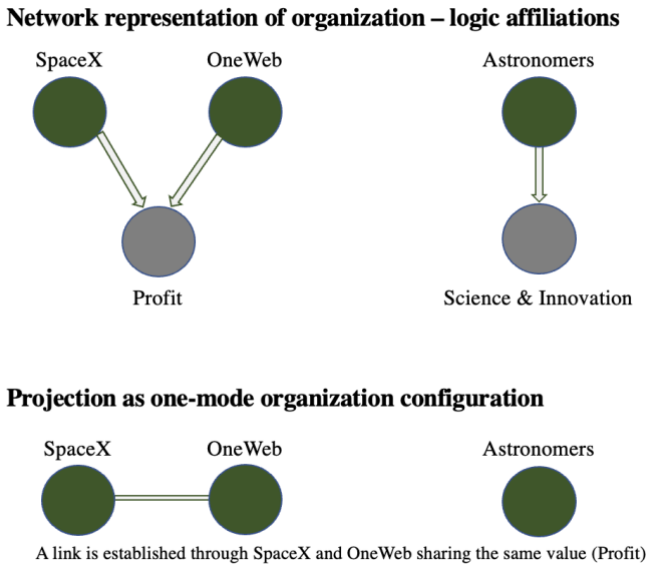


*Figure 2: STCA network representation from affiliations to one-mode projections (illustration inspired by Heiberg & Truffer (2021))*

As a final step, an agglomerative clustering algorithm, Ward's method, was performed to identify the field logics. Ward's method is a bottom up, or hierarchical, clustering approach where objects are assigned with their own clusters and then the clusters are merged based on similarity (Hervada-Sala & Jarauta-Bragulat, 2004). By clustering, the node-level value-based proximities

are aggregated to the field logics level (Fuenfschilling & Truffer, 2014). It was then determined which number of clusters for each phase best represented the networks since each cluster represents a field logic. In other words, during the analysis stage, each phase generated the options of 2,3,4, or 5 clusters. The cluster amount which best represents the situation of the sector was selected. For instance, too many or too few clusters did not allow for a proper analysis of logics because the resulting logic distributions were either too siloed or not distinct enough in their values. The dominating field logics could then be determined and analyzed based on the values present in each cluster. For every network presented in *Section 4. Results*, there is a corresponding bar graph which displays the values which make up each *field logic* (also referred to as a *cluster*).

### 3.4 Data validity and reliability

To ensure research quality, this research considered reliability, replication, and validity (Bryman, 2012). Reliability addresses whether a study can be repeated. All data collected for the STCA was collected from public records making it possible for the study to be repeated. To account for replication, the search string and coding scheme were transparently documented. Operationalization of the method was also explained. This allows future studies for similar contexts or sectoral cases to be replicated with adaptation to the mentioned research steps. Additionally, coding schemes (*Appendix A & B*) were checked and discussed with the supervisor repeatedly in an iterative process to negate any possible bias from the researcher and ensure internal validity. This process increased the trustworthiness of the analysis by excluding personal values in the analysis process (Nowell et al., 2017). The primary data analysis for this research (STCA) was complemented with desk research about the topic. This information was used to gain an understanding of the sector, through the historical background (*section 3.1.2*), as well as an aid for additional information that was not included in the dataset to better assess the sectoral development. This process of data triangulation increased the validity of the study (Daytner, 2006).

## 4. Results

The analysis is presented by first, giving an overview of each time phase. This analysis is presented in the form of an actor network, alongside a detailed breakdown of the value orientations that form each cluster (i.e., field logic) that is represented in the network. Each cluster includes a description of the empirical findings with the connected field logics which is based on the value-based proximities method (described in section *3.4. Data Analysis*) between the actors and their respective value orientations. Thereafter an evolution of the field logics of the sector over time is given which indicates how the field logics formed, split, or merged throughout the time phases under review. This section will also describe how the evolution of field logics impacts the development of the sector and compare how actors' value orientations changed over time.

## 4.1 Period I (1997 – 2013): Analysis of Field Logics

During the analysis, 20 actors were identified from the discourses for the years 1997 through 2013. During this timeframe, several companies tried to formulate LEO satellite mega-constellations but were not successful. The LEO satellite mega-constellation idea then went into a hibernation period where little activity was happening in the second half of Period I. Many actors started to emerge in the late 1990s as the New Space era began, and the Space sector was increasing in privatization, and several supporting companies saw the value in business models which utilize Space. This is depicted in *Figure 3* by the tight cluster (yellow) of companies on the left side of the network.

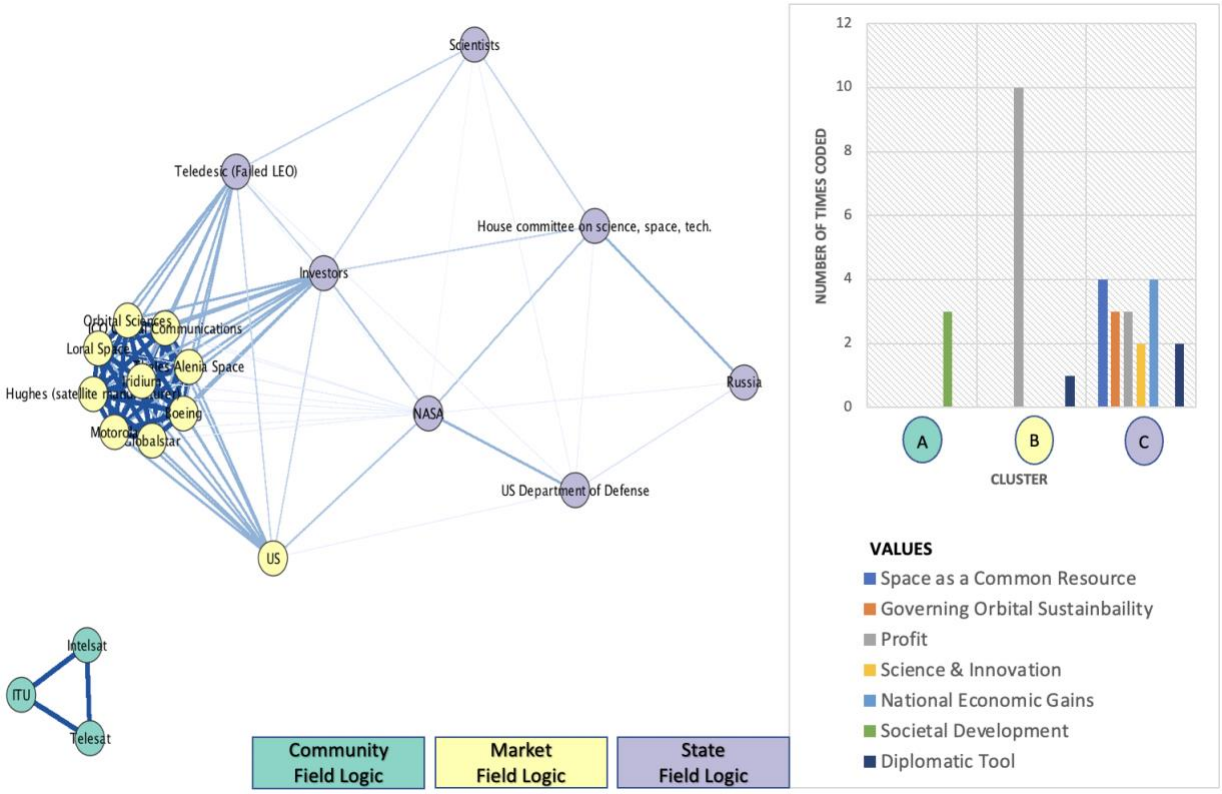


*Figure 3: Phase I Actor-Network & Field Logics Distribution*

Three prominent groups with distinct value dispositions were identified after applying the Ward cluster coefficient. Cluster A contains 3 actors, Cluster B is made up of 10 actors, and lastly, cluster C is 7 actors.

The network presented above is very dispersed, except for cluster B. At this time Space activities were traditionally only pursued by a few actors, namely the United States and Russia. NASA, a government funded administration, is at the center of the cluster. This signifies its dominance

within the network. The U.S. Government (represented in the network as "US"), Investors[7], and Teledesic are very strong links between two differing field logics. This means that the actor shares similar values with those they are connected to but are most similar to the actors that are in their own cluster.

Cluster A

Cluster A is unique because it is disconnected from the rest of the network. All actors adhere to the *Societal Development* value during this time (See bar graph in *Figure 3*), which forms the cluster. This study identifies actors with this value disposition as part of the **Community Field Logic**. The actors in this triad are connected due to their belief that increasing the accessibility of the internet through satellite mega-constellations will aid in bridging the digital divide. These actors have mobilized their discourses to educate that citizens without internet are not able to take advantage of the benefits that come from knowledge sharing and communication technologies. This includes access to healthcare, education, business development, or even participating democratically. Therefore, having access to the internet can contribute to one's socio-economic status. For example, the statement made by the deputy secretary-general of the ITU clearly shows his organization's adherence to the value of societal development by referring to closing the telecommunications gap:

*"The significance of the Internet lies not so much in what it is, but in what it can become […] It is important to employ technology to close, not widen, the telecommunications gap."*[8]
*– Henry Chasia, Deputy Secretary-General, ITU*

LEO satellite connectivity is seen as being superior to traditional broadband in certain places where conventional internet infrastructure is difficult to build. So not only is LEO satellite technology easier to set up for the provider, but it has the added capability of securing a larger customer base. In the media analyzed, companies such as Intelsat have strongly adhered to the vision of providing equal internet accessibility to all. As part of their discourse mobilizing strategy the actors in this cluster share a common belief that everyone should be entitled to access the service of the internet, should they want it, and they are on a mission to provide such services. Companies like Intelstat have been planning to add services provided by LEO satellites in an effort to expand their service reach.

*"Broadband satellite solutions are extremely attractive to telecom service providers seeking to complement their terrestrial offerings and provide similar global solutions to every customer they serve."*[9] *- Conny Kullman, Chief Executive, Intelsat*

[7] Investors are often mentioned in the discourses as such but this also includes more specific actors including (but not limited to): Goldman Sachs employees, venture capitalists, or Astana International Financial Centre which is the largest financial hub in central Asia.
[8] Mobile Satellite News (May 29, 1997): News Brief (Dataset)
[9] Flight International (2000): Paying the way (Dataset)

Despite market attractiveness, all actors have most strongly referred to the vision of providing access to those disparaged by lack of internet access in communications, seeking to close this accessibility gap. Therefore, their discourses were coded to reflect their corresponding value of engaging in *Societal Development* for the industry, which is the Community Field Logic.

Cluster B

Cluster B is a dense cluster, whereby most actors are at the same distance in the network, meaning their assigned value propositions are identical. The exception is the U.S. Government being at a further distance from the rest of the actors, illustrating that the values are still very close due to Ward's clustering but not identical to the rest of the cluster, as indicated by the position in the network. The value orientation of *Profit* is by far the most **dominant** in this network, indicated by the number of times coded. Therefore, these actors subscribe to a **Market Field Logic**.

Actors in this cluster are seeking the profit potential of Space resources through various business endeavors. One example is how Boeing considered satellite infrastructure for the development of a global, and integrated traffic control management system.[10] While this study does focus on mega-constellations for internet access, the method of discourse analysis is unique as it allows for the tracing of actors and their strategies overtime. It can be common for a company to start a project with one intended purpose and pivot their business offerings to reflect the market development. Therefore, this study was able to incorporate businesses that support accessory technologies. The success or failure of adjacent businesses, or businesses which provide supporting technology, can influence the uptake of satellite mega-constellations and influence whether or not these mega-constellations become a viable endeavor.

The U.S. Government is motivated by interests that stress the importance of profits from the satellite mega-constellation sector. They seek to facilitate market growth of the sector through several laws which should ensure the success of the New Space movement. This clearly depicts the Market Field Logic and is well explained by the following excerpt:

*"The proper role of the federal government in facilitating private sector space activities has been debated for many years. Congress has passed a number of laws-including the 1984 Commercial Space Launch Act and its 1988 Amendments, the 1990 Launch Services Purchases Act, the 1992 Land Remote Sensing Policy Act, and the 1998 Commercial Space Act - to encourage and facilitate space commercialization."[11] – Marcia S. Smith ('US' in Figure 3)*

[10] Military and Aerospace Electronics (2005): The next generation of air traffic control (Dataset)

[11] Federal Document Clearing House Congressional Testimony (2000): Testimony July 18, 2000 Marcia S. Smith resources, science, and industry division house science energy and environment low-dose raidation measurement methods (Dataset)

However, the U.S. Government has an added motivation for the New Space industry to strive. This explains their less central position in this particular cluster and the adherence to the Diplomatic Tool value in the bar graph (Figure 3). The success of the industry can be used to cultivate their image of being a world leader in Space as part of their diplomatic strategy:

*"Our space professionals must be sensitive to the needs of the many and varied end-users of space capabilities, and be able to formulate and articulate new space doctrine to fully control and exploit the medium of space in support of our nation's security objectives. They must be able to develop new technologies, systems, training methods, concepts of operations and organizations that will continue to sustain the U.S. as a world leader in space."*[12]
*- Peter B. Teets, Under Secretary Air Force, United. States ('US' in Figure 3)*

In summary, the increasing privatization of Space activities explains the variety of actors in the network. Additionally, possessing a thriving industry can be attractive for nations, contributing to their overall national profit potential, thus this cluster operates under a Market field logic.

Cluster C

The network shows a much more diverse set of values in cluster C than in A and B. Additionally, this cluster is very spread out, meaning that actors are connected by common values, but these are not as closely tied as in clusters A and B. Cluster C is dominated by values of *Space as a Common Resource* and *National Economic Gains* with additional values present in the distribution of the bar graph. In this study there are several values that contribute to the State Logic, including *National Economic Gains*, *Space as a Common Resource*, *International Cooperation*, and *Diplomatic Tool*. Therefore, actors in this cluster are driven by the **State Field Logic** and are focused on how orbital resources are governed.

During this time NASA was one of the most dominant actors in the network, illustrated by its central positioning. It is also a connector to the Market cluster (B). NASA subscribes very strongly to the values of *Space as a Common Resource*, *Science & Innovation,* and *National Economic Gains*. This is an interesting combination of values which is driven by NASA's encouragement of private company growth in New Space activities, freeing them up to use public funds for more exploratory and scientific endeavors. [13] The following quote explains the intersect between the values of *Science & Innovation* and *National Economic Gains*:

*"NASA has an important role to play in driving innovation and supporting basic research in the space industry and related sectors of the economy. Sustained federal investments in NASA and*

[12] Federal Document Clearing House Congressional Testimony (2004): Fiscal 2005 budget: defense strategic forces programs (Dataset)
[13] CQ Congressional Testimony (2008): NASA Reauthorization (Dataset)

*other science agencies can further strengthen our nation's high-tech industrial base and ensure America's position as the world leader in innovation."* [14]
*– Ralph M. Hall, House Representative, Texas*

In the 90s the Unites States and Russia had the two dominating space programs in the world. They both highly subscribe to State ideals as described by Figure 3, valuing the state as a bureaucratic redistribution mechanism. In 2006 Russian President Vladimir Putin also talked about the importance of *"actively developing new space technologies to meet Russia's security and economic needs."*[15] This statement provides further evidence of the *National Economic Gains* value, solidifying the State field logic.

## 4.2 Period II (2014 – 2017): Analysis of Field Logics

Thirty-three actors were present during the analysis of the documents for the second phase. During this time a new set of companies, including SpaceX, Amazon, and OneWeb, emerged and announced their plans for LEO satellite mega-constellations. This sudden interest in mega-constellations is apparent in the network by the increase in actors and frequency of *number of times coded* in *Figure 4*.

Four clusters were found to show the best represention of field logics during this time. Cluster A contains 12 actors, cluster B is made of up 9 actors, Cluster C is 7 actors, and lastly, Cluster D contains 5 actors.

[14] VIA Satellite (2012): NASA sees private sector as key to escaping LEO (Dataset)
[15] VIA Satellite (2006): Russia: promising satellite services market may be tough to crack (Dataset)

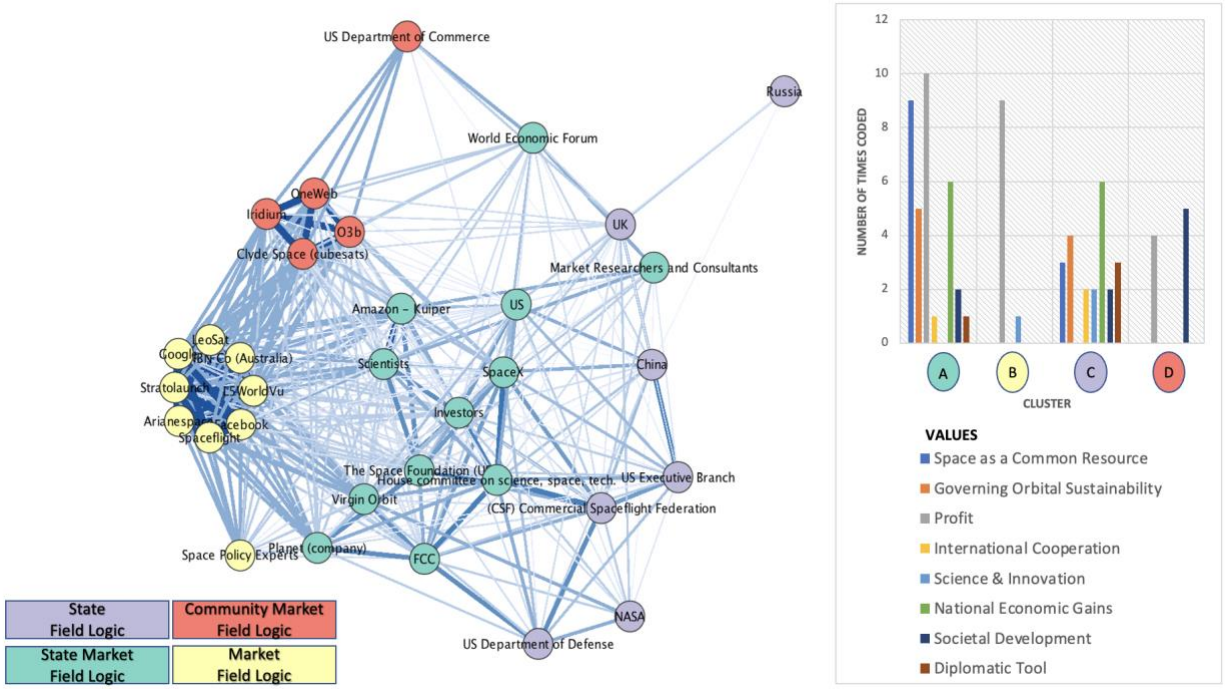


*Figure 4: Phase II Actor-Network & Field Logics Distribution*

Cluster A

Actors in cluster A most strongly adhere to the interests of *Profit* and *Space as a Common Resource*, but interests in *National Economic gains* and *Governing Orbital Sustainability* also play a rather important role in the formation of this cluster. This cluster is an evolution from the State (Cluster C) field logic from Phase I, known because of the distribution of values and the migration of 25% of actors (House Committee of Science, Space, and Tech.; Investors; Scientists) from phase I Cluster C. This cluster is **dominant**, indicated by the central position in the network and it contains the highest number of actors and times coded. Displaying very strong profit interest as well as many governing elements, it is therefore considered the **State Market Field Logic**.

The Market Logic in this cluster shows the adherence of actors towards profit interest from LEO mega-constellations. This is present among the actors in this cluster in a few varying sources of data. While the companies (SpaceX, Amazon, etc.) seek to gain profits, the market researchers are speculating about the potential of the sector, and often this then drives the investors to make the monetary contributions to the companies, further fueling the economic potential of the businesses by providing the capital to create the viable mega-constellations. Additionally, the government organizations also contribute to the economic potential via their regulatory power over the industry, contributing to the State logic. This explains the interconnectedness of such varied actors to one field logic (State Market) and can be further substantiated through the example of SpaceX.

SpaceX is now at the center of the network with strong ties to the United State House Committee on Science, Space, and Technology. Of the articles analyzed the dataset contained several documents where SpaceX lobbied to the House Committee and the FCC for their preferred governance practices of the sector. One such argument is that SpaceX feels that the FCC should only be allowing the most spectrum efficient technologies access to maximize broadband service, thus prioritizing technologies which would be able to provide service to the most customers.[16] These discussions often resulted in an adherence to the same interests which in this case is *Profit*, establishing a relatively strong link between the actors within the network.

*"Leveraging our experience in space launch system and spacecraft design, development, production, and on-orbit operations, SpaceX is developing an innovative NGSO constellation. Our system is designed to reach directly to end users, and provide global broadband services at speeds, latencies and prices on par with terrestrial alternatives available in metropolitan communities. Accordingly, we filed applications with the Federal Communications Commission (FCC) in November 2016 and April 2017 that detail those plans."[17]*
*– Patricia Cooper, Vice President of Satellite Government Affairs, SpaceX*

Additionally, during this time governments are also understanding the market potential of privatizing space and how this could be leveraged for national interests. The following statement clearly shows that The House Committee strongly adheres to the interest of *National Economic Gains* and describes the coupling between government and private industry to make up the **State Market Field Logic**:

*"Government space programs explore the unknown, discover new worlds, and develop new science and technologies. But to unlock the great economic potential of outer space, we need to encourage the ingenuity, innovation, and interest of our private sector."[18]*
*– Lamar Smith, House Representative, Texas*

Cluster B

In this phase there remains a tight cluster of actors who value profit. Therefore, the **Market Field Logic** remains from the previous phase. The cluster remains similar in size during this period compared to the previous period. However, the actors have changed based on the companies (actors) that have survived over time, newly emerged, or disappeared from the discourse. This cluster contains the addition of the actor Space *Policy Experts* as shown at the bottom corner of

[16] U.S. Senate Documents (May 3, 2017): Senate Commerce, Science and Transportation Committee Hearing; "Investing in America's Broadband Infrastructure: Exploring Ways to Reduce Barriers to Deployment."; Testimony by Patricia Cooper, Vice President of Satellite Government Affairs, SpaceX (Dataset)
[17] U.S. Senate Documents (October 25, 2017): Senate Commerce, Science and Transportation Committee Hearing; "The Commercial Satellite Industry: What's Up and What's on the Horizon."; Testimony by Patricia Cooper, Vice President of Satellite Government Affairs, SpaceX (Dataset)
[18] CQ Transcriptions (March 8, 2017): House Committee on Science, Space, and Technology Subcommittee on Space Hearing on Regulating Space (Dataset)

the same cluster (see *Figure 4*), away from the tight cluster, connecting to cluster A. In the discourses analyzed this group of experts was most often represented in government documents. The group of actors includes anyone who is referred to as a space policy expert regardless of their national affiliation. The group often preferred a *permission-less innovation* approach, rather than a top-down regulatory approach. Proponents of permission-less innovation believe that not placing regulations on the industry will allow actors to innovate faster and more quickly develop business models that are profitable and efficient. Therefore, this study has identified this cluster as representing the **Market field Logic**. The following excerpt from a policy expert goes into further detail on the importance of innovation without restrictions:

*"Permission-less innovation can also be applied to space. Congress should seek to maximize the latitude. The private sector has to experiment with commercial space endeavors. As with other domains, this freedom to experiment will result in some mistakes and failures. Yet over the long run, permission-less innovation will result in faster progress and more robust solutions to policy problems in a precautionary regulatory mentality."*[19]
*– Eli Dourado, Regulation of Emerging Technologies, George Mason University*

The Market actor group continues to grow throughout the periods observed in this study, including many launch companies, accessory companies, and actors that state they have an interest in forming their own satellite mega-constellation in the future. Most of the discourse surrounding these actors' states the market potential of the business plan. While they discuss providing connectivity for those who do not have it, providing access to the previously unreachable was rather used only as a marketing tool. The following is an example of a purely profit driven value orientation statement which depicts the **Market** field logic:

*"It makes business sense for large internet companies such as Facebook and Google to increase access in the developing world. Having benefited from the huge uptake of internet connectivity among developed countries, these companies see an as-yet-untapped market opportunity among those who do not currently have internet access."*[20]

Cluster C

This cluster is comprised of government actors who remained very closely tied to values that concern national interests, forming the **State Field Logic**. These actors are concerned with *National Economic Gains*, *Governing Orbital Sustainability*, and utilizing their space sectors as a *Diplomatic Tool*. This cluster does not contain any coding to the pure *Profit* value, while all other clusters during this phase share *Profit* as a common value orientation. Additionally, every actor in this cluster has some type of government affiliation, further solidifying this cluster as a State Field Logic.

[19] CQ Transcriptions (March 8, 2017): HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY, SUBCOMMITTEE ON SPACE HEARING ON REGULATING SPACE (Dataset)
[20] Space Daily (2015): A new space race is on to bring the internet to the whole world (Dataset)

These actors believe that the industry is important for fueling the country's economy and political power which is adjacent to Cluster A (illustrated by the thick, blue links), but differs because cluster A is more focused on profits. Additionally, this cluster is comprised of all State actors while cluster A has many private actors as well. The government actors in this cluster are more focused on utilizing space resources for *National Economic Gains* and as a *Diplomatic Too*l. Using the Chinese government as an example, The Chinese State Council Information Office issued a statement that participation in New Space activities can *"protect China's national rights and interests and build up its overall strength."*[21]

Additionally, the Commercial Spaceflight Federation (CSF) also adheres to the values of National Economic Gains and Space as a Common Resource by the following statement:

*"Founded in 2006, CSF and its more than 70 members are laying the foundation for a sustainable space economy and democratizing access to space for scientists, students, civilians, and businesses. CSF members are responsible for the creation of thousands of high-tech jobs driven by billions of dollars in investment. Through the promotion of technology innovation, CSF is guiding the expansion of Earth's economic sphere, bolstering U.S. leadership in aerospace, and inspiring America's next generation of engineers and explorers."*[22]
*– Eric Stallmer, President, CSF*

Cluster D

The final cluster in this phase that has formed contains the values of *Profit* and *Societal Development*. The actors who make up this field logic have insisted that their motivation behind New Space activities lies in the potential benefits for societal development. At the heart of this cluster lies OneWeb, an LEO mega-constellation which reported to have the vision of bringing the internet to remote schools for the purpose of improving education. Additionally, the U.S. Department of Commerce has cited the importance of internet accessibility due to its ability to provide access to healthcare and education, social stability, and in turn increase economic growth.[23] These actors are set apart from those in cluster A due because they do not appear often in the regulatory discourses. This study therefore refers to this set of value dispositions as the **Community Market** Field Logic.

Other examples of Community oriented satellite mega-constellation business models include Clyde Space and O3 b. Clyde Space is a CubeSat technology company, announced its plans to

[21] BBC Monitoring Asia Pacific (2016): Full text of China's space activities in 2016 (Dataset)
[22] Congressional Documents and Publications (April 19, 2016): House Science, Space, and Technology Subcommittee on Space Hearing; "The Commercial Space Launch Industry: Small Satellite Opportunities and Challenges."; Testimony by Eric Stallmer, President, Commercial Spaceflight Federation (Dataset)
[23] Capitol Hill Hearing Testimony (May 3, 2017): Broadband infrastructure investment; committee: Senate Commerce, Science and Transportation (Dataset)

launch a mega-constellation to make internet free and unrestricted across the globe.[24] O3 b, which stands for "the other 3 billion", referring to those that do not have access to high speed internet, is another example of a company that intents to utilize its market position for the greater good.[25]

*"Those who stand to gain the most from OneWeb are the four billion people who currently have no access to fast internet. Particularly in developing and newly industrialized nations, OneWeb will offer people new opportunities for information, education and economic growth."*[26]

The above statement about OneWeb shows the adherence of the *Societal Development* value by explaining how the company's mega-constellation could increase the socio-economic status of people in developing nations if they have access to their services. This clearly depicts the Community Market Field Logic.

## 4.3 Period III (2018 – 2021 Q1): Analysis of Field Logics

Period III saw a boom in activity with an increase of actors to 78. Additionally, there was a sharp increase in data availability for analysis (*Figure 1*). This period is marked by several major companies being given permission to launch their LEO mega-constellations. *Figure 5* shows how the network grew to be very interconnected. This is represented by the many connections (blue links) between actors seen throughout the network. Additionally, there is a smaller, very tight cluster (B) oriented on the left side of the whole network and several other very tight connections throughout the figure that are represented by the dark, thick blue lines.

Using Ward's clustering coefficient, 3 distinct clusters were found in the following network (*Figure 5*). Cluster A is comprised of 39 actors, Cluster B is 16, and Cluster C is made up of 23 actors.

[24] Plus Company Updates (2017): Clyde Space wins Queen's Award for Enterprise.
[25] Investor's Business Daily (2015): Big-Name Investors On Mission To Launch Commercial Space; Google, Fidelity Fuel Advance; SpaceX the biggest early success in industry where startups also getting funds (Dataset)
[26] ENP Newswire (2016): RUAG technology is key enabler for OneWeb (Dataset)

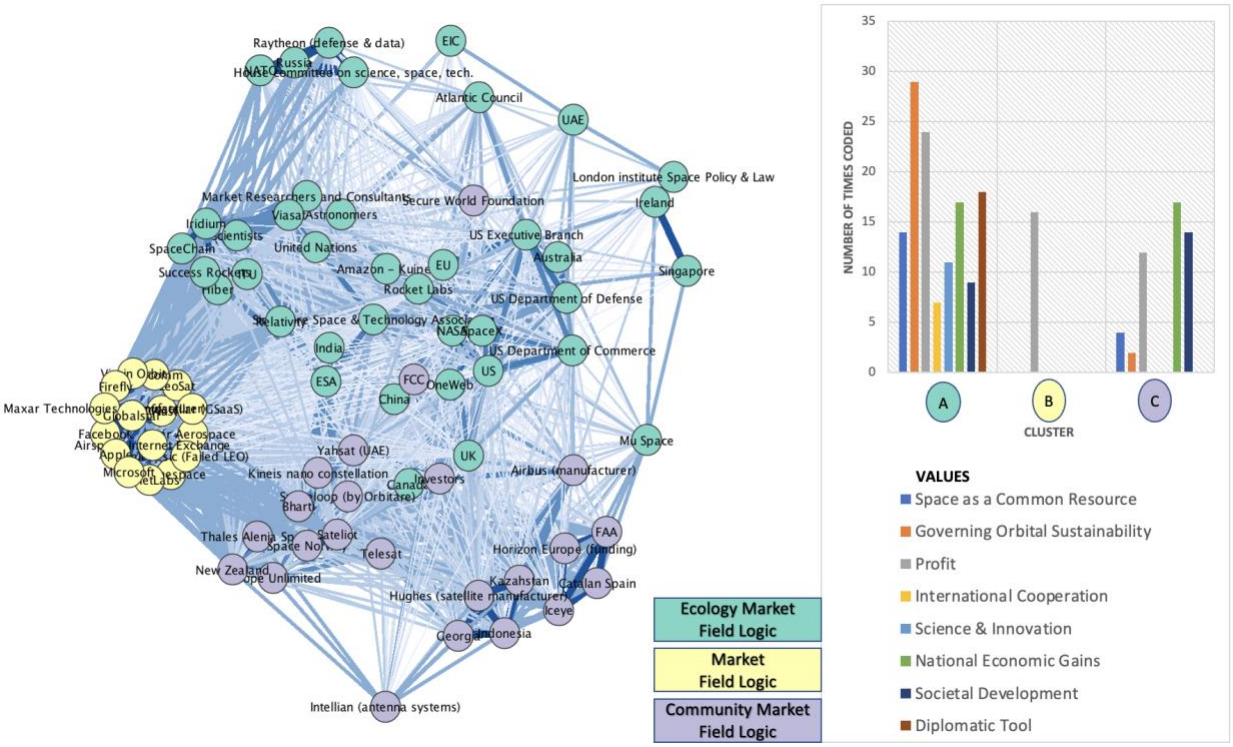


*Figure 5: Phase III Actor-Network & Field Logics Distribution*

Cluster A

The central positioning and abundance of actors indicates that cluster A is the **dominant cluster**. This cluster contains a variety of actors and has a varied value disposition. The most common values are *Governing Orbital Sustainability*, *Profit*, *Diplomatic Tool*, and *National Economic Gains*. Therefore, this cluster is considered to be the **Ecology Market** field logic. These actors value profit while still preserving the sustainability of earth's orbit.

The main LEO mega-constellations, SpaceX's Starlink, Amazon Kuiper, and OneWeb all are present in this cluster and hold very central positions, indicating that they are at the center of mobilizing discourses. These dominant clusters continue to be more enmeshed with major government bodies, sharing the same field logic (i.e., being present in the same cluster). From the discourse analyzed, it can be inferred that the companies and governing bodies could be influencing each other in tandem. An example of co-influence is SpaceX, with their lobbying tactics to the FCC already in period II regarding spectrum efficiency regulations. During that time the Starlink mega-constellation was proposed but had not yet been given market access. In 2018 SpaceX was given approval by the FCC to launch the mega-constellation with an added endorsement by the chairman, Ajit Pai, saying: "*Satellite technology can help reach Americans who live in rural or hard-to-serve places where fiber optic cables and cell towers do not reach."*[27]

[27] Reseller Middle East (2018): SpaceX gets the go-ahead for broadband satellite services (Dataset)

Which matches the language used by SpaceX's chief operating officer, Gwynne Shotwell, when the FCC approved the network:

*"This is an important step toward SpaceX building a next-generation satellite network that can link the globe with reliable and affordable broadband service, especially reaching those who are not yet connected"*[22] *- Gwynne Shotwell, COO, SpaceX*

This example shows the Market interest of varying actors in the cluster.

However, as the mega-constellation grew, more concerns appeared regarding regulatory, viability, constellation interference with the work of astronomers, and the ever-prevalent worries about space pollution from an excess of satellites floating around in LEO. In 2019, the Business Insider reported that SpaceX filed permission to launch 42,000 satellites rather than it's originally proposed 12,000. This would be 20 times the total number of total working satellites in orbit at the time of the request. If 1 in 20 satellites fails, there is a 6% chance of collision.[28] This creates huge concerns for the scientific community and the *Governing Orbital Sustainability* value.

*"That is huge. At a 6% chance of collision, astronauts would be put into an escape hatch to possibly escape,"*[29] *- John Crassidis, Space debris researcher, University of Buffalo*

Along with concerns about space debris, astronomers have their own concerns about mega-constellations due to the brightness of the satellites. Due to their presence being so much closer to earth's surface they tend to be much brighter than GEO satellites, creating light pollution in the night sky and interfering with the work that astronomers do. Astronomers are raising their concerns, stating that just like with industrial activities on earth, there may need to be regulations concerning those in Space as well.[30]

*"If I get sick and tired of living in Columbus, Ohio, I could move out to a remote cabin and disconnect from the internet. But here, everybody on the entire Earth that ever wants to look at the sky has to look at the Starlink satellites. Obviously not everyone can pick up and relocate to the woods to experience the unobscured beauty of the sky. But there still are, for now, places where you'd expect not to see artificial stars passing overhead."*[31]
*- Krzysztof Stanek, Astronomer, Ohio State University*

As a result of these complaints, companies are having to take the criticism seriously, and adjust in order to gain approval for their business endeavors. These concerns adhere to the value of *Governing Orbital Sustainability* and are therefore considered contributing to the Ecology Logic.

[28] The Business Insider (2019): SpaceX may want to launch 42,000 internet satellites — about 5 times more spacecraft than humanity has ever flown
[29] Space Daily (2015): A new space race is on to bring the internet to the whole world (Dataset)
[30] Express Online (2020): Asteroid shock: SpaceX Starlink to make spotting new city-killers 'very difficult'; ASTEROID experts hunting for new space rocks on potential collision courses with Earth have warned SpaceX Starlink could hide rogue killer space rocks.
[31] Atlantic Online (2020): The Night Sky Will Never Be the Same (Dataset)

Due to the strong Market and Ecological values in this cluster, the actors subscribe to an **Ecology Market Field Logic** whereby, they are struggling to strike a balance between viable businesses which also take into consideration the related environmental impacts.

Cluster B

Throughout all clusters there remains a field logic with the most succinct value orientation and that is the **Market Field Logic**. Since phases I and II the cluster has gained actors and become even more rooted due to the Profit value disposition, as can be seen by the tight clustering and the bar graph on the right side of *Figure 5* which indicates that *Profit* is the only value for this group of actors. Additionally, the prominence of *Profit* has now spread throughout all clusters in the whole network. This is made evident by the logic distribution breakdown (bar graph in *Figure 5*) and the many connections throughout the network (blue links). Overall, the entire network is more closely linked than in the two previous periods.

More companies are seeing the value in the New Space sector, establishing varying business models in an attempt to profit from Space activities. This cluster has doubled in size since the previous time phase (II). Austin based company; Firefly aerospace is a prime example of a company that has joined the New Space movement. At the moment, Firefly focuses on flexible access to space, by providing economical and convenient access to LEO through their launch services. In an interview between Texas Monthly and Firefly's owner, Tom Markusic, Markusic explains that he wishes to transition to a rocket parts supplier, standardizing the industry to lower the barriers to entry.

*"In the past, parts were unbelievably expensive because they were being primarily sold to the government. If you wanted to buy a space-shuttle main engine, it was tens of millions of dollars. But if you could buy rocket engines for a couple of hundred thousand dollars from this company in Austin? It would totally change the economics."*[32]
*– Tom Markusic, Founder and CEO, Firefly Aerospace*

Standardizing parts would lower their costs, lower overall launch costs, and thus reduce the barriers to entry making it easier for more companies to shoot internet satellites into orbit.
This business idea further validates the existence of the **Market Field Logic**. More companies are also coming up with their own innovative ideas to transform satellite launch services:

*"Relativity's groundbreaking, patented 3D printing technology platform together with Terran 1's unique and flexible architecture provides mu Space a faster and more reliable launch at a lower total mission cost than any other launch services company in the world. With this launch partnership, two of the most visionary and innovative aerospace startups are sharing expertise,*

[32] Texas Monthly (2019): Getting to liftoff (Dataset)

*resources, and capabilities to transform the satellite launch and services industry across the U.S. and Asia-Pacific regions."*[33]

Additionally, the data included several statements regarding the potential plans of several companies to build their own mega-constellations due to the market potential. The following is one example of such statements:

*"Given the size of the potential market it's no surprise that SpaceX, OneWeb, Amazon and Facebook and others are all engaged in building internet-based satellite constellations, or are actively making efforts to do so."*[34]

Cluster C

The third, and second largest cluster regarding the number of actors represents a collection of a few different values. The overarching values are guided by *Profit* and *Societal Development*. *National Economic Gains*, although a logic which is primarily supported by the State, also includes many market interests. Therefore, this cluster is considered the **Community Market Field Logic** whereby actors seek to promote markets through mobilizing the discourse with the intent to reach rural places.

This Community Market field logic has a similar value disposition to the Community Market field logic in phase II but contains a new set of actors. The actors grew from 5 (phase II) to 23 and vary greatly, including companies (e.g., Yahsat, Bharti, Airbus, etc.), governments (Indonesia, New Zealand, and so forth), regulatory commissions (The Federal Aviation Administration (FAA)), and a multi-national organization (The Secure World Foundation). The following quote from Brian Weeden, Director of Program Planning for the Secure World Foundation, explains how mega-constellations benefit society. It is an example of how the *Societal Development* value shows up in the data:

*"The purpose of these constellations is to either collect imagery and other remote sensing data about the Earth or to provide broadband internet and other communications services to the world, both of which would deliver valuable socio-economic benefits."*[35]

[33] Business Wire (2019): Relativity's 3D Printed Terran 1 Rocket to Launch mu Space's Low Earth Orbit (LEO) Satellite (Dataset)

[34] The Irish Times (2020): Little looms large in new space race; With smaller rockets launching micro satellites, Ireland could be primed to win a share of an exploding market (Dataset)

[35] U.S. House of Representatives Documents (February 11, 2020): House Science, Space, and Technology Subcommittee on Space and Aeronautics Hearing; "Space Situational Awareness: Key Issues in an Evolving Landscape."; Testimony by Brian Weeden, Director of Program Planning, Secure World Foundation; WAX20621120H038

The most notable addition to this cluster is the inclusion of new government actors (Indonesia, New Zealand, Catalan Spain, Georgia, and Kazakhstan) who understand the benefits the services would provide to their citizens as well as their national economies, explaining the presence of the State supported market logic of *National Economic Gains*. From the discourse analyzed, evidence was found that governments are now willing to support companies in order to address societal challenges, thus improving the socio-economic status of its' citizens. In some cases, governments are providing federal investments or tax breaks to companies, creating partnerships to reach societal development goals. This is the case with the Canadian Communications company, Telesat and the Canadian government:

*"Thanks in part to this federal investment, Telesat will create and maintain 485 jobs over the next decade and invest $2.4 million in activities and scholarships in the areas of space and science, technology, engineering and math (STEM) for young Canadians. Telesat will also create 40 new co-op learning opportunities for post-secondary students and expand collaborations with Indigenous communities to address broadband service gaps and needs."*[36]

- *Navdeep Bains, Minister of Innovation, Science, and Economic Development, Canada*

This is a clear example of the **Community Market** field logic, whereby business and public-private partnerships can be used to increase communications access, leading to greater opportunities of societal development.

## 4.4 Evolution of Field Logics and implications on sectoral development

Based on the empirical evidence presented, a change can be observed in the respective field logics over time. The LEO satellite mega-constellation sector underwent significant changes from 1997 through the beginning of 2021. The networks experienced tremendous growth in core actors from 20 in period I to 78 in period III. In period I, one dominant field logic was identified, cluster B, which was driven by what this study called the **Market** Field Logic. The tight cluster was comprised of the largest number of actors and centrally located in the network presented. The Market Field Logic remains strong throughout the periods, while the adherence towards profit values also dispersed to other logics throughout time, as shown by the logic distribution graphs in *Figures 3,4, and 5*. Profit values remaining important can also be explained by the dominant clusters being the **State Market** and thereafter **Ecology Market** Field Logics in phases II and III respectively. This section will explain the changes of the field logics over time and how actors' guiding principles have implications on the overall development of the global internet mega-constellation sector and its potential trajectories. More specifically, it will focus on the most prominent actor preferences identifiable in the study, in terms of regulations and policies, as well as business strategies.

[36] Thai News Service (2019): Canada: minister Bains announces major investment in the future of connectivity for Canadians living in rural and remote communities (Dataset)

*Figure 6* shows the development trends in field logics. The thick green boarder around a particular field logic indicates that it is the dominant field logic during that phase. The satellite icon indicates the emergence of a new field logic while the dark arrows show how a field logic evolved from other previous field logics.

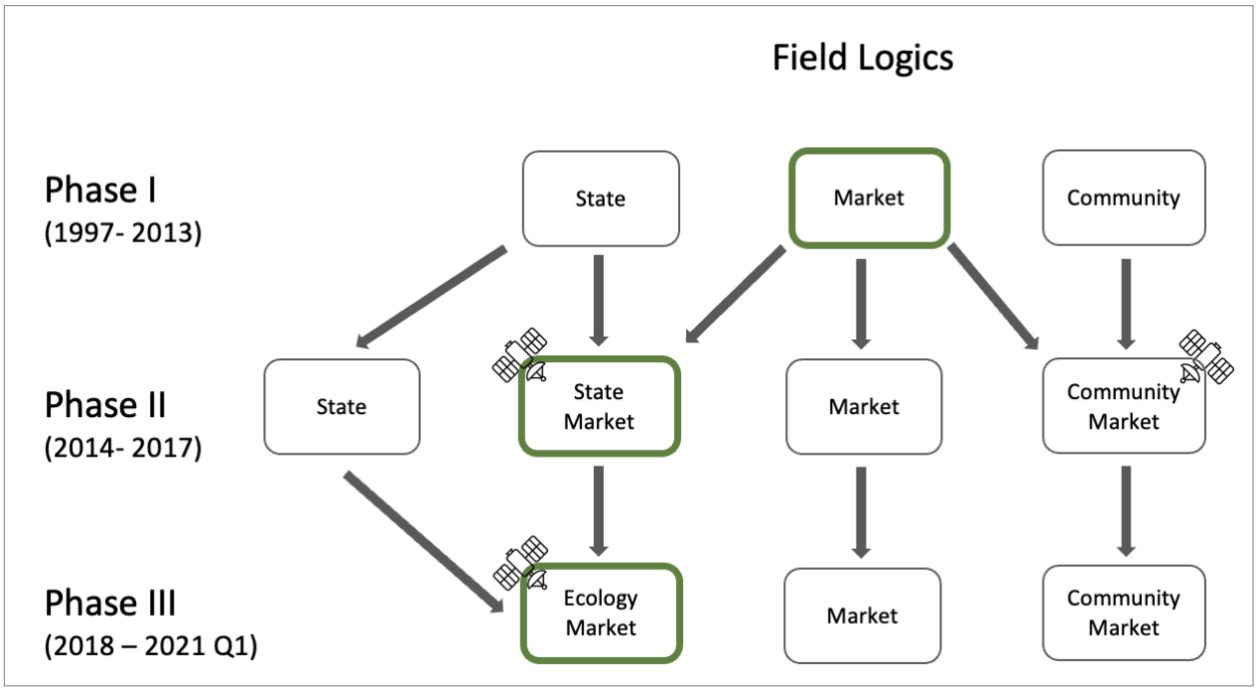


*Figure 6: Field logic changes over time*

The **Market** Field Logic drives the development of the sector from the onset and continues to be a prominent theme over the course of time, with its values being present in all field logics in phase III. *Figure 6* shows how the **Market** Field Logic spreads to two additional clusters in phase II and then remains present in phase III. Values from the **State** Field Logic from phase II converge with the newly formed **Ecology Market** Field Logic in phase III, which represents a cluster of state and private actors now increasingly concerned with orbital sustainability issues.

This research starts at the beginning of the New Space era, whereby private actors began to commercialize space. Included are a diverse set of actors with varying business activities, which continued to grow overtime. **Market** Field Logic clusters in the networks (phases I, II, and III) are comprised of actors that are primarily companies with ranging business activities from communications, satellite manufacturing, rocket launching, to accessory companies (e.g., software). It is to be expected that profit values would dominate the emerging sector due to the niche innovations that are seeking to gain traction during this time. However, the operating costs were still very high during the time of phase I, causing the early pursuers of mega-constellations to not be able to carry out their plans.

During Phase II there remained a clear **Market** Field Logic but value orientation towards *Profit and National Economic Gains* also contributed to the newly emerging field logics of **State Market**

and **Community Market**. Additionally, in phase II, a new cluster emerged, showing a change in overall field logics to four instead of three. While the market is gaining traction this period can best be explained as a time of increased regulatory concerns of the sector, explained by the presence of both the **State Market** and **State** Field Logics, given the increasing concerns about *Governing Orbital Sustainability*. It can be seen that Clusters A (State Market) and C (State) in phase II formed from a split of Cluster C (State) from phase I. This is known by the distribution of value orientations (see bar charts *in Figures 3* and *4*) and the fact that 25% of actors from Phase I Cluster C travelled to Phase II Cluster A, and another 25% travelled to Phase II Cluster C (see *Appendix C*). Additionally, values from the **Market** Field Logic cluster in phase I emerged in the newly formed **State Market** Field Logic cluster in phase II. The values were strong enough to lead to a new clustering of interests in Phase II that could exist independently of one another, thus the emergence of four field logic groups from three in phase I. The new Cluster (A) contained a much higher times coded of *Profit* and *Space as a Common Resource* making it the **State Market** Field Logic, while Cluster C contained absolutely no *Profit* value with strong governing and nationalistic values, making Cluster C the **State** Field Logic.

Based on the empirical data, it was found that the **State** Field Logic prefers a top-down approach to governing the increasingly privatized Space sector, rather than the permission-less innovation approach which was discussed in the analysis of Phase II Cluster B, which is the **Market** Field Logic. In 2016 the Obama administration (shown as *U.S. Executive Branch* in the network) called for regulations on all types of private commercial Space activities. The policy required explicit authorization from the Secretary of Transportation for every mission, which is defined as the operation of any space object. Actors in the clusters of the **Market** Field Logic responded by voicing their opinions that the regulations are too strict, favoring more freedom to experiment with their business endeavors. The following is an excerpt from an actor favoring the permission-less innovation approach, who is depicted as *Space Policy Experts* in the Phase II network (*Figure 4*):

*"Instead of adopting the Obama administration's proposal, I urge the Congress to consider blanket authorization for all non-governmental operations in space that do not cause tangible harm to other parties, foreign or domestic, in their peaceful exploration and use of outer space. Such an approach would meet our treaty obligations while maximizing the scope for innovation and experimentation in space."*

- *Eli Dourado, Regulation of Emerging Technologies, George Mason University.*[37]

Even though actors in the **State** Field Logic cluster (in this example, the United States government) prefer a top-down approach, they are aware of the challenges of attempting to govern Orbits. Even with an international code of conduct, it is a challenge for government organizations to constrain the activities of actors in Space given how difficult it is to verify and

[37] Committee Hearing (March 8, 2017): HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY, SUBCOMMITTEE ON SPACE HEARING ON REGULATING SPACE (Dataset)

regulate international agreements.[38] State actors value the ability for all nations to have access to Space, making drawing such an agreement as to which activities should and should not be allowed an immensely difficult starting point. However, some actors believe that an international legally binding regulatory approach is the best course of action for managing the New Space sector. A *Scientist* in the **State Market** cluster says international cooperation for rule making is needed:

*"Apart from the serious problem of managing space debris, the increasing role of new space actors from the private sector underscores the need to create international rule-based and legally-bound regulations for the space common. This complex undertaking requires international coordination and cooperation."[39] – Ghulam Mujaddid, Scientist*

The study provides further evidence to support the changes in regulatory preferences in phase III. More specifically, the change in field logics loss of the State Field Logic, points to the decline of the top-down regulatory approach and the strengthening of the permission-less innovation approach. Using the FCC as an example, which is a core actor in the cluster of the Community Market Field Logic, in 2019 Chairman Pai announced his decision to loosen restrictions on the industry to fuel American innovation for the benefit of businesses and consumers:

*"A byzantine licensing and regulatory approval system is a bottleneck that hurts businesses and consumers alike. That's why under my leadership, the FCC has been committed to matching the tempo of the industry we regulate. Our space agenda involves cutting red tape and giving green lights." – Ajit Pai, Chairman, FCC[40]*

As a result, this study observes a trend towards the preference of letting private actors lead in finding solutions for orbital sustainability challenges. For instance, the FCC Chairman has also made his opinions clear that Space debris is a valid concern for the FCC. However, the FCC will be "*looking for entrepreneurs to take a leadership role in this area*"[41] with the hope that New Space companies will find ways to solve potential crashes in Low-earth orbit rather than needing to regulate access to Space.

In Phase II there emerged a difference in actors' business strategies between the **State Market** and **Community Market** Field Logics. The Community Market actors framed their narratives by promoting the social benefits of mega-constellations. Alternatively, State Market actors were more focused on creating potential coalitions with State actors, as outlined in the analysis of Phase II, cluster A.

[38] CQ Transcriptions (January 7, 2014): GENERAL WILLIAM SHELTON (USAF) DELIVERS REMARKS AT THE GEORGE WASHINGTON UNIVERSITY ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS ON SPACE AND CYBERSPACE (Dataset)
[39] Ghulam Mujaddid (2013): Second tragedy of global commons: strategic competition and conflict over humanity's common assets (Dataset)
[40] Impact News Service (2019): Chairman Pai Remarks on the Space Economy at U.S Chamber of Commerce
[41] Satellite Today (2019): FCC Chairman Wants to Cultivate Innovation in Space

Overall, concerns about different ways of *Governing Orbital Sustainability* increased drastically in Phase III. There appeared the convergence of the State and State Market Field Logics into one, resulting in three distinct clusters from four in phase II. Additionally, this period saw the emergence of a new dominant cluster, the **Ecology Market** Field Logic (Cluster A), whose strongest value is *Governing Orbital Sustainability*. Period III is distinct because it is a time where mega-constellations began to put their plans into practice and thus, much criticism came up as a result. Varying actors began to voice their concerns regarding the potential implications of sending such large amounts of satellites into Low-earth orbit. The discourse grew very strong in this period regarding the effects that the bright lights from these satellites would have on astronomers' work and Space safety concerns due to the number of objects floating in Low-earth orbit.

*"If OneWeb goes ahead and launches its proposed constellation without mitigation, that is going to have very severe impacts on ground-based astronomy to the point that, for at least four months out of the year, it's going to be pretty impossible to do most observations. You might as well just shut the observatory down for the summer months, because there's going to be so many satellites screwing up your data."*[42] *– Johnathan McDowell, Astronomer*

Despite these concerns, clear preferences towards actors being in favor of LEO mega-constellations were coded in 71 articles throughout the entire period under review (phase I – III) in contrast to the 33 articles which explicitly stated that an actor was not in favor of the technology. However, the discourse found many examples of actors who were in favor of mega-constellation projects as long as the growth of the market was handled in a responsible manner (45 articles), causing one to question what the orbital debris boundaries of LEO are and how it can be ensured that core actors in the industry respect this. As was the case with the FCC example above, several discourses preferred a permission-less innovation strategy, placing trust that private innovations will find a way to solve these concerns, rather than increasing regulations on the sector. In other words, these actors believe that market competition will solve its' own problems, which could be an explanation as to why phase III displayed such strong market values in all the field logics. It is argued by actors that a thriving market with competition will incentivize actors to innovate:

*"Competition forces every company to provide the best possible options for the government and the taxpayer at the best possible price."*[43] *– Kristin Grantham, Spokeswoman, SpaceX*

The above remark was made regarding NASA's decision to encourage the private sector to build rockets, providing launch services for satellites and other uses. This increasing privatization, or democratization of Space, was also emphasized by the New Zealand rocket company, Rocket Lab:

[42] The Business Insider (2020): SpaceX just launched new Starlink satellites with sun visors to make them less bright. A scientist says that won't stop them from interfering with astronomy. (Dataset)
[43] Via Satellite (2012): NASA Sees Private Sector as Key to Escaping LEO (Dataset)

*"Our rocket is one of the tools that is enabling much more access to space. It will allow some really cool things to happen that will have significant effects on humanity. […] You are seeing the democratization of Space. Space is tipping from a government dominated domain to a commercial domain."[44] – Peter Beck, Founder, Rocket Lab*

The statement further substantiates the influence of Market values during phase III. The study found evidence that companies are starting to innovate and revise their business models so that they meet some sustainability expectations. Rocket Lab believes that LEO satellites are more sustainable than traditional GEO satellites due to their ability to burn up when they re-enter Earth's atmosphere. The company also has designed additional technology that leaves little behind in orbit:

*"Small satellites are a good way to build space infrastructure, because you can do it very sustainably. A geosynchronous satellite will be around for tens of thousands of years; a small satellite will decay orbit and re-enter the Earth's atmosphere and burn up. That kind of sustainability flows back into how we have designed the vehicle and how we insert satellites into orbit. […] So we are very conscious of not leaving anything behind except the spacecraft. Historically, that's not been done."[45] – Peter Beck, Founder, Rocket Lab*

Another concern that was gaining traction based on the study is how business can build their LEO infrastructure to improve societal development. This change was observed over time in regard to the **Community** Field Logic. Phase I showed a very clear small cluster of actors that subscribed to the field logic, emphasizing the importance that internet capabilities can have on increasing citizens' socio-economic standings. Over time this cluster grew and was influenced by new concerned values, evolving into the **Community Market** Field Logic. What the data shows is that some companies have framed their marketing narratives to say that they intend to bring internet connectivity to underdeveloped regions. However, it is unclear if this is their target consumer since this may not be a profitable business endeavor considering the cost to deploy these mega-constellations is so great.

Therefore, criticisms can be found regarding the business models of the Internet satellite mega-constellations and their potential ability to widen the digital divide instead of closing it. Some believe the internet service provided from mega-constellations would be too expensive at first to be bought by the average customer and that the increase in speeds would only matter for specific industries. Therefore, development of satellite mega-constellations may be strongly driven by targeting specialized industries rather than focusing on the general public as a consumer who do not have Internet access, despite this population being the most in need of the service. Below is a statement regarding an ideal consumer for SpaceX's Starlink constellation (referred to as *'the project'* in the quote):

[44] Financial Times (2018): Small satellites and big data: a commercial space race hots up (Dataset)

[45] The Observer (London) (2018): One man's mission to conquer space; Rocket Lab entrepreneur Peter Beck's recent launch into orbit of Humanity Star drew a barrage of flak. But he remains undaunted (Dataset)

*"The final realization of the project will see something that is less orientated to the world's population but instead offers a service that will be more appealing to high-frequency traders at big banks, who might be willing to fork out large sums for dedicated, faster connections. Paying customers will be critical, given the exorbitant costs of the project."*[46] *– Mark Handley, University College London*

At the moment the data greatly favors the discussion on *Governing Orbital Sustainability* over *Societal Development* with 217 to 104 total codings respectively to each category throughout the total analysis time period. Overall, the results indicated a lack of discourse regarding how broadband from these mega-constellations would be brought to disadvantaged consumers. It is important to consider that one would still need access to stable electricity and a device from which to connect from to utilize these services.

[46] Digital Journal (2018): SpaceX advances plan to build a global wireless Internet network (Dataset)

# 5. Conclusion

The aim of this thesis was to understand the factors that have shaped the rapid development of the internet satellite mega-constellations sector to identify opportunities and challenges for a sustainable transition. More specifically, it focused on actors' value orientations to identify different field logics over time, as well as their preferences in terms of regulations, policies, and business strategies. This led to a deepened understanding of the emerging socio-technical regime surrounding the global internet satellite mega-constellation sector, to gauge how the industry might develop given this increasingly privatized and arguably under-regulated sector. Hence, the following overarching research question was addressed:

*How does the emerging socio-technical regime of the global internet satellite mega-constellation sector look and in what direction might the sector develop in the future?*

To answer this question the literature on socio-technical transitions was used. More specifically, an institutional logics perspective from Fuenfschilling and Truffer (2014). The combination of values that actors subscribe to gives rise to field logics which describe the coherent bundles of rules, goals, and visions of actors in the sector. Discourses from newspapers and government documents were analyzed for the actors' value orientations and preferences regarding the mega-constellation sector across three time periods. This information was then coded and the socio-technical configuration analysis method using value proximity from Heiberg and Truffer (2021) was applied to create logic-based actor networks. Ward's method was then utilized to cluster the actors' value dispositions into groups based on similarity. The resulting actor networks are based on the existing value dispositions found in the satellite mega-constellation discourses. The overarching field logics identified give an indication as to the preferences of sectoral development by the corresponding actors. To answer the primary research question, the question is broken down into three corresponding sub questions for a deeper analytical perspective:

1. *How have the conflicting interests, i.e., different field logics, in the satellite mega-constellations sector evolved over time?*

The results of this study show that the LEO satellite mega-constellation sector has evolved over time, with different field logics being dominant in different time periods. These differing interests help to explain the rapid developments that were outlined in *section 3.1.2*, *A Historical Overview*. The first-time phase was characterized by three distinct clusters of interests. The dominant cluster was the prominent Market Field Logic which consisted of companies seeking to profit by entering the New Space industry. The second field logic is that of Community, which is characterized by actors whose discourses are focused on bridging the digital divide. Third, a State Field Logic which focuses on the interest of governing was present but weak, understood by the large distances between actors which shows that their values were not in close proximity to one another. Additionally, there was not much discourse regarding policies during phase I. However, this changed in phase II when the State Field Logic gained prominence as the business idea of

LEO mega-constellations re-emerged and companies were seeking regulatory approval. There was an addition of a fourth cluster of interests in phase II, the State Market cluster, which combined the interests of Market and State Actors. This field logic was defined by a more collaborative approach to governing the emerging sector whereby governments and private actors were working together to shape regulations. This field logic influenced the sector a great deal, most notably due to the lobbying tactics used by private actors. While the Market cluster was interested in creating new Space businesses which were geared for profits, the State actors were focused on whether to, and how to regulate the growing number of actors in the Market cluster.

Due to the prominence of the Market and State Market Field Logics in phase II that is increasingly driven by the interests in profit and economic gains, in phase III actors' interests towards a pure State-driven governance logic subsided. Instead, actors became increasingly concerned about Community and Ecology values, leading to the emergence of the dominant Ecology Market Field Logic. It can be found that there are emerging signs of a more coordinated effort to deal with orbital sustainability as actors increasingly discuss and shape discourses regarding which regulatory path to take to tackle this issue. However, throughout all phases there remained a very clear Market Field Logic which is growing more prominent. This leads to opposing clusters of interests. On the one hand, actors of the Market Field Logic benefit from the sector remaining under-regulated, on the other hand, the evidence shows that the Ecology Market Field Logic contains actors who are interested in correcting the orbital sustainability challenges that the Market Field Logic might create. The growing Market Field Logic is a sign that these opposing logics are creating growing resistance that slows down a rapid transition towards more sustainable business models and a governance approach regarding the use of low-earth orbit.

2. *Who have been the most prominent actors in influencing the sector's development?*

The actors of the LEO mega-constellation sector changed drastically throughout the analysis. Most notability, the increase from 20 to 78 core actors from phase I to III, which were identified through the data analysis. However, only 8 most important actor types appeared in all three time phases, which is only 10% of the total in period III. These are *Investors, Iridium, the Russian governments (presented as 'Russia'), Scientists, NASA, The United States (US), U.S. Department of Defense, and the U.S. House Committee on Science, Space, and Technology*. Apart from *Iridium* and *Russia*, these actors remained among the most influential actors throughout the study. Iridium originally started launching its' satellites in the late 1990's before going through bankruptcy and then only in 2017 did they resume the launch of their satellites. Their system is being used by the United States Department of Defense and thus did not appear much in publicly available data. It is unclear why the Russian Government's discourse weakened. One explanation is due to government security reasons. From the data analyzed, there was no evidence found that the Russian government is planning on launching its own satellite mega-constellation or facilitate any other actors to do so. The other six actors remained rather central in the networks throughout all three phases.

Phase II introduced several more dominant actors including *SpaceX, OneWeb, Amazon*, and the *FCC*, which grew to be even more dominant in phase III. Based on the historical background and the data analyzed it was found that this revival in actors was due to changes in the launch market which decreased costs, therefore making mega-constellations a more viable business endeavor than in a previous time. It was during phase II that these actors began actively shaping business strategies which became decisive for the sector's development. Despite the large number of actors found to be participating in the sector this study uncovered that only a handful of actors are influential in steering the sector's development. These actors include the companies with plans for the largest mega-constellations (*SpaceX, OneWeb*, and *Amazon*). Especially with the case of *SpaceX* and *Amazon*, these companies have an incredible amount of capital which break the barriers to entry because previously companies needed funding from many sources to realize their mega-constellation projects which could determine their success. The money is readily available therefore allowing them to act on their business decisions more quickly. Varying branches of the United States government with distinct regulatory roles were also found to be highly influential. This includes the *House Committee on Science, Space, and Technology*, which is a unit of the U.S. Government that has been given special oversight to review and study laws, programs, and government activities involving non-military research and development. This committee has jurisdiction over NASA, making their actions highly influential in shaping the sector's development.

Additionally, actor groups such as *Scientists*, *Market Researchers*, and *Investors* were also found to have influential discourses, most notably due to their expert testimonies which were found in government transcript documents. A major concern regarding the sector is that most of the dominant actors are from the United States which means that essentially the beliefs of one country are largely influencing the orbit which is shared by all nations. At the moment, the FCC remains the primary regulator for LEO mega-constellations in the U.S., therefore this actor is incredibly influential in shaping the sector. The FCC can decide whether to enforce stricter regulations for companies to enter the market, making them a primary actor who determines the number of satellites that will be orbiting in LEO. The analysis results, which shows certain private actors clustered with the FCC, is an indication of them lobbying, or framing narratives, to the liking of the FCC. Therefore, these private companies' values align very closely with those of the FCC.

3. *How does the emerging socio-technical regime shape the direction of different development trajectories of the sector?*

The analysis showed that there was a lot of evolution in the field logics throughout the phases observed in this study. In phase I field logics remained very siloed with a clear Market, State, and Community Field Logic. Moving onto phase II the market interests began to influence other field logics and the State Field Logic became very prominent. Over time the field logics evolved to the Ecology Market, Market, and Community Market Field Logics in phase III. Additionally, the study found increasing coordination among the three different trajectories due to the presence of

market values in all three field logics. This points to the emergence of a socio-technical regime of the sector. Three different development trajectories for the sector have been identified.

The three potential development paths are as follows: First, one development path is where the Market Field Logic gains prominence. In this scenario more actors will emerge, and the sector will favor a period of innovation before any global regulatory decisions are made. In other words, it is unexpected for the State Field Logic (phase II) to resurface before more satellites are deployed, and at least one mega-constellation is fully operational because only then will the exact regulatory challenges become clear and necessary. Second, many new companies will be aligned with the Ecology Market Field Logic by seeking to tackle orbital sustainability challenges. In this scenario governing values will remain, but orbital sustainability issues will likely be handled through public-private partnerships. This is evident by the mixture of these actors present in the cluster indicated in the results. Since this is the dominant field logic at the moment, containing many influential actors, this is a very likely scenario for the sectors' development. Third, the Community Market Field Logic will gain prominence in the future or become co-dominant with the Ecology Market Field Logic. In this development path the sector will experience a growth of actors that seek to explore the best ways to deploy the technology's services on earth. Since the SpaceX Starlink mega-constellation is becoming operational for a limited number of users[47], discourses are expected to increase regarding the accessibility of this service and those which precede Starlink.

It is expected that these three trajectories will co-develop with one becoming the most dominant. Another scenario would be that one trajectory will develop while the rest disappear. However, the later scenario is unlikely since the results show the field logics are all quite strong. There are no logics which are pushed to the periphery in phase III, which would indicate a radical trajectory, making that scenario a path which is less likely to be taken. Overall, the results of this study show that the infiltration of profit values throughout all field logics will cause increasing conflict for a quick transition to a Space sector which considers orbital and social sustainability.

# 6. Discussion

This final section will discuss the theoretical implications of this research. Following this is a reflection on the methodology which includes the limitations of this study. Additionally, the quality criteria used for the analysis is discussed. Thereafter, policy implications based on the results are provided with recommendations for further research.

## 6.1 Theoretical implications

This research has made several contributions to the theoretical development of transitions studies. Most notably, the research builds onto the growing literature that explores the

[47] At the time this section was written, October 2021, Starlink is 'now delivering initial beta service both domestically and internationally'. Source: https://www.starlink.com

development of a sustainable Space sector and is among the early studies that utilizes STCA to map an emerging socio-technical regime. Previous studies on transitions have taken a more localized approach, focusing on transformations of the energy, water, or transportation systems on a national level. Based on the argument put forth by Fuenfschilling and Binz (2018), transitions should also be studied at the global level, which this thesis has made an effort to do (limitations will be discussed in *section 6.2*). Additionally, utilizing an institutional logics approach to better understand transitions of the Space sector is underexplored. The benefit of the institutional logics approach is that this study was able to map New Space actors' beliefs regarding the technology under study. This was done through an expanded coding scheme of the original institutional logics (Fuenfschilling & Truffer, 2014; Thornton et al., 1999;2012) which was able to grasp the more specific value conflicts that the sector is experiencing. This gives greater insights to the unique value-proximities between actors, allowing for a clearer understanding of where similar or conflicting interests arise regarding the development of the sector. More specifically, the coding scheme developed in this study has divided the Community logic into a Community and Ecology logic, pinpointing which actors are more focused on orbital sustainability and which are engaged in how technology could benefit societal development. Another expansion is the specific State values which give further insights as to the reasons State actors endorse the use of a technology, which could greatly impact future policy. By uncovering these nuances, the study takes a progressive path for contributing to transitions research in terms of expanding the basic institutional logics. Furthermore, the approach allows a sector to be viewed on both the national and global level since actors' values can be viewed independently or within the larger context of the study, i.e., the field logics.

The method used for this study by Heiberg and Truffer (2021) is new. By applying the institutional logics approach (Fuenfschilling & Binz, 2018) and combining it with this method of value-proximity, this study is able to clearly identify actor groups which share similar interests. The method used creates a clear picture of these actors and their corresponding field logics, as well as an analysis of potential cooperation patterns in the sector. Therefore, the method proves to be promising for future transitions research. By time slicing the data this study is able to show the evolution of field logics over time which can provide for a clearer prediction of a sector's future development. Additionally, this is one of the first studies to map a formative regime. Based on the principles of institutionalization set forth by Fuenfschilling and Binz (2018), it is *"typically highest when principles have been translated into binding formal or material structures in practice, such as policies, technologies, actors, financial investments or routines" (p. 739).* Due to the lack of policy and the technology still being in its' infancy (the sector does not yet have a complete mega-constellation), it can be inferred that the regime has not yet been institutionalized. Therefore, the sector is highly susceptible to be influenced by the most dominant actors and their corresponding field logics before sedimentation is achieved.

## 6.2 Quality indicators, limitations, and further research

To ensure research quality, this research considered reliability, replication, and validity (Bryman, 2012). Reliability, or the consistency of measures, was ensured through utilization of varying

sources of data with other relevant secondary data that was not included in the STCA analysis. The findings from the STCA, which was based on newspaper articles and government documents, where triangulated with desk research on the historical background of the sector through information found from internet searches. By meticulously including information on the data collection, data analysis procedure, and coding scheme this study allows for replication. To ensure research quality in terms of validity the research was supported by the supervisor, who is one of the few experts of the method used for this study. By having constant, detailed discussions throughout the data analysis period in an iterative process, possible biases were negated from the research, thus ensuring internal validity. This was especially important when first creating the coding scheme. Additionally, this process increased the trustworthiness of the analysis by excluding personal values in the analysis process (Nowell et al., 2017). However, due to the qualitative aspects of this study, validity can be difficult to measure. It should be noted that it is possible that replication of the study would yield different results. This is because the coding process is subjective, and the coding scheme could be interpreted differently by different individuals. Replication of the study with multiple researchers, and cross-coding of discourses could minimize this limitation.

While this study followed proper research protocols for reliability, replication, and validity, there are some limitations to this research. A point of criticism is the use of LexisNexis for data collection. LexisNexis includes a wide range of news and government reports, but the researcher only filtered for English articles. Therefore, this study may not have included discourses from all nations possible considering there was a language barrier. Further research should assess articles in more languages or conduct interviews with experts from underrepresented nations to better account for the global focus of the study. Another opportunity for expansion is adopting a different theoretical scope. This study focused on actors' values and how they relate to the institutional logics of market, community, state, and profession that emerged in the discourse. In this moment the sector is under-regulated, so a value-based approach fits the emerging regime. However, in the future, increasing the focus on governance tactics as the sector gives increasing focus to regulatory or policy issues, could lead to more concrete use of policy-oriented frameworks.

To account for some of these limitations this study included *sensitivity testing* - *"analyses which test the effect on the synthesis of including and excluding findings from studies of differing quality"* (Thomas & Harden, 2008, p. 8). Along with the analysis of value dispositions to identify the field logics the researcher also traced all actors cluster movements. Once the networks were completed different amounts of clusters could be selected to find the amount of field logics that best represents the time phase. Actors' movements between clusters were tracked in an Excel document to pinpoint any clustering patterns that were illogical. Viewing the data in this way allowed the researcher to select specific actor discourses to review in even more detail. For example, this was especially true for phase III when looking at three versus four clusters. This is when the actor tracing became especially helpful. The researcher could look at which actors were separated into an additional cluster and determine whether their discourses were specific enough to be separated, warranting the creation of a new field logic. While a fourth cluster could be derived, the separation of actors and value dispositions did not reflect the ongoing dynamics

of the sector at that point in time. Therefore, it was determined that three clusters were the best representation of field logics for phase III. *Appendix C* contains a complete list of actors and their corresponding cluster for each time phase. This list shows the clustering affiliations using the final choice of three, four, and three clusters, for phases I – III, respectively. The list also includes a column with the affiliated cluster per actor if four clusters had been chosen for phase III. Finally, discussions with the supervisor about the number of clusters were vital in establishing the validity of the analysis. It allowed the researcher to discuss the possibilities and gain a second interpretation of the varying scenarios.

## 6.3 Policy Implications

The visual representation of the results of this study which maps actors and their logic affiliations is a promising tool for studying transitions and can be a useful tool to help guide policy making. Understanding actors' values in the sector can facilitate information-based decision making. The results indicate a challenge, that the infiltration of profit values throughout all field logics will cause increasing conflict for a quick transition to a sustainable Space sector. It was determined that both orbital sustainability and societal development implications must be considered when regulating the growth of the sector moving forward.

The challenge of the Market logic increasing in strength is that it will be unlikely for regulations which govern orbital sustainability to be set in place in a timely manner. It is common for scientists to study highly complex systems which are intended to inform policy decision making, juggling the balance between economic growth and environmental protection (Kriebel, et al., 2001). In cases where cause and effect relationships are not fully established it is best to adopt a precautionary principle, whereby preventative action is taken in the face of uncertainty (Kriebel, et al., 2001). However, the precautionary principle is often criticized because it can stifle innovation (Applegate, 2000; Bishop, 2000). This presents a unique opportunity for the Ecology Market Field Logic to maintain its' dominance. The results indicated that some actors might benefit on the lack of regulation of the sector by creating businesses which seek to maintain orbital sustainability (e.g., develop technologies that remove Space debris). Additionally, since this field logic contains a mix of public and private actors there is an opportunity for cooperation, leading to a more seamless introduction of regulation which benefits all actor groups.

There is evidence to support that the Community Market logic, which means concerns over bridging the digital divide, are growing. While the governance challenges regarding orbital sustainability are being addressed there is still an opportunity for the *Societal Development* values to be further explored. Even though there are conversations taking place in this area, the data shows a need for realistic solutions to bridge the digital divide. Developing business models that ensure the technology is distributed to those most in-need of broadband will be an important factor in the future development of a sustainable sector. Previous studies have explored the implementation of community telecenters for increasing the socio-economic status of populations (McFalls, 2007; Rashid, 2017; Graham, 2015). The mega-constellation sector would benefit from similar frameworks on inclusion, whereby private investments are

understood to be crucial for socio-economic growth in developing countries. Additionally, although after the period of data collection for this study, In August 2021 the United States passed a new infrastructure bill which includes $65 billion to fund the expansion of broadband services in the country (Snell, 2021). Depending on allocation, this funding presents a unique opportunity for an even more rapid uptake of satellite mega-constellations in the United States. However, it remains unclear which populations will benefit if services expand. Aligning actors' efforts through a mission-oriented policy could develop the sector in a way where it will aid in bridging the digital divide. The ethos of mission-oriented policy is that it is vital to strategically tackle problems rather than throwing funds at the problem (Mazzucato, 2018). This is in line with the Markard et al. (2012) definition of a transition which states that a transition should be purposeful and intended, whereby actors coordinate their work to reach a common goal.

Lastly, a very important policy direction regarding this sector is international cooperation. Currently low-earth orbit activities are governed based on the country where the company is based even though all nations should have equal access to low-earth orbit. Without a common understanding it is easy for actors to move their businesses to whichever territory (e.g., country or State) has regulations that match a company's' preferences. An example of this being companies that have chosen to operate out of Texas because the State's laws are preferred for the Space sector when compared to other States (Lott, 2021). Furthermore, the results indicated a lack of *International Cooperation* as a value despite this being present in the data analysis (see *Figures 3,4, & 5*). The value did not appear in phase I and remained low in phases II and III. Therefore, governments should align their vision of this emerging sector to aid in the transition to a sustainable transition, whereby orbital congestion is considered, and effective business practices are put into place so that those most in-need of the services provided by mega-constellations are able to access them.

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# Appendix

## Appendix A: Expanded coding scheme of logics and values, including frequency

| Logic | | Times Coded | Description |
|---|---|---|---|
| **Value (in bold)** | **sub-code** | | |
| **Logic – Community & Ecology** | | | |
| **Ecology - Governing Orbital Sustainability** | | 217 | Concerns and governance ideas regarding the orbital boundaries of Space. This includes regulation of spectrum frequencies and physical orbiting paths |
| | Concerns - space congestion | 56 | Debris and Space situational awareness (SSA) |
| | Longevity of space | 7 | Notion of protecting space for future generations and multiple uses |
| | Astronomy observation (solutions) | 7 | Solutions on how to cope with interference for astronomy observation |
| | Space safety | 39 | Need for orbit to remain safe. Space situational awareness (SSA) |
| | Regulation | 45 | Statements of changes that have happened or are set to happen in regulation |
| | Astronomy observation (concerns) | 45 | Concerns about astronomy observation due to interference from satellites |
| **Community - Societal Development** | | 104 | LEO satellites used to bridge the digital divide |
| | Global Connectivity | 16 | Need for global connectivity - not necessarily specific to connecting the unconnected/underprivileged (& other terms) |
| | SDGs | 3 | When tackling a specific SDG is mentioned |
| **Logic - Market** | | | |
| **Profit** | | 424 | Use of constellations with the intent to profit off the technology. |
| | Direct-to-consumer | 11 | Provide service directly to consumer with no middleman |
| | High Speeds | 12 | Intent of constellation is for high internet speeds |
| | Specialty market | 13 | Service for ships, plains, remote resorts, etc. |
| | Unserved and underserved as market segments | 31 | Intent of constellation is to provide internet for those that are currently not connected or have terrible connections |
| | Varying services or BMs | 52 | When the satellites can be used for multiple things, rather than exclusively for internet. Ex. Earth observation |

| | | | | |
|---|---|---|---|---|
| | | Competition - among companies | 25 | When text mentions the various actors in the market who plan on launching their own constellations. Some discourses exclusively mention that the actors are going after the same market |
| | | Affordability (for profit) | 58 | Discussions of LEO being cheap to set up for a provider |
| | | Tech. to lower costs | 15 | When the affordability for the provider is specific to certain technological advancements related to the technology |
| | | Support from government | 27 | Need for support (financial incentives) to grow business |
| | | Regulatory support (ITU, FCC, etc.) | 21 | Permission to operate, spectrum usage |
| | | Logic - Corporation | 12 | Corporation as hierarchy, increase firm size |
| | | Market doubt | 27 | Usually from market analysts or consultants - their opinions on the market potential |
| **Logic - Science & engineering** | | | | |
| | **Science & Innovation** | | 32 | Importance of science and innovation |
| | | Support unregulated innovation | 6 | Highlights need for loose regulations. Comes from policy experts. |
| | | Adaptive Capabilities | 10 | Industries that are strong enough and have the capabilities that could easily be transferred to New Space & the other way around |
| **Logic - State** | | | | |
| | **International Cooperation** | | 17 | Balancing different needs and cooperating with other nations. |
| | **Diplomatic Tool** | | 55 | Utilizing New Space activities to increase or maintain national power |
| | | National (own) infrastructure | 32 | State actors stating the need for a nation to have its own constellations |
| | **National Economic Gains** | | 146 | New space activities fueling the economy |
| | | Support rural residents | 15 | Need for constellations to support a nations' rural residents |
| | | Public-private partnership | 74 | Discussion of the need to collaborate with private actors to spur innovation or intent to create a commercial market in space |
| | **Space as a Common Resource** | | 61 | All nations should have access to space |

| | | | |
|---|---|---|---|
| | Democratization of space access | 15 | Opportunities for developing countries. Could also be called 'inclusive participation'. This code is for when actors make a reference to the fact that new space allows for new actors to get into an industry which was heavily dominated by specific governments (e.g., U.S., Russia, China). Includes the concept of a sharing economy in space |
| | Democratization of space governance | 20 | Allows more actors to have a say in how space is governed. 'Opening up' the space sector to more actors. |

## Appendix B: Coding scheme for additional aspects

These codes allowed for a deeper analysis when needed. They were not used to derive the actor networks (*Figures, 3,4, and 5*) but rather to search for patterns while writing.

| Category (blue) & Sub Categories below | Sub-Code | Times Coded | Description |
|---|---|---|---|
| **Factors for industry update** | | | Factors that contribute the uptake or success of the industry |
| Government funding (or lack thereof) | | 2 | Doubts about a viable commercial market and NASAs role in particular |
| Launch market | | 31 | Changes in launch market. Supports satellites. Very relevant when discussing how the cost to space has decreased |
| Programs, incubators, partnerships | | 34 | whether this be partnerships between companies or research programs. Could be used to explain some of the links in the networks. More empirics |
| Technological advances | | 6 | If other than launch market advancements |
| **Technology Legitimization** | | | Discussions surrounding the need for internet satellite constellations |
| Affordability (for consumer) | | 13 | Constellations as an affordable option for the consumer |
| Internet of things connectivity | | 6 | Another use for constellations besides broadband |
| Investment - monetary | | 14 | Statements about investments into new space industry - shows that people believe in it/are willing to take a gamble |
| Need for internet | | 32 | Why internet necessary |
| Remote connectivity | | 28 | Why remote areas need internet |
| Satellites | | 2 | How satellites specifically are a useful technology |
| **Preferences** | | | When there is a **very clear preference** regarding the internet satellite constellation sector |
| Avoidance of governance (LEO growth favored) | | 22 | Opposition to governing the sector. ex. Regulations would hamper innovation |

| | | | |
|---|---|---|---|
| Con LEO (or concern) | | 59 | In opposition to LEO constellations |
| Private sector growth | | 44 | Support of the private sector or 'pro space economy' |
| Pro LEO (aggregated) | | 263 | ****broken down by constellations mentioned**** |
| Pro space innovation (LEO not explicit) | | 77 | Need for innovations in space |
| Responsible growth of sector (aggregated) | | 113 | Preferences that actors state so that the growth of the sector can be managed |
| | Organized growth of sector | 24 | An organized growth. Not specific to LEO but rather the general space sector. Common values that actors wish to see thrive in the space domain. Typically, actors also discuss the need for partnerships. |
| | Pro governance (stricter or standardized) | 49 | Pro governance of the sector. Some of these codes include discussions about specific laws. |
| | Reusable technologies | 8 | Actors' discussions on sustainable or environmentally friendly technology (ex. Launch vehicles, satellites). |
| | Sharing technology | 9 | Distributed ownership of space assets. I.e., several nations sharing the use of a constellation |
| | Space safety protocols | 20 | Examples of ideas for maintaining Space safety |
| **Strategies** | | | Actor's strategies manipulating the regime to fit their logic. What are their **actions**? |
| Actor blocking | | 8 | Trying to keep a company/actor from getting a certification or market access. Includes buying out another company. |
| Lobbing | | 29 | Lobbying and other verbal endorsements. |
| Market access | | 19 | Being given frequencies to use or a launch site |
| Partnerships | | 25 | Actors working together or stating that they are seeking opportunities for cooperation |
| Planned constellation | | 39 | Plans for LEO mega-constellation |
| Policy | | 28 | General policies or need for policy |
| | Hard | 5 | Legally binding |
| | Soft | 18 | ex. Memorandum of understanding - not legally binding but signals willingness to move forward |
| Privatization | | 19 | ex. NASA's push in funding of private companies so that they can focus their resources on novel space missions |
| R&D | | 18 | Research & Development efforts put into the sector |
| Rationalizing or defensiveness | | 10 | ex. Company X receives criticism. X then issues a statement why the criticism is invalid |

| | | | | |
|---|---|---|---|---|
| | Space debris mitigation or removal | | 55 | Technologies for debris mitigation or removal, debris tracking, and SSA |
| | Stakeholder engagement | | 11 | Need for all voices to be heard (ex. An actor stating that astronomers should be part of the conversation) |
| | Structured program | | 3 | Programs dedicated to fostering the space sector (ex. Digital Khazakistan) |
| **Satellite Challenges** | | | | Challenges for uptake of LEO constellations. **This category served as a list of themes that come up.** |
| | Increase digital divide | | 1 | Argument that these constellations will increase the digital divide |
| | Safety challenges | | 2 | Most safety challenges fall into a logic of 'governing orbital sustainability' so this is not well developed. This is arguments about digital hacking safety |
| | Short lifespan | | 3 | Satellites have a short lifespan. After-life and removal must be considered. Again, this is not well developed because most related discourses fall into a logic |
| | Launch challenges | | 4 | Difficulties with launching the LEO satellites |
| | Rights to frequency spectrum | | 4 | Concerns about the frequency spectrum. This is also limited and a satellite must be granted a frequency from which to operate. |
| | Fundraising challenge | | 11 | Difficult to gain investments for building a mega-constellation |
| | Profitability | | 15 | Concerns about whether mega-constellations will be profitable |

## Appendix C: Tracing actors cluster affiliations over all phases

All core actors with corresponding cluster number. This process was used as a sensitivity test. A comparison is shown here between phase III as 3 clusters or 4 clusters. This is used as an example to show how the sensitivity testing was performed. This process was performed for several scenarios when deciding on the best cluster amount (i.e., field logics) to represent the data.

| Actor | Phase I | Phase II | Phase III (3 clusters) | Phase III (4 clusters) |
|---|---|---|---|---|
| (CSF) Commercial Spaceflight Federation | | 3 | | |
| Airbus (manufacturer) | | | 3 | 3 |
| Airspace Internet Exchange | | | 2 | 2 |
| Amazon - Kuiper | | 1 | 1 | 1 |
| Apple | | | 2 | 2 |
| Arianespace | | 2 | 2 | 2 |
| Astronomers | | | 1 | 1 |
| Atlantic Council | | | 1 | 1 |
| Australia | | | 1 | 1 |
| Bharti | | | 3 | 3 |
| Boeing | 2 | | | |

| | | | | |
|---|---|---|---|---|
| Canada | | | 1 | 1 |
| Catalan Spain | | | 3 | 3 |
| China | | 3 | 1 | 1 |
| Clyde Space (cubesats) | | 4 | | |
| EIC | | | 1 | 1 |
| ESA | | | 1 | 4 |
| EU | | | 1 | 1 |
| Europe Unlimited | | | 3 | 3 |
| FAA | | | 3 | 3 |
| Facebook | | 2 | 2 | 2 |
| FCC | | 1 | 3 | 3 |
| Firefly | | | 2 | 2 |
| Fleet (Australia) | | | 2 | 2 |
| Georgia | | | 3 | 3 |
| Globalstar | 2 | | 2 | 2 |
| Google | | 2 | | |
| Hiber | | | 1 | 1 |
| Horizon Europe (funding) | | | 3 | 3 |
| House committee on science, space, tech. | 3 | 1 | 1 | 4 |
| Hughes (satellite manufacturer) | 2 | | 3 | 3 |
| Iceye | | | 3 | 3 |
| ICO Global Communications | 2 | | | |
| India | | | 1 | 4 |
| Indonesia | | | 3 | 3 |
| Infostellar (GSaaS) | | | 2 | 2 |
| Intellian (antenna systems) | | | 3 | 3 |
| Intelsat | 1 | | | |
| Investors | 3 | 1 | 3 | 3 |
| Ireland | | | 1 | 1 |
| Iridium | 2 | 4 | 1 | 4 |
| Isar Aerospace | | | 2 | 2 |
| ITU | 1 | | 1 | 4 |
| Kazahstan | | | 3 | 3 |
| Kineis nano constellation | | | 3 | 3 |
| L5WorldVu | | 2 | | |
| LeoSat | | 2 | 2 | 2 |
| London institute Space Policy & Law | | | 1 | 1 |
| Loral Space | 2 | | | |

| | | | | |
|---|---|---|---|---|
| Market Researchers and Consultants | | 1 | 1 | 1 |
| Maxar Technologies (manufacturer) | | | 2 | 2 |
| Microsoft | | | 2 | 2 |
| Motorola | 2 | | | |
| Mu Space | | | 1 | 1 |
| NASA | 3 | 3 | 1 | 1 |
| NATO | | | 1 | 4 |
| NBN Co (Australia) | | 2 | | |
| New Zealand | | | 3 | 3 |
| O3b | | 4 | | |
| OneWeb | | 4 | 1 | 1 |
| Orbcomm | | | 2 | 2 |
| Orbital Sciences | 2 | | | |
| Planet (company) | | 1 | | |
| PlanetLabs | | | 2 | 2 |
| Raytheon (defense & data) | | | 1 | 4 |
| Relativity | | | 1 | 1 |
| Rocket Labs | | | 1 | 1 |
| Russia | 3 | 3 | 1 | 4 |
| Sateliot | | | 3 | 3 |
| Scientists | 3 | 1 | 1 | 4 |
| Secure World Foundation | | | 3 | 3 |
| Singapore | | | 1 | 1 |
| Singapore Space & Technology Association | | | 1 | 1 |
| Space Norway | | | 3 | 3 |
| Space Policy Experts | | 2 | | |
| SpaceChain | | | 1 | 4 |
| Spaceflight | | 2 | | |
| Spaceloop (by Orbitare) | | | 3 | 3 |
| SpaceX | | 1 | 1 | 1 |
| Stratolaunch | | 2 | | |
| Success Rockets | | | 1 | 4 |
| Teledesic (Failed LEO) | 3 | | 2 | 2 |
| Telesat | 1 | | 3 | 3 |
| Thales Alenia Space | 2 | | 3 | 3 |
| The Space Foundation (US) | | 1 | | |
| UAE | | | 1 | 1 |
| UK | | 3 | 1 | 1 |
| United Nations | | | 1 | 1 |

| | | | | |
|---|---|---|---|---|
| US | 2 | 1 | 1 | 1 |
| US Department of Commerce | | 4 | 1 | 1 |
| US Department of Defense | 3 | 3 | 1 | 1 |
| US Executive Branch | | 3 | 1 | 1 |
| Viasat | | | 1 | 1 |
| Virgin Orbit | | 1 | 2 | 2 |
| World Economic Forum | | 1 | | |
| Yahsat (UAE) | | | 3 | 3 |