Can Regulating Large Satellite Constellations as Monopolies Improve Sustainability Standards While Providing Effective and Equitable Internet Access?

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Can Regulating Large Satellite Constellations as Monopolies Improve Sustainability Standards While Providing Effective and Equitable Internet Access?

Thesis directed by Prof. Lauren Blum and Prof. Zachary Donohew

Large satellite constellations (LSC) in Low Earth Orbit (LEO) provide the means to deliver internet to previously underserved populations. The LSC's economic potential combined with a growing demand for internet access has led to multiple companies pledging their own internet LSCs in hopes of capitalizing on this need. This, in addition to growing interest in LEO, risks destabilizing the LEO environment if not regulated properly. The current U.S. Orbital Debris Standard Mitigation Practices (USODSMP) are woefully outdated and only sporadically followed by operators. Furthermore, there are no licensing regulations for other key sustainability requirements, such as propulsion and tracking. Accelerated growth of internet LSCs without proper regulation will lead to an unsafe and unsustainable LEO environment. There needs to be a change in how governments regulate private and public LSCs, in particular those providing internet telecommunications. Internet LSCs are the fastest growing population in LEO, often directly competing for orbits and broadband frequencies.

In this thesis I investigate whether the U.S. could apply aspects of terrestrial utility infrastructure to better regulate satellite internet. In particular, I question whether the U.S. government could regulate internet LSCs as monopolies. Such regulatory control would allow the U.S. to better enforce and revise sustainability regulations and ensure fair access to internet services. Viewing internet as a utility, as a necessity of modern life to which all citizens deserve access, this thesis proposes the U.S. license a single internet LSC from within its borders. I explored two potential regulatory approaches: one based on the U.S.'s public utility system and one based on European internet infrastructure. I then presented these approaches to five experts in the field of space sustainability and solicited their feedback. From these results, I determined that both of my regu-

latory approaches are not feasible in their current forms within the U.S.; however, both approaches produce potential partial applications and variations of their initial design that may find traction. This thesis concludes that adopting an *interoperability framework* in LEO would allow for precise and targeted sustainability, technology, and capacity standards for each orbital corridor, empower regulatory bodies to enforce these standards, and preserve competition among Commerical Satellite Operators (CSOs). Finally, a government internet LSC competing against commercial internet LSCs, akin to terrestrial municipal internet, would demonstrate technological feasibility, satisfy equity requirements, and provide a baseline LSC for CSOs to compete against.

Dedication

To Mom and Dad. Thank you for letting me take the wayward road.

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Contents

Chapter 1

Introduction

"Gentlemen, my idea is as radical as the Constitution itself".[1] With these words, President Franklin D. Roosevelt declared his intention to convert electricity from a privately controlled amenity to a tightly regulated public utility.[2] Electricity's growing importance to daily life, congested competing electricity systems in urban areas, and scant service offerings to rural America fueled a movement to better provide and manage electricity.[3] This idea was not received with open arms. The existing electricity companies knew that government entry into the market would severely undercut their profits, if not knock them out of the business entirely. They labeled the plan as "socialist" and the beginning of a slippery slope to a full communist revolution.[4] In the end, the clear benefits of having electricity managed as a public utility overcame the desires of private industry. From President Roosevelt's actions came America's modern electrical infrastructure and the American public utility system.

Today, America is experiencing a similar dilemma with the internet. There is unequal access between urban centers and rural communities,[5] with lagging quality and rising prices relative to

1. Eschner, 2017
2. For this thesis, I will be defining a public utility according to Colorado law, in particular CO Rev Stat § 40-1-103 (2016). To quote this definition: "The term "public utility", when used in articles 1 to 7 of this title, includes every common carrier, pipeline corporation, gas corporation, electrical corporation, telephone corporation, water corporation, person, or municipality operating for the purpose of supplying the public for domestic, mechanical, or public uses and every corporation, or person declared by law to be affected with a public interest, and each of the preceding is hereby declared to be a public utility and to be subject to the jurisdiction, control, and regulation of the commission and to the provisions of articles 1 to 7 of this title."
3. Eschner, 2017
4. *Roll On Columbia the Documentary*, 2005
5. Pollard & Martinez, 2021

other nations.[6] Spurred by the Covid-19 pandemic, when quality internet access became crucial to the welfare and livelihood of millions of Americans, activists have been gathering support for converting internet into a public utility.[7] The echoes of history are loud and clear with internet utility: private companies argue that government interference suppresses private rights while public advocates call for greater coordination of services and both affordable and equitable access to internet. Bolstering the public argument is the stark divide between urban and rural internet access. It is more costly for private companies to deliver internet to rural communities compared to urban cities, and there are few incentives to build such infrastructure. Satellite-based internet could bridge this gap and provide a way for internet to become a truly accessible public utility.

Satellite-based internet broadcasts internet from orbit, most successfully by Starlink. The CubeSat and launch revolution[8] have made access to Low Earth Orbit (LEO) easier than ever.[9] As a result, companies have begun launching constellations in LEO to offer services previously limited to terrestrial infrastructure or blocked by a price barrier.[10] If the U.S. were to pursue the conversion of internet from a private service to a public utility, creating an internet LSC on the order of 10^4 in satellite count could be an effective way to provide internet access to isolated suburban-rural communities and transportation services (trains, planes, ships, etc.).[11]

A government-administered large satellite constellation (LSC) in LEO could also allow for easier implementation and continual revision of modern sustainability norms. While easier access to LEO has opened the space economy to new endeavors, it has also led to an explosion in the number of satellites in orbit.[12] Competition is crucial for a healthy economy, the spatially limited nature of LEO means that competition must be balanced against preservation of orbits for safe use and for the use of future generations. It is these concerns that drive the field of space sustainability.[13]

6. Downes, 2015
7. Lazarus, 2020; Milano, 2021; Toh, 2020; Whipple, 2021
8. Jones, 2015
9. Weinzierl, 2018; Rao, 2019; Start-Up Space 2020, 2020; Low Earth Orbit (LEO) Satellites Global Market Report 2022, 2022
10. Constellations are defined as a group of similar satellites operated by the same operator and working towards the same purpose. Common examples include the Starlink internet constellation and NOAA earth imaging constellation.
11. *Space-Based Broadband Internet Market — A Global and Regional Analysis*, 2021
12. *Count Evolution by Object Orbit*, 2019; *Space Sustainability Infographic*, 2022; Kulu, 2022; Lewis, 2020; Pardini & Anselmo, 2021

Space sustainability, can trace parts of its heritage to the works of Dr. Donald Kessler and the Kessler Syndrome.[14] The Kessler Syndrome is a theorized chain reaction where the collision of two satellites in an over-congested orbit sparks a chain reaction of collisions caused by exponentially growing debris. Such an incident will render orbital space uninhabitable for generations. As deployment of satellites in LEO increases, so does the chance of a Kessler Syndrome.

How can the global space community avoid triggering a Kessler Syndrome? The risk of a collision can be mitigated with appropriate regulation by government and proper behavior by satellite operators. This includes governments updating their sustainability norms to reflect the current LEO environment and operators practicing space situational awareness (SSA). SSA focuses on operators maximizing all potential options towards minimizing collision occurrence. This includes greater ground-based observation and tracking of satellites and debris, improving communication with other operators, and minimizing one's orbital footprint. While operators are ultimately liable for implementing these behaviors, regulatory bodies can play a major role in promoting and enforcing such behaviors. However, progress has been slow on improving sustainability standards, especially in terms of regulation. The current U.S. space debris mitigation guidelines are outdated,[15] and the continually changing nature of LEO's population combined with evolving technology makes the creation of fixed sustainability standards difficult. If the U.S. regulated LSCs like monopolies it could regularly and quickly update its sustainability standards.

How does this idea square with international law? When considering new space legislation, one must ensure that proposals abide by the Outer Space Treaty (OST) and the International Telecommunications Union's (ITU) broadband allocation process. These are the primary institutions which govern how, where, and when governments and CSOs operate in space. Addressing the

13. For this thesis I will be defining "Sustainability" as *the ability to meet the needs of the present without compromising the needs of future generations.* This is adapted from the Oxford English Dictionary's definition of sustainability (2b): "the property of being environmentally sustainable; the degree to which a process or en terprise is able to be maintained or continued while avoiding the long-term depletion of natural resources" and is the definition used by the UN (*Report of the World Commission on Environment and Development: Our Common Future*, 1987).

14. Kessler et al., 2010. Note, this is an update on his 1978 paper, adapting his findings to the changing space environment.

15. *U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update*, 2019; Chow, 2021; Christensen, 2016; Undseth et al., 2020; Boley & Byers, 2021; *Mitigating Space Debris Generation*, 2022; *Space Sustainability Infographic*, 2022

OST, my monopoly proposal falls safely within its regulations, noting in particular Articles I, II, and VI.[16] Article I states that access to outer space shall be "free for exploration and use by all States", meaning that so long as the State—in this case the U.S.—doesn't restrict other countries, it can self-regulate and create a monopoly. Along similar lines Article II states that no nation can appropriate space while Article VI asserts that nations must bear responsibility for their nation's assets, regulating as needed.[17] Within its own borders, the US can set up an internet monopoly, offering services to its citizens and any paying customers abroad. Such a monopoly does not prevent other countries from launching their own satellites and regulating operators to their own standards.

Where the OST dictates the basic rights and restrictions of actors in space, the ITU facilitates how actors communicate in space. The ITU allocates broadband frequencies to satellites in orbit, working to manage their usage between state and private actors. The ITU's Radiocommunication Sector handles the allocation and management of radio-frequency spectrum from terrestrial and orbital sources. Their goal is to "ensure rational, equitable, efficient and economical use of the radio-frequency spectrum… including those using satellite orbits" for all potential actors.[18] While the ITU holds no enforcement power, the benefits of having a central agency allocating spectrum, ensuring interference-free broadcasting for all parties is enough incentive for countries to abide by its rules. For this reason, countries request frequency allocations from the ITU for each satellite launched. These frequencies are determined by orbit, purpose, time of use, strength of broadcast, region, and other factors laid out in the ITU Radio Regulations.[19] So long as the U.S. registers its selected internet LSC with the ITU and sticks to its allocated frequencies, then it can regulate domestically as it pleases.

This thesis considers this context and asks the question: could the U.S. regulate an internet LSC as a monopoly while offering quality, nationwide internet, implementing modern sustainability norms, and keeping costs low without unreasonably stifling innovation? I will explore two possible

16. *The Outer Space Treaty*, 1966
17. *Id.*
18. *Telecommunications Union Radiocommunications Sector Mission Statement*, 2022
19. *Radio Regulations - Articles - Edition of 2020*, 2020

frameworks, one modeled after the U.S. public utilities system and one modeled after the European internet infrastructure. Experts from across the space industry will then consider these frameworks with respect to five sustainability goals, the desire for equitable access to internet, and the need to keep the space economy strong and growing. I will then compile their responses as evidence, analyzing and comparing opinions to draw conclusions. The combination of background research with expert testimony, compiled by opinion, will inform a conclusion as to whether a monopoly-centered regulatory regime is a reasonable option in its entirety, in parts, in a revised form, or whether it should be eliminated from the pool of possible solutions.

Chapter 2

Background Research

There are two ways to test policy without implementation. The first is to run a simulation using numerical data guided by parameters and functions (quantitative), while the second is to source the opinions and criticisms of relevant experts (qualitative). I elected to pursue the latter option for four reasons:

(1) The constantly shifting nature of the LEO environment and economy requires a human expertise that can't be found in data alone.

(2) A quantitative analysis would take more time than this thesis allows, as I do not have the training to complete a quantitative economic and policy analysis.

(3) A quantitative analysis might not be able to measure sustainability, quality of product, and innovation in sector, factors that are subjective by nature.

(4) For theoretical concepts human expertise provides the highest quality data. Interviewing notable experts allows for all these criteria to be thoroughly considered and contrasted.

As a result, the data for this thesis comes from a series of interviews with relevant experts from industry, academia, policy, law, and satellite operation. As this thesis relies on expertise of participants, the interviews are non-anonymous, recorded, and each participant's name and title are included in Appendix B and this thesis's analysis.

Preceding these interviews I conducted a six-month literary review, supplemented by informal dialogues with colleagues in the field of space sustainability. My past research focused on implementing sustainability norms through self-governance among CSOs. My existing expertise from past research, much of which surrounded CSOs and self-governance, was not enough to comprehensively approach this thesis. This topic required additional review of anti-trust law and history, the history of utilities and the internet, the economic reason for monopolies, and the history of monopolies in space.[1] I brought my initial findings on these topics to experienced colleagues, with whom I checked my understanding against their experience and knowledge.

This initial research phase produced a few key findings, and while not all supported my proposal for an exclusive internet constellation within the US, they all supported the need to propose and challenge this idea. Below I discuss these findings in brief. A list of additional readings and sources I consulted for my literary review can be found in Appendix A:

2.1 Finding 1: INTELSAT

INTELSAT was one of the first satellite networks, holding an international monopoly on satellite communications from its inception in 1964[2] until deregulation concluded at the end of the 1980s.[3] INTELSAT was a multi-national satellite constellation in geostationary orbit (GEO) that offered international telecommunications via satellite. Prior to INTELSAT, international calls from non-central cities had to be routed through major international hubs, increasing operation costs and reducing call capabilities.[4] With INTELSAT someone could place a direct call to and from anywhere on the globe, no routing required. International participation by governments, regulatory priority within the US and abroad, and a high barrier to entry that private funding struggled to

1. For a detailed walk-through of the literary review, along with additional sources that may go unreferenced directly in the main thesis, see Appendix A.

2. *Agreement Establishing Interim Arrangements for a Global Commercial Communications Satellite System, and Special Agreement (with Annex).*, 1964

3. "Satellite Warfare: Undoing Intelsat's Monopoly," 1991

4. Levy, 1975. Footnote 2, "As President Johnson said in the 1967 policy message on telecommunications: 'A telephone call from Rangoon to Djakarta must still go through Tokyo. A call from Dakar, Senegal, to Lagos, Nigeria, is routed through Paris and London.... Such an archaic system of international communications is no longer necessary.' (Lyndon B. Johnson, "Global Communications Systems," Message to Congress, August 14, 1967)"

reach elevated INTELSAT to a successful monopoly.[5] However, this monopoly would not last.

What ended INTELSAT's monopoly proved to be the success of airline deregulation. Prior to deregulation, the government enacted price control measures on airline tickets, only allowing unrestricted profit through secondary payloads such as mail and packages.[6] Faced with an oil crisis, half-full flights, and rising prices, the Carter Administration and the Reagan Administration deregulated the airlines. Prices dropped, air travel rose, and new companies entered the business.[7] Successful deregulation of airlines pushed the U.S. to deregulate space access. Free market thinkers at the time sought to solve the high cost of INTELSAT's services by ending its monopoly on satellite communication, opening the market to private companies. Advocates argued that commercial companies could provide satellite telecommunication services more efficiently than INTELSAT.[8] Heeding the desires of free market advocates, President Reagan announced the development of a separate communications satellite constellation, citing national interests. Not wanting to lose the international partnerships and coalition built by INTELSAT, he committed to continued collaboration and consultation with INTELSAT as a legitimate competitor.[9]

Not all favored the end of INTELSAT's monopoly. As detailed by Marcellus Snow in 1987,[10] US allies and pro-government advocates within the US stressed INTELSAT's 'natural' monopoly as a reason for its protected existence,[11] citing the existing stability and international cooperation of INTELSAT. Proponents argued that having INTELSAT remain a monopoly would be beneficial to bloc cohesion, not separating countries into satellite owners, operators, and paying users.[12] These arguments were not enough to prevent deregulation, and since overcrowding space was a nascent

5. Levy, 1975; Fimea & Mann, 1986
6. Kahn, 1988, Soulier 2018
7. Kahn, 1988
8. Snow, 1987
9. *Memorandum on International Communications Satellite Systems*, 1984
10. Snow, 1987
11. Natural monopolies are defined as monopolies that form due to economies of scale, or when it becomes more cost-effective for one entity to provide a service versus multiple competitors, when the consumer savings from splitting infrastructure costs are greater than consumer savings from increased competition. It is assumed that a sustainable natural monopoly needs no protection, as it is the natural result of market forces, however it is often the case that traditional natural monopolies like utility companies gain protection from local, state, and federal government.
12. *Id.*

idea, legislators did not yet view space as a scare resource.[13] Indeed by the 1990s INTELSAT faced competition from various private companies, eventually going private itself in 2001.[14]

INTELSAT failed as a public monopoly because lawmakers did not consider space a scarce resource nor consider telecommunications a public utility. Why restrict competition when there is theoretically unlimited space to build competing infrastructure? It made sense to deregulate under the assumptions of the time. In 2022, however, experts recognize that this assumption is false. We now know space, particularly LEO, is a scarce and limited resource,[15] and the requirements of modern-day society have opened discussions regarding internet as a public utility.[16] If the U.S. shifts internet to a public utility, spearheaded by an internet LSC, then it is logical to consider the existing U.S. public utility system.

2.2 Finding 2: U.S. Public Utility System

In the U.S.,[17] states and corporations jointly manage public utilities,[18] granting one entity monopoly rights over a set area.[19] These entities are either government owned[20] or private corporations beholden to tight regulation by the state's public utility commission (PUC).[21] Using the State of Colorado and Xcel Energy (the state's electricity and natural gas provider) as an example, the state fixes how much Xcel can charge households for electricity and gas, declaring that no profit can be made from these services. Instead, Xcel gains profits from the maintenance and development of energy infrastructure such as power plants, wires, solar panels, and other forms of energy generation and transmission.[22] Xcel charges the consumers a rate of return, usually spread out over years,

13. Matignon, 2019
14. Pelton, 2017
15. AMES Orbital Debris Program Office, n.d.; Macaire, 2017; Patel, 2019; *Requirements on Space Debris Mitigation for ESA Projects*, 2002; *Space Debris Guidelines*, 2007; *U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update*, 2019; Sampaio et al., 2014; Silbert et al., 2010; Undseth et al., 2020; Boley Byers, 2021; Lewis, 2020; M*itigating Space Debris Generation*, 2022; *Space Debris by the Numbers*, 2022; *Space Sustainability Infographic*, 2022; Pardini Anselmo, 2021
16. Litan, 2014; Rahman, 2017a, 2017b; Downes, 2015
17. Due to its unique approach to energy management, this thesis will not use Texas for any comparisons.
18. Here I include electricity, natural gas, water, and sewage systems.
19. Triedman et al., 2021
20. "Tennessee Valley Authority Act of 1933." [48 Stat. 58-59, 16 U.S.C. sec. 831]
21. *Public Service Company of Colorado Electric Tariff Index*, 2022
22. Brasch, 2022

a contentious topic that has garnered accusations of wasteful infrastructure building.[23] If the U.S. government applies its public utility system to an internet LSC, it will need to find a reasonable way to allow the monopolist a rate of return based on the nature of the LEO environment. This is the job of the PUC.

PUCs hold substantial control over policy and standards, with some states using PUCs to mandate a transition to carbon-free energy.[24] Members of PUCs are either elected by voters or appointed by the state, and while PUCs are intended to be non-political, PUCs often support political agendas. As pointed out by Triedman et al., PUCs that fall under industry control or political agendas fail to effectively regulate and provide the best possible product to the public. If LSCs are regulated like public utilities, the PUCs could negotiate fair rates while also requiring key sustainability standards. While a space PUC may need to alter the monopolist's profit mechanism (if the LSC is operated by a private company), the concept holds substantial potential if the internet LSC is part of a larger public utility internet infrastructure.

The U.S. is unique in how it allocates public utility management. Some states feature direct government control (such as the Tennessee Valley Authority), some allocate a single company for each utility (such as Colorado), and some have a more open market unique to their state (such as Texas). However, contemplating internet as a public utility without mentioning how other countries manage internet and other utilities would produce in an incomplete analysis. Thus, I turn to the European internet infrastructure.

2.3 Finding 3: The European Internet Infrastructure

Unlike in the US, where internet service providers compete over who has the best infrastructure and service, most European countries[25] operate under a service-only competition model.[26] In this model the government constructs and manages the physical internet infrastructure, allowing

23. *Id.*
24. Brasch, 2022; Triedman et al., 2021
25. While the United Kingdom has formally left the European Union, this thesis will consider the United Kingdom a European country with regards to internet infrastructure.
26. Yoo, 2014

companies to provide competing services using that infrastructure. Each apartment and house can connect their chosen company's adapter to a government provided rack connected to the country's internet infrastructure. Through this adapter, the internet provider can channel broadband via the infrastructure to the equipped house. As an example of how competition may vary, Company A might charge higher rates for quicker services, while Company B charges half the price of Company A but provides slower internet access. However, both companies deliver their services through the same infrastructure.

It is well documented that European internet lags behind the U.S. in terms of coverage and speed.[27] As of 2013, the FCC found that 83% of Americans had access to internet at a speed of 25 Mbps or greater,[28] while Europe achieved a 62% connectivity rate for the same speed.[29] Furthermore, the U.S. tends to have faster advertised speeds, reporting a median speed of 150 Mbps compared to 100 Mbps in Europe.[30] However, the price of broadband is generally less in Europe than in the U.S., with a 2020 report finding average European monthly prices to be $44.71 compared to $68.38 in America.[31] This supports the common arguments regarding private vs. public services; the private sector tends to provide higher quality service, but the public sector is often more affordable.

2.4 Conclusion

This background research illuminates a few insights regarding what makes a monopoly successful. INTELSAT succeeded when it provided a common tool that made international communication easier and supported the needs of many parties, but it failed when terrestrial and space technology eliminated the need for it. The U.S. public utilities system works well when the PUCs are well organized and empowered to regulate and modernize the utility system as needed but

27. Yoo, 2014; Cooper, 2022; Downes, 2015; Gruber et al., 2014
28. *2015 Broadband Progress Report and Notice of Inquiry on Immediate Action to Accelerate Deployment*, 2015. 25 Mbps (megabytes per second) is considered the standard for basic internet operation, hence its use as a benchmark minimum usable speed.25 Mbps (megabytes per second) is considered the standard for basic internet operation, hence its use as a benchmark minimum usable speed.
29. Downes, 2015
30. Chao et. al., 2020
31. *Id.*

fails when PUCs lose power to political agendas or industry influence. Finally, the European internet infrastructure provides more affordable but delivers internet to fewer households then free market internet does in the U.S. Building on these lessons, this thesis creates two potential regulatory approaches in an attempt to provide quality, affordable, and accessible satellite internet while empowering regulatory bodies to enact modern sustainability norms.

Chapter 3

The Initial Frameworks

The US and Europe have different systems, each with their own strengths and weaknesses; there are lessons to be learned from investigating both. In this section I will adapt the US public utility and European internet approach to LSC regulation in LEO. I will present two approaches for regulating an internet LSC within the US as part of a larger internet-as-utility framework, with each reflecting one of the two infrastructure and regulatory approaches. These frameworks become the basis of later interviews with experts and professionals, evolving with their feedback. Below are the original approaches.

3.1 Approach 1: the U.S. Public Utility System (The PU Approach)

Modeling an internet-LSC after the U.S. public utility system centers on the U.S. government giving one company exclusive rights to operate and provide internet from orbit.[1] In this approach the monopoly would be contingent on providing a base level of utility and internet speed, ensuring it remains competitive with land-based internet. Furthermore, access would be nation-wide, providing the same quality internet to all regions and communities.

The company would be regulated by a national public utilities commission (PUC), either located within an existing department like the Federal Communications Commission (FCC) or a

1. As I will discuss later in my *Discussions* section, this idea opens the door to the *National Champion* concept. This is when each country or bloc (like the EU) promotes one satellite internet provider. These national champions would then compete on the global satellite internet market, with consumers able to choose from among the various networks. This would both provide competition while also limiting satellite buildup in orbit.

new department. The PUC would:[2]

- Determine the market price for services, calculating operational costs,
- Determine the profit percentage the monopolist can charge relative to a break-even price,
- Negotiate and regulate the break-even price plus the profit percentage,
- Monitor and evaluate the monopolist, ensuring they abide by the required sustainability and equity standards along with other regulatory requirements,
- Perform audits of where the LSC needs maintenance and upgrades, and adjust the monopolist's percentage profit depending on the success or neglect of said monopolist.

Following current trends of satellite internet usage,[3] the focus would be on providing rural and off-grid access to areas where terrestrial internet struggles to reach. Being part of an internet-as-utility plan, satellite would fill in the gaps, hence the rural focus. Thus, the PUC would negotiate rates comparable to urban and suburban fiber-optics. The PUC should have an odd number of members, be appointed by the President, approved by the Senate, and hold positions for a set number of years.[4] The PUC's members should be a mix of scientists, engineers, policy experts, and economists. Their goal would be to take a holistic approach to internet regulation, balancing consumer desires, business needs, technical requirements, and scientific understanding of the space environment to best determine regulations.

3.1.1 Expected Challenges

The primary expected challenges of the PU approach stem from government overregulation: stagnation, monopolist abuse, and mismanagement. With the PUC's members being Presidentially

2. These duties are based off the Colorado Public Utilities Commission (*Public Service Company of Colorado Electric Tariff Index*, 2022) and a report conducted by the Brown University Climate and Development Lab on how state utility commissions can affect the transition to clean energy (Triedman et al., 2021)

3. Cooper, 2022

4. There are concerns surrounding presidential appointments and public service companies, so suggestions on more effective membership selection processes are welcome. Concerns rise from the politicization of the Postal service and the Postmaster General.

appointed and Congressionally approved, this framework runs the risk of political influence causing mismanagement. Managing interest groups and party desires will be a struggle, requiring careful bureaucratic protection. In the same vein, the nature of government risks this LSC falling prey to needless bureaucracy. The lack of corporate competition, driven by profits and competitors, increases the risk of mismanagement. Such mismanagement can allow slip-ups to occur, for the monopolist to gain undue influence, and for standards to drop, harming the consumer.[5] Any PUC would need to balance insulating itself from outside interest groups while remaining cognizant of changes to technology, consumer needs, and the LEO environment.

Regarding the monopolist, its unique position allows it to unduly influence the PUC, lobbying for favored rates and contracts that could harm the consumer. Furthermore, the monopolist has few inherent incentives to innovate and develop new technologies, as no one can threaten its monopoly. There are potential remedies, such as rewarding profit based on the development of new infrastructure,[6] but this runs the risk of encouraging unnecessary development of new infrastructure purely for the sake of profit. While the government should encourage the monopolist to develop and implement new technology, infrastructure development without improvement risks counteracting the very sustainability desires that spurred this form of regulation.

These are just a few of the roadblocks and challenges I expected to encounter through my interviews. While I listed the major challenges above, some other possible roadblocks include:

- Congressional deadlock creating a commission lacking full membership,
- Existing satellite constellations providing similar services,
- Broadband congestion in urban areas,
- Accurate auditing of the monopolist and fair price negotiations,

5. For a poignant example of bureaucracy and corporate influence, see the 2019 scandal involving the Boeing 737 MAX, where ethics were compromised and the system fell prey to a single interest group gaining influence. See Herkert et al., 2020 for a detailed description of the engineering ethics compromised by the 737 MAX certification process.

6. This is how the State of Colorado allows Xcel Energy, its gas and electricity provider, to generate profits. Xcel Energy breaks even on services and maintenance, but can net a profit from the construction of new energy infrastructure. For specific details, see the *Public Service Company of Colorado Electric Tariff Index*, 2022.

- Foreign competition from nations who act as flags of convenience (lax regulations to encourage investment).[7]

3.1.2 Conclusion

The PU approach is native to the U.S., derived from existing institutions for inspiration. The next approach originates outside of the U.S., taking its principles from European countries and applying them to the American political structure.

3.2 Approach 2: European Internet Infrastructure (The EI Approach)

This model attempts to apply the European internet infrastructure to the LEO internet LSC. As such, the U.S. government would operate an internet-providing LSC, overseeing maintenance and relevant updates such as new technology, higher speeds, and greater coverage. Through this LSC, commercial entities could offer internet services, allowing for multiple companies to compete for consumers and ensuring nation-wide access, fulfilling Article I. Each satellite would be equipped with multiple broadcasting and receiving transponders, which companies can use to provide their service. Consumers would then equip their chosen provider's antenna (the rack-adapter of this scenario) and receive service from their provider through this shared infrastructure. Funding for this project would come from the taxpayer, however this could be recouped by offering additional services internationally. Furthermore, contracting out the development and construction of the LSC would help bolster domestic industry and employment.

The LSC would adhere to an open access agreement such that internet providers can use the infrastructure to supply services to consumers and businesses. If the LSC were a highway, the internet companies would be the freighter trucks delivering parcels to consumers. As with highways, companies would pay a toll to use the LSC, a fee which would contribute to operation and maintenance.[8] Under this open access agreement, the government could enforce net neutrality

7. However, as I will detail when discussing results from my meetings, this can be used as a solution to stagnation and monopolist abuse.

8. As with most taxes, the cost of this tax would be borne by both the company and consumers, however with

rules, preventing throttling and blocking of traffic for competition reasons and following a non-discriminatory traffic management regime.[9] The direct control would also extend to implementing sustainability regulations.

Regarding sustainability, this framework is the easier of the two to enforce. With the government controlling the LSC, it can enforce sustainability standards via law and policy, much akin to the standard mitigation practices that U.S. missions currently follow.[10] In order to abide by the sustainability metrics detailed in the next section, the U.S. would need to develop and implement more advanced SSA technology.[11] A wide-scale adoption of SSA technology by a government LSC would lower the cost of producing and purchasing said technology. This is where the greatest strength of this framework lies, in setting precedent and developing SSA technologies for other companies and countries to adapt, follow, and utilize. This is what is missing from the current U.S. approach to debris mitigation guidelines, as a lack of precedent and implementable technologies prevent widespread compliance.[12]

3.2.1 Expected Challenges

The most obvious challenge to this idea is the existence of U.S.-based internet LSCs such as Starlink. For this approach to succeed, the government would need to purchase rights to or nationalize existing constellations, something the U.S. has rarely done in modern times, although there is precedent. Historically, the U.S. has only done this during times of war or extreme financial strife. Considering the country's aversion to government overreach and fear of socialism, such a move would need to be extremely well-played and well-argued. While a market takeover in the form of stock ownership exists for publicly traded companies, it is unlikely the U.S. government would want to do this unilaterally without massive public support. It is more likely to negotiate a

the service-based competitive market driving prices companies would find this balance based off market prices.

9. Note that in the EU's regulation there are three exceptions to these requirements: "compliance with legal obligations; integrity of the network; congestion management in exceptional and temporary situations" (Detrekoi, 2018)

10. *U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update*, 2019

11. See page 4 for a definition of space situational awareness (SSA)

12. Hitchens, 2020

shared ownership with existing satellite internet providers, as done between the United Kingdom and OneWeb.

There would also likely be pushback from the private sector, which does not want to compete with the government. Americans tend to place the free market at a premium, not wanting government interference outside of time of crisis. Americans historically have preferred venture-capitalist backed endeavors, wanting the private sector to maintain control of revenue and costs. While designating internet as a utility may alleviate some aspects of this problem, a continued cultural shift among influential Americans preferring a larger and more involved government might be required to cement this approach's success.

While these are the two major roadblocks I expect to encounter, some other challenges may include:

- Competition with other public/taxpayer funding for development and launch; it would need a secure way to gain back expenditures,
- US government's historical inefficiency and history of cancelling projects,
- Contracting vs in-house for development, risk of contracting reliance for satellites, large financial burden.

3.2.2 Conclusion

This method is a proven success for terrestrial internet, supporting most of Europe's internet economy today. Whether this approach could be successful in the U.S. will depend upon the willingness of politicians and their business partners to support a government-controlled internet infrastructure. If successful, this model could expand into U.S. terrestrial internet, combining the vast existing internet infrastructure with greater oversight and regulation.

3.3 Sustainability Goals

One of the objectives of these proposed approaches is to increase the sustainability of the LEO environment. Over the last 15 years the number of active satellites and ensuing debris has spiked, with objects above 100 kg increasing by a factor of 7 and objects above 10 kg by a factor of 10 or more.[13] Between 2019-2021 the number of active and inactive satellites in LEO has increased by more than 50%.[14] The existing U.S. orbital debris mitigation standard practices (USODSMP), while last updated in 2019, have gone mostly unchanged since 2001,[15] with many of the critical requirements still unchanged. There has been a sustained call from industry and academia to update these practices to reflect the current state of LEO.[16] At the same time, there is no way for the U.S. to enforce its existing standard practices once a satellite is in orbit,[17] resulting in less than 50% of operators following the USODSMP in its current form.[18] And with the value of the space industry expected to continue growing into the future,[19] there is no better time than the present to improve the sustainability of LEO.

Pulling from my background research, I have chosen five sustainability goals to use as metrics of success. Each regulatory approach will be judged based on how well it can satisfy these sustainability goals. These goals are intended to address five major problems present in the existing USODSMP. They are as follows:

(1) Establishing a maximum risk tolerance regarding conjunctions and standardizing how operators assess risk. This targets miscommunication regarding collision avoidance and differing assessments of how risky a conjunction may be.

13. McDowell, 2020
14. *Id.*; Boley & Byers, 2021
15. *U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update*, 2019
16. Boley & Byers, 2021; Christensen, 2016; Chow, 2018; Davies & Woodburn, 2021; Foust, 2021a; Kahn, 2021; Lewis, 2020; Macaire, 2017; McDowell, 2020; *Mitigating Space Debris Generation*, 2022; Rao, 2019; *Space Sustainability Infographic*, 2022; Undseth et al., 2020; Young, 2007; Pardini & Anselmo, 2021
17. Smith, 2018
18. Hitchens, 2020
19. Commercial Space Activities, 2021; Jones, 2018; Lag, 2019; Low Earth Orbit (LEO) Satellites Global Market Report 2022; 2022; Rao, 2019; Roberts, 2020; Space-Based Broadband Internet Market — A Global and Regional Analysis, 2021; Start-Up Space 2020, 2020; Undseth et al., 2020; Weinzierl, 2018

(2) Mandating standard transponder tracking, requiring that all satellites have active transponders attached so their location can be precisely determined by other operators. This ensures that other operators know the location of all satellites in their proximity and desired orbital, decreasing unknowns and increasing the capacity of each orbital.

(3) Tightening of deorbiting protocol, in particular reducing the 25-year rule to five years or less. This goal aims to decrease net congestion by more rapidly removing satellites once their mission has ended.

(4) Increasing the durability of satellites to minimize shedding debris and mandating reusable rockets for launch. Having more secure satellites that shed fewer parts and using reusable launch vehicles will lead to a reduction in debris propagation, specifically high-velocity particles too small to track with telescopes.

(5) Mandating standard propulsion requirements such that all satellites have a base-level of maneuverability to avoid debris and collisions. This allows operators to determine more easily who should move in the case of a conjuncture as well as ensure all satellites can maneuver around incoming debris.

These five goals do not address all sustainability objectives;[20] however, if a regulatory approach can accomplish these goals, it can likely accomplish the rest (such as active debris removal). In addition, these goals were intentionally left open-ended in their final execution, as each regulatory approach will tackle these goals in its own manner. Furthermore, defining exact criteria for each goal would be a foolish task, as the space sustainability community is still debating the metrics of success as well as how to accomplish each goal.

20. For a detailed generalized sustainability framework, see the U.N. Long-term Sustainability Goals for Outer Space Activities (*United Nations Office for Outer Space Affairs 2021 Annual Report*, 2022).

Chapter 4

Methodology

As discussed earlier, this thesis employs a qualitative analysis, collecting data through a series of interviews with relevant experts. These interviews were non-anonymous, semi-scripted, and recorded. As the data relies on the authority of experts, I kept these interviews non-anonymous. Guided by the historical lessons from INTELSAT, the current state of LEO activity, and the existing regime of space policy and law, I drafted a series of questions intended to spur productive conversation. I presented each expert with the same preamble, set of questions, consent form, and preliminary framework. The preamble and questions can be found in Appendix B with the interview briefs, and the consent form and preliminary framework in Appendix C.

I designed these questions to be conversation starters, seeking back-and-forth discussions focused on each participant's expertise. I encouraged participants to ask their own clarifying questions, as I did the same. The interviews were designed to last between 30-45 minutes, however some extended longer at the participant's request. Through my questions, I had the participants judge each regulatory approach on three categories:

- Efficiency – How well each approach can maximize the productive use of LEO and the quality of the internet product.
- Equity – Ensuring fair access to space and the internet product being regulated.
- Sustainability – How durable these regulations are in keeping LEO a viable, safe, and marketable operating domain in the long run according to the five goals listed above.

I recruited participants through two methods: I either had a pre-existing connection, or they were referred by a mutual third party, often by another participant. Each participant filled out a consent form agreeing that their name, position, and comments could be used in this thesis. These comments were then compiled and analyzed in isolation and in holistic context.

In the next section I will breakdown the results from each interview, setting the stage for analysis of the discussions.

4.1 Participants

- Chris Kunstadter– Global Head of Space at AXA XL. Mr. Kunstadter specializes in space insurance, activities, and their associated risks, seeking to use risk analysis and insurance to make space a safer place.[1]

- Dr. Brian Weeden– Director of Program Planning at the Secure World Foundation. Dr. Weeden directs strategic planning for future-year projects to meet the Foundation's goals and objectives, and conducts research on space debris, global space situational awareness, space traffic management, protection of space assets, and space governance.[2]

- Daniel Oltrogge[3] – Center for Space Standards and Innovation Director and Director, COMSPOC Integrated Operations, COMSPOC Corporation. Mr. Oltrogee is the Director of Ansys Government Initiative's Center for Space Standards and Innovation research group and Program Manager for Space Data Center, providing on-demand SSA for global space community spanning all orbit regimes, including 60% of operational GEO satellites.[4]

- Dr. P.J. Blount – Lecturer in Law in the School of Law and Politics at Cardiff University. Dr. Blount's primary research areas are international space law, with a focus on space security and cyberspace law and governance.[5]

1. Mr. Kunstadter's interview, introductions
2. *Dr. Brian Weeden — Secure World Foundation*, n.d.
3. Mr. Oltrogge provided a written response to my script. Our conversation expanded on particular answers he provided.
4. Oltrogee, 2022
5. *PJ Blount Cardiff University Bio*, n.d.

- Dr. Darren McKnight – Senior Technical Fellow at LeoLabs. Dr. McKnight focuses on developing technical solutions and encouraging global behavior that leads to sustained space operations assurance through limiting the risk of debris collisions hazard to space systems in Earth orbit.[6]

Note: for the remainder of this thesis I will cite interviews in this fashion, "Participant's Interview, Question Number. For example: Mr. Kunstadter's interview, Q2.1.[7]

6. *Dr. Darren McKnight LeoLabs Bio*, n.d.

7. P. J. Blount, personal communication, August 1, 2022; C. Kunstadter, personal communication, July 6, 2022; D. McKnight, personal communication, August 18, 2022; D. Oltrogee, personal communication, July 21, 2022; B. C. Weeden, personal communication, July 12, 2022.

Chapter 5

Analysis

From my discussion with the five experts, I've determined that neither of my potential frameworks are viable today in the United States in their initial form. However, they may be viable in partial form or if modified, and I believe there are merits to regulating internet as a utility. The effects of both approaches on potential sustainability regulation can be applied to other regulatory frameworks, particularly with regards to standardizing technology and mandating greater compliance through greater government oversight.

Both frameworks would ensure internet access for poorly serviced rural areas, the success of a satellite constellation, consistent and fair prices, emergency government operation and control in times of crisis, and reduce the number of satellites in orbit. Even so, all experts are concerned that the PU approach[1] would stifle competition. Dr. McKnight is uncomfortable with lack of competition, noting that "competition is what usually improves performance and improves service."[2] Dr. Weeden and Dr. Blount cite a lack of existing enforceable infrastructure restrictions typical of utility creation, with Dr. Blount attesting that the government would have to "create the reason in order for there to be a monopoly".[3] The EI approach received similarly mixed reviews. For example, Mr. Kunstadter recognizes the benefits of government standardization but struggles with balancing the serviced-based competition against the risks of a single-source, government-operated

1. I will reference the U.S. Public Utilities approach to an internet LSC as PU and the European Internet approach as EI.
2. Dr. McKnight's interview, Q1.2B
3. Dr. Blount's Interview, Q2

infrastructure.[4]

Both approaches would be successful at implementing sustainability norms within the U.S., particularly reducing the total number of satellites in orbit and the price of standard collision avoidance technology. According to Dr. Weeden, "neither [approach] has an inherent advantage over the other", a claim countered by Dr. Blount, who notes that that "the PU model... is more suited for sustainability... [because] it actively reduces the number of satellites in orbit". Regardless, both approaches succeed in enforcing sustainability standards. In addition, both approaches allow for quicker updating and revision of these sustainability standards as conditions in LEO evolve. This ability is crucial for maintaining a sustainable LEO environment, as the failure to easily address and update sustainability standards is one of the largest flaws in today's sustainability regulations. However, since neither of these approaches extend beyond the bounds of U.S. law, Dr. Blount rightly raises concerns about the 'free space' issue, with other constellations outside of the U.S. abusing the U.S.'s self-restriction.

From these discussions came potential variations of my frameworks: a *National Champions* model, a *Partial Government Ownership* of internet LSCs centered around the PU approach, and a regulated *Interoperability Framework* inspired by the EI model, courtesy of Dr. Weeden, Dr McKnight, and Mr. Oltrogge respectively.[5] **Of all the approaches and variations, I believe the *Interoperability Framework* is most viable and widely acceptable while accomplishing the needed efficiency, equity, and sustainability goals. Furthermore, establishing a government internet LSC within the *Interoperability Framework* may help to lower the price of satellite internet and provide faster speeds, forcing the competition to lower their prices and innovate new technologies.** I will consider the responses to both frameworks, identifying their strengths and weaknesses, and follow with a discussion of potential variations to each approach. I will then revisit the concept of internet as a utility, applying evidence collected in the interviews to examine its viability.

4. Mr. Kunstadter's interview, Q2.1, 2.2, & 5

5. Note: Italics indicate the variation's label. For example, "*National Champions*" refers to the entire variation while the standard "national champion" refers to the chosen organization.

5.1 The Public Utilities Approach

5.1.1 Strengths

The PU approach would keep operations under private control, allowing the monopolist to seek efficiency and innovation in the pursuit of greater profit.[6] Dr. McKnight, although maintaining the preference for no monopoly, notes that if the internet LSC is "owned by [a] private company" it would operate with less bureaucratic drag, potentially increasing efficiency and cost-effectiveness compared to the EI approach. If the PUC bases its rates off terrestrial internet prices, this drive for greater profits would, by classical economic theory, encourage the monopolist to innovate and increase efficiency. Furthermore, Dr. McKnight points out that the greater flexibility of a privately operated LSC would allow for quicker reaction times when non-national security crises arise, as there is less bureaucracy to manage.[7] I note that the desire for private operation falls in line with the traditional U.S. mentality of preferring private control of goods and services, a benefit which Dr. Blount believes makes the PU approach slightly more viable over the EI approach.[8] Dr. McKnight believes it would be easier to convince Congress to implement a privately managed utility rather than a government-based program.[9] In addition to ideological reasons, Congress may be able to offload much of the work to its private partner. Perhaps most importantly, there already exists a fully functioning internet LSC in LEO: StarLink. Should Congress wish, Mr. Oltrogge points out that they could grant monopolist rights under the PU regime to StarLink at any time.[10] The shorter implementation time and private operation allowed in the PU approach made this approach the preference of Mr. Oltrogge and Dr. McKnight.

The advantage of a public-private partnership extends to regulating sustainability standards. Dr. Weeden and Dr. Blount both commend the PU approach's fusion of government regulation and business practicality with regards to establishing and enforcing sustainability standards. They note

6. Dr. McKnight's interview, Q2.1
7. *Id.*
8. Dr. Blount's interview, Q5.1
9. Dr. McKnight's interview, Q5
10. Mr. Oltrogge's interview, Q2.1

that the PU approach would demonstrate that private companies can operate an LSC according to modern sustainability norms[11] while being informed by business practices.[12] In theory, the monopolist would strive to lower its operational cost as much as possible. In doing so, they would seek to launch the minimum number of satellites needed to achieve its service goals. In the EI approach, the government has less of an incentive to maximize each satellite's efficiency, as the burden of cost overruns fall on the taxpayers. Dr. Blount confirms that "the PU model... actively reduces the number of satellites in orbit" more so than the EI approach.[13]

5.1.2 Weaknesses

The biggest weakness of the PU approach is its lack of competition. Mr. Kunstadter worries that regulation of an internet LSC like a public utility would create the same problems as regulation of the airlines in the '70s and '80s did, when fixed profit margins proved to be a barrier to lower prices and better services.[14] In his words, if "the heavy regulatory layer... didn't help civil aeronautics", then why will it help with managing LEO? While I see his point, I would argue that airlines don't have to contend with a similar spatially limited environment and were bound by a more established international operational regime than exists in LEO. Furthermore, planes are temporary inhabitants of the sky, while satellites occupy space for years. Similarities exist between the industries, and there are valuable lessons to be learned from the over-regulation of airlines, but the physical differences in environments limit the value of direct comparison.

Mr. Kunstadter also fears the monopolist will try and vertically integrate, controlling everything from R&D through to operations.[15] We currently see this with SpaceX, which can develop, launch, and operate entirely in-house. While the desire to increase profits can lead to innovation by a monopolist, Mr. Kunstader argues that the open market would make innovation a 'must have' rather than an option. Should competition be introduced, the former monopolist would need to

11. Dr. Blount's interview, Q3.1
12. Dr. Weeden's interview, Q3
13. Dr. Blount's interview, Q3
14. Mr. Kunstadter's interview, Q2.; Kahn, 1998
15. Mr. Kunstadter's interview, Q2.

innovate or risk losing business. He states plainly that the PU approach would "definitely [stifle] competition, not just in operators but in satellite manufacturing", a claim that I must agree with in concept. Mr. Oltrogge shares Mr. Kunstadter's concern, noting that a poorly regulated monopoly "can stifle innovation and... limit the quality of service that the customer is able to obtain."[16] The government could solve this problem through performance reviews and rigid quality standards, as I referenced in my original framework, but the PUC would need to be extremely insulated from the interests and influence of the monopolist. Otherwise, this regulatory approach risks falling into the same trap as the Boeing 737 MAX incident, where industry influence created a failed and deadly product.[17]

In addition to the lack of competition, Dr. Weeden notes that "if we are going to adopt either of these two solutions we would essentially have to go and tell the other companies to [either] remove their stuff from space" or let the government buy out its satellites.[18] On top of this, the U.S. would need to revoke any planned launches for competing U.S.-based internet LSCs. He is rightly concerned that this would receive incredible industry pushback and require extreme action by Congress; he does not believe that the political momentum and public support would be there for such a dramatic move.

5.1.3 Variations

As noted above, one of the largest weaknesses of the PU approach is its lack of competition. However, it does not prevent international competition. Internet LSCs from other countries can still offer their services within the U.S., as the orbits of other LSCs pass over the western hemisphere. Dr. Weeden points out that government-sponsored internet LSC can compete against each other on the international market, describing this as the *National Champions* approach.[19] If participating countries each agree to have one national champion that competes on the international market, all agreeing to sustainability standards, then this would provide competition and improve the

16. Mr. Oltrogge's interview, Q2.2
17. Herkert et al., 2020
18. Dr. Weeden's interview, Q2
19. Dr. Weeden's Interview, Q2.1

sustainability of the LEO environment. The international competition would also allow the return of a for-profit system, encouraging innovation. Meanwhile, government sponsorship would allow national PUCs to moderate prices and monitor sustainability practices. Furthermore, this would allow countries to maintain access to a flexible, non-terrestrial, and protected internet highway.

When presented with this variation, Dr. Blount noted how the *National Champions* model could prevent the "free space" issue from arising if applied internationally.[20] In short, the free space dilemma is the fear that other actors will abuse the self-restraint of others to greater exploit a shared resource. If countries agree to compete among government-sponsored internet LSCs, then there are fewer parties that need to be consulted when making international sustainability commitments, decreasing the chance of a free space free-rider.

Dr. McKnight argues that there could be a national security imperative to have satellite internet under partial government operation. In the case of crisis events like space weather, hacking, and military conflict, he suggests it might be wise to have 15% of infrastructure owned and operated by the government for emergency internet access. As we have seen in the Ukrainian conflict, StarLink satellite internet has been crucial in delivering needed information, and as a result suffering hacking and jamming from the Russian government.[21] Relevant to the U.S., the government could use this emergency internet capability to provide communication in disaster zones for easier search and rescue, as happened with Starlink during Hurricane Ian.[22]

Although Dr. McKnight recognizes that the *National Champions* approach does allow for protected emergency satellite internet, he questioned whether "it has to be one or the other" — whether it must be either a government sponsored monopoly or a commercial free-for-all.[23] Countering Dr. Weeden, Dr. McKnight put forward the idea of *Partial Government Ownership* for all internet LSCs. This seeks to address the lack of competition as well as the self-imposed handicap against competing international LSCs by having the government become a participant in

20. Dr. Blount's Interview, Q2.2
21. Duffy, 2022
22. Singh, 2022
23. Dr. McKnight's interview, Q5.1

each CSO's LSC. If Congress chooses to empower the FCC accordingly, part of the licensing process could include the U.S. government optioning to own and operate a minority quantity of the internet LSC.[24] The company would then reserve a percentage of satellites (15%) for exclusive government use. This would allow the U.S. government to protect satellite internet from external stimuli such as space weather, hacking, and emergency internet deployment, or to use its share for cost-assisted internet programs, providing internet for those who cannot afford market prices. Through this usage, the government could more easily enact the five sustainability goals, requiring the propulsion and transponder technology for operational reasons and the launch, risk tolerance, and deorbiting standards for security reasons. This would allow for multiple U.S. satellite internet companies to exist in LEO while still achieving the listed sustainability goals. However, I am concerned by Dr. Blount's comments on the PU approach which highlight the largest sustainability loss due to partial government ownership: there would be duplicate internet LSCs, resulting in increased traffic and congestion.[25] The *Partial Government Ownership* variation fails to reduce the net number of satellites in orbit as it allows multiple competing internet LSCs. Unless this variation includes greater regulation to ensure that CSOs launch the most efficient number of satellites, minimizing redundant satellites, this variation fails to accomplish one of the key sustainability goals. I see this variation needing more research to conclude whether it can reduce unnecessary congestion.

5.1.4 Conclusions

There are aspects of the PU approach that are valuable, but it is not viable in its current form. It keeps control in the hands of the private sector while allowing greater government oversight for sustainability regulations, equity requirements, and negotiated usage rates. However, it eliminates competition. It also poses a massive legal and logistical challenge, with the establishment of a single monopoly requiring the take-over and license-revoking of other internet LSCs. If the U.S. government wanted to apply the PU approach, then the *National Champions* variation holds real

24. *Id.*
25. Dr. Blount's interview, Q3

potential since it allows for international competition, forcing the U.S. company to innovate with the support of government investment. If regulators want to take a softer stance, then the *Partial Government Ownership* variation remains an option. This would allow regulators to reap the benefits without losing competition. Looking into this variation with Dr. Blount, I realize this would come at the cost of no direct moderation of the LEO population, negating a key purpose of the increased government control. The PU approach is a moderate form of government control, one that may be more palatable to influential Americans but faces heavy legal obstacles. However, should government control become politically viable, then new possibilities for regulation emerge. To explore the results of total government infrastructure control, this thesis investigates the European Internet approach.

5.2 The European Internet Approach

5.2.1 Strengths

The EI approach addresses the PU approach's greatest weakness: it "helps facilitate... some level of competition", an advantage highlighted by Mr. Oltrogge.[26] Multiple internet providers can use a shared satellite network, competing on service instead of infrastructure. Such competition can encourage serviced-base innovation, such as maximizing broadcast efficiency, antenna technology, and provider capability. Mr. Kunstadter echoes Mr. Oltrogge's recognition of the benefits of competition, noting that the serviced-based model will provide consumers with choice.[27] Building upon their consensus, Dr. Blount notes that the government-provided infrastructure combined with service-based competition forces prices towards a market equilibrium. In theory, this should result in prices lower than an infrastructure-based competition model would produce.[28] He also adds that the open-access infrastructure of the EI approach would allow the U.S. government to ensure fair and protected internet access, establishing a more diverse and accessible internet infrastructure.

In the same vein, Mr. Kunstadter points out that more government control would allow

26. Mr. Oltrogge's interview, Q3.1
27. Mr. Kunstadter's interview, Q5
28. Dr. Blount's interview, Q5

for easier implementation of sustainability goals.[29] The LSC would likely fall under control of the FCC, which would establish the sustainability regulations. The government's operation of the LSC would set a precedent for the satellite industry at large, demonstrating the feasibility of sustainability goals. If the government sets a maximum risk tolerance and deorbiting timeline, creating and legitimizing a consistent set of sustainability regulations, industry will likely follow its precedent.[30] In particular, "having [an equipped] government monopoly... will bring down the costs" of tracking transponders and propulsion devices, as highlighted by Mr. Kunstadter.[31] The equipment that the government LSC purchases for its satellites will lower manufacturing costs for the rest of the industry. This would remove notable financial barriers formerly preventing private companies from equipping modern collision avoidance technology, increasing the sustainability of LEO across the board. Direct government ownership would guarantee satisfaction of equity and sustainability criteria and facilitate a new form of commercial competition through service-based internet packages.

5.2.2 Weaknesses

All three of the participants actively working in the private sector (Mr. Kunstadter, Mr. Oltrogge, and Dr. McKnight) fear that government control will be inefficient and more expensive than private control,[32] while Dr. Weeden expressed concern that America's fear of government control may be too difficult a barrier to overcome.[33] Dr. McKnight believes that the lack of profit-incentive and the complexity of government bureaucracy would "lead to over-budgeted costs and [a] loss of efficiency", barriers to deploying and maintaining a complex technical system.[34] The slower rate of innovation could mean that service providers don't find a satellite arrangement or set of capabilities that best fit their desired product. Although Dr. Blount recognizes the potential of the EI approach, he cautions that unless the constellation is properly planned out and updated

29. Mr. Kunstadter's interview, Q3
30. Chambers, 2009
31. Mr. Kundstadter's interview, Q3
32. Mr. Kunstadter's interview, Q2.2; Mr. Oltrogge's interview, Q2.2; Dr. McKnight's interview, Q2.2
33. Dr. Weeden's interview, Q5
34. Dr. McKnight's interview, Q2.2

regularly, the LSC may not meet the evolving needs of the service providers.[35] He details how the satellites would need to be modular, adapting new transponders and antennas over time, or be over-engineered to accommodate future service providers and their needs. Both would require additional funding, whether from taxpayers or businesses. To overcome the political squabbling that would ensue, there would need to be a restructuring of the way the U.S. licenses and regulates satellites, either vesting greater authority in the FAA and FCC or consolidating these new responsibilities in a single organization.[36] Both options require additional administrative costs in terms of funding and time spent properly structuring such a regulatory body.

Reinforcing and restructuring regulatory power are not the only costs associated with a shift towards government ownership of internet LSC infrastructure. Dr. Weeden's acquisition problem rings as true for the EI approach as it does for PU: the U.S. government would need to buy out or nationalize existing internet LSCs such as StarLink.[37] While possible, Dr. Blount and Dr. McKnnight point out that this would require a seismic shift in tolerance for large government programs and the nationalization of companies among influential Americans and representative in power.[38] Steve Lohr of the New York Times wrote in 2008 that the U.S. has historically disliked large government programs outside of times of war or intense economic stress,[39] with existing programs under constant threat of cancellation or defunding.[40] While there is a cultural shift towards larger government among members of the Democratic party, as seen in the rise of Democratic Socialists in Congress,[41] this is far from the majority. To make the EI approach feasible as initially proposed, it is clear to me that the U.S. would require a greater cultural and political tolerance for government-controlled industries.

35. Dr. Blount's interview, Q2
36. *Id.*
37. Dr. Weeden's interview, Q2
38. Dr. Blount's interview, Q5.1; Dr. McKnight's interview, Q5.1
39. Lohr, 2008
40. See the repeated attempts by the Republican party to defund or cut back entitlements for a cultural understanding.
41. Lowery, 2020

5.2.3 Variations

When discussing the EI approach, Mr. Oltrogge proposes a different "flavor", one centered around an interoperability framework.[42] In short, the government would define the framework in which the LSCs operate, allocating the orbital corridors in which each LSC can reside. This would limit buildup in each corridor, and if there are limitations based off the corridor's position and ITU broadband allocation,[43] then it's on the company to innovate accordingly. Instead of the government providing a shared LSC through which service providers can use transponders attached to each satellite, the government 'owns' the orbital corridors[44] and operators can claim those as their transponders/racks. In contrast to the government owning the satellites, Mr. Oltrogge emphasizes that his *Interoperability Framework* "allows multiple LSC operators to live within that framework but in constrained and pre-coordinated ways", swapping them out and upgrading as needed. Meanwhile, the control and classification of the orbital corridors for specific uses empowers regulators to tailor sustainability regulations for each orbital. The interoperability framework could include standards of communications, crosslinks between orbit regimes, maximum orbital capacity, different altitudes serving different parts of space infrastructure, and criteria on how to best allocate corridors.

With the *Interoperability Framework*, multiple internet LSCs can exist in safe, tightly regulated spaces while competing on both infrastructure and service, a selling point discovered through back-and-forth conversation with Mr. Oltrogge. LSCs will have the ability to innovate within the regulations provided by the U.S. government and the constraints of the orbital corridor's broadband allocation as detailed by the ITU. [45]

42. Mr. Oltrogge's interview, Q2.1. This and his response to Q5 will be the primary interview sourced for this section. It should be noted that Dr. Blount also supports this concept, as cited in his answer to Q5.1

43. *Regulation of Global Broadband Satellite Communications*, 2012; *International Telecommunications Union Radiocommunications Sector Mission Statement*, 2022

44. Within the current international regulatory framework, the U.S. government would need to apply for these orbitals and their respective frequencies through the ITU as well as apply for a set number of satellites in each. This would give them the international standing to operate within these orbitals and use the associated broadcasting frequencies. The size of the orbital, the size of the constellation, and the allowed frequency would all be restrictions within which the commercial LSC operator must innovate and adapt.

45. This concept can be expanded internationally if desired; countries could agree to empower the ITU to allocate specific orbital corridors to specific uses across nations, uses such as internet LSCs, assigning the corridors to operators

Since the government regulates these corridors, they could set appropriate sustainability standards, updating as needed over time. The US can vary these requirements based on the conditions of each corridor, as the intensity with which all five sustainability goals need be applied will vary based off altitude and existing capacity. For example, a corridor at 350 km will have fewer end of life propulsion requirements than a corridor at 600 km. Control of the corridors would also allow the U.S. government to monitor and enforce the sustainability regulations that the operator agreed to before launch. As of right now, there is "no regulation of on-orbit operations by the FAA or any agency",[46] so once a constellation is in orbit, no U.S. agency monitors the satellite and ensures that operators follow the agreed regulation.[47] Should the U.S. set up this interoperability regime, it would have an easy way to monitor and ensure that operators behave appropriately.

This variation on the EI approach does have weaknesses. The international community, specifically the ITU, would have to accommodate the U.S.'s preference for specific orbital corridors and frequencies for its LSCs, an issue that has been historically controversial.[48] However, if the international community follows suit, establishing their own orbital corridors and/or sharing parameters, then not only will there be a new standard for global LEO sustainability norms, but a more comprehensive structuring of LEO's capacity and usage. I find this idea to be very encouraging.

5.2.4 Conclusion

The EI approach holds the potential to accomplish every goal, but its success depends on its execution. Shifting from a privately-owned infrastructure to one owned by the government requires

directly. This, however, would need additional international momentum and is outside the scope of this thesis beyond being mentioned. Currently, the ITU can only regulate broadband frequency. However, this power has the added effect of limiting which orbits satellites can use, as they must avoid sharing an orbital with satellites communicating on the same frequency.

46. Smith, 2018

47. In the EU, the EU SST monitors the behavior of operators from member state, so there is precedent to follow should the U.S. wish to monitor the behavior of its operators (*Services – EU SST*, 2022)

48. For examples of controversial preemptive claims of orbital space, see Tonga's attempted claim of 16 geostationary satellite spots (detailed in an Edmund L. Andrew's Dec 1990 article in the New York Times) and the international backlash to the filing for 300,000 satellites by the Rwandan government in 2021 (as reported on by Jeff Foust in SpaceNews on Dec 14th of that year).

careful planning, structuring, organizing, and implementation. This will likely require a shift in how the U.S. government operates and could involve a steep learning curve, and it will be expensive; the biggest barrier to the EI approach is the government itself. If the government wishes to accomplish similar goals but cede control over the LSC(s) to CSOs then it should establish an interoperability framework. This would still require an overhaul of how the U.S. allocates orbital space and how it regulates operators, but it would allow for increased influence over operator behavior and the orbital population while still allowing for competition and innovation. Even with this reduction in overall control, the government could set standards for internet access and distribution across its orbitals, requiring CSOs to reserve a percentage of internet capacity for those in marginalized or impoverished populations, and redirect internet to disaster zones in times of crisis. **Of all the approaches and variations, I believe the *Interoperability Framework* is most viable and widely acceptable while accomplishing the needed efficiency, equity, and sustainability goals.**

5.3 Revisiting Internet as a Utility

Both of these frameworks hinge on the idea of internet becoming a utility, recognizing that the internet is a necessity of modern-day life that must be protected from exploitation and provided to all. Every participant acknowledged the importance of internet to the function of daily life and the expectation that it will be available. Dr. McKnight humorously illustrates this point with an analogy to "utilities" at Starbucks: "If you go to Starbucks and use the internet. it's like using light: you don't get charged for light, you don't get charged for water, for using the toilet!"[49] Every expert recognizes the gap between urban internet availability, quality, and price when compared to rural internet, and that something must be done to address this divide. However, the experts also note the importance of competition to provide quality service and support innovation. A company could offer 5G broadband streaming as an alternative to cable-internet (a technology Dr. Blount used

49. Dr. McKnight's interview, Q1.2B

in the past),[50] or someone could source internet from a satellite, as this entire thesis details. The dichotomy of internet being necessary for modern life and unequal in its availability, quality, and price, combined with the need for competition to provide innovation has led me to a conclusion not explicitly stated by any participant but one drawn from comparing their responses: a government internet option. I suggest that there should be a government option to compete against commercial providers, at the local, state, or if satellite-based, national level.

This may seem similar on its face to the Affordable Care Act and the government option for healthcare,[51] however there is ample evidence to suggest that this is not an exact copy. Municipal internet already exists across the U.S., where local governments establish non-profit companies to compete against commercial providers.[52] In Longmont, CO the city operates and manages its own fiber-optic internet company as a nonprofit, offering equal or quicker internet speeds than its fiber-optic competitors at lower prices across the board.[53] The same situation plays in other Colorado cities, including Fort Collins, Loveland, and Estes Park. Colorado is not alone in this development: municipal internet is sprouting up across the U.S. as local governments compete against private businesses. These publicly-owned networks often beat commercial competitors in price[54] and speed.[55] Having competition from local governments who treat internet as a utility appears to work.

This concept can be applied to satellite internet and its focus on rural areas. A government internet alternative may help to lower the price of satellite internet and provide faster speeds, forcing the competition to lower their prices and innovate new technologies.[56] Of all the variations on my initial PU and EI frameworks, the concept of government competition best suits the *interoperability*

50. Dr. Blount's interview, Q1.1
51. *Affordable Care Act, 2010*
52. Institute for Local Self-Reliance, 2021
53. *CenturyLink Internet Plans*, 2022; *NextLight Residential Internet Plans*, 2020; *Xfinity Internet Plans*, 2022
54. Talbot et al., 2017
55. *Snapshots Fact Sheet,* 2021
56. For reference, StarLink costs $110 a month in addition to a $599 upfront cost for in-home setup while boasting download speeds of 50-250 Mbps and upload speeds of 10-20 Mbps (Gerhardt, 2022). As stated by every participant, competition will force lower prices, faster speeds, and higher quality internet. As municipal competition alludes, a government alternative for satellite internet would accelerate this process.

framework.[57] One of the orbital corridors could house a government-owned internet LSC, competing with commercial entities occupying other corridors. Pulling from terrestrial comparisons, this would help lower prices while forcing innovation. And since the *Interoperability Framework* creates specialized sustainability regulations for each corridor, this addition would cause minimal disruption to the overall sustainability of LEO. In fact, it could provide a baseline against which CSOs must compete and would set an example for what behavior the government expects from each orbital corridor.

This thesis, and its collected data, points to the internet being a utility, but not in the same manner as electricity, sewage, and water. Rather, the rational for making internet a utility is the desire to ensure affordable, accessible, and quality access to all citizens through a combination of commercial and government providers. **If policymakers desire intranational competition among internet LSCs, the most logical route may be to implement the textitInteroperability Framework while reserving an orbital corridor for a competitive government-LSC.**

57. The *National Champion* variation of the PU approach is less flexible in accommodating government competition, as any intranational competitor would by nature break the concept of a national champion. Regarding the *Partial Government Ownership* idea, the addition of a governmental competitor would turn the concept into a weakened and arguably less-effective form of the *Interoperability Framework*.

Chapter 6

Conclusion

This thesis began by asking whether the U.S. could regulate an internet LSC like a monopoly in such a manner that the LSC offers quality nationwide internet, implements modern sustainability norms, and keeps costs low without overly stifling innovation. Postulating internet as a utility,[1] I drafted two frameworks, one based on the U.S. public utility system and one inspired by Europe's internet infrastructure. I presented these two regulatory approaches to five experts in space industry, law, policy, and sustainability, soliciting their opinions and criticism in one-on-one interviews. The quality and detail of each conversation surpassed my expectations.

From these conversations I have determined that neither of my original regulatory frameworks are currently feasible for implementation within the United States.[2] The Public Utilities approach would stifle competition beyond an acceptable level and faces roadblocks revoking the licenses of unlaunched competitors to the likely monopolist: StarLink. Meanwhile,

1. See the criteria for being considered a utility explained in the introduction and revisited in my discussion section "Revisiting Internet as a Utility" for clarification if needed.

2. It is worth mentioning that the proposed original PU and EI approaches may find further success in fields outside of internet LSCs. Each expert gave alternative applications on where they see a government-supported space monopoly succeeding, with Earth imaging, weather data, and scientific constellations all receiving interest. Dr. McKnight and Mr. Oltrogge both highlighted Earth imaging as a potential successful application of the PU approach. With its ubiquitous and increasingly important use, combined with a minimal desire from everyday persons to pay for such a product, having a single supplier supported by the government, with fixed rates for government and commercial use, would allow the company to maintain profit and operations while assuring free and accessible data for citizens. Dr. Weeden and Dr. Blount saw similar potential with Weather data. While already provided by the government free of charge, the growth of weather-monitoring capabilities could benefit from a hybrid-commercial operation. Regarding a general scientific satellite constellation, Dr. Weeden further believes that the EI approach, with its ability to be accessed by all who wish and flexibility to accommodate multiple attachments, may be the perfect fit for equipping a comprehensive and capable scientific satellite constellation for scientists across the U.S. and the globe to utilize. Whether the U.S. public utility, European internet, or either of their variations would work for these alternative uses merits additional studies.

the European Internet approach risks falling prey to the bureaucratic curses of cost overruns, lagging innovation, and slow speed of operation, and must overcome America's cultural aversion to government-owned businesses. While both regulatory approaches would create a more sustainable LEO environment and be capable of achieving all five sustainability goals, my thesis sought to find a solution that is both sustainable and politically possible; these two original frameworks do not fully achieve both criteria.

This is not to say that my thesis is a wash. By exposing their weaknesses, both approaches produced partial positive results and policy lessons, as well as spurred the development of more feasible variations. As they analyzed the public utilities approach and its effect on competition, participants highlighted the need for less expensive satellite internet and continual innovation. This led to consideration of the *National Champions* concept, where the U.S. supports a single commercial internet LSC to compete on the international stage against other country's constellations. Along similar lines, the *Partial Government Ownership* and operation of commercial internet LSCs by the government would allow for greater regulatory control, ensuring LSCs practice and follow their mandated sustainability regulations and reserving part of each LSC for federal use, whether this be for national security purposes or cost-assisted internet programs. Likewise, discussing the efficiency flaws in the European Internet approach pointed us to the *Interoperability Framework* concept. In this concept, the U.S. controls a monopoly on its ITU-approved orbital corridors and licenses their usage out to commercial LSCs, thus providing competition while ensuring adherence to sustainability regulations. **It is this final variation, the *Interoperability Framework*, that I see as the most effective, efficient, and politically feasible among all frameworks and approaches considered, enough so that it could be reasonably adapted into policy today.**

The consideration of these frameworks confirmed the need for modern sustainability regulations within the U.S. government and increased authority to enforce these norms. **In particular, the participants desired a modern and administratively consistent set of sustainability regulations and guidelines** regarding space debris, collision avoidance, risk management,

active debris removal, and satellite tracking. While the participants did not want these regulations to be applied through the PU or the EI frameworks, they recognized the need for these regulations. They also acknowledged the need for increased monitoring and enforcement of sustainability requirements, albeit to different levels of control. As Mr. Oltrogge noted, there is no agency empowered to monitor and ensure that operators follow the sustainability guidelines and regulations to which they agreed prior to launch. While much smaller in terms of government involvement than either of my frameworks, the need for an empowered agency resonated across all discussions.

All this can be achieved if the U.S. government adapts the *Interoperability Framework*. Designating orbital corridors for each application of LEO allows for streamlined management of launch and operations requests, including broadband allocation. With like-LSCs located in the same orbital corridor, regulatory agencies can draft specific and targeted sustainability standards, taking into account the corridor's altitude, active and inert population, technologies present, and physical restrictions, updating the standards as the orbital evolves. Furthermore, such allocation will allow government and industry to easily establish standards of communication, crosslinks between orbit regimes, and provide domestic and international operators with clear information regarding where U.S. satellites will be and what maneuvering capabilities they have, a crucial need for global space sustainability. Finally, the physical allocation of LSCs to specific orbital corridors would create a consistent and predictable schedule for Earth-based astronomical observation, potentially avoiding satellite interference with celestial imaging. **This thesis encourages U.S. policymakers to adapt the *Interoperability Framework* with the assistance of academics and industry, and calls for further study to refine its parameters, determine how best to allocate orbitals, and the exact sustainability standards to keep each orbital safe and prosperous for the needs of today and tomorrow.**

Chapter 7

References

2015 Broadband Progress Report and Notice of Inquiry on Immediate Action to Accelerate Deployment (FCC 15-10; Broadband Progress Report, p. 117). (2015). Federal Communications Commission. https://docs.fcc.gov/public/attachments/FCC-15-10A1.pdf

2016 Colorado Revised Statutes: Title 40 - :: Utilities :: Public Utilities :: Article 1 - Definitions :: § 40-1-103. Public utility defined. (2016). Justia Law. Retrieved September 29, 2022, from https://law.justia.com/codes/colorado/2016/title-40/public-utilities/article-1/section-40-1-103

Agreement establishing interim arrangements for a Global Commercial communications Satellite System, and Special Agreement (with annex)., no. 7441, United Nations (1964).

AMES Orbital Debris Program Office. (n.d.). *Debris Measurements*. Astromaterials Research & Exploration Science. Retrieved October 18, 2021, from https://orbitaldebris.jsc.nasa.gov/measurements/

Approval in principle—Telesat Canada (COMMSTELLATION). (2015). [Governmental]. Innovation, Science and Economic Development Canada. https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11064.html

Blount, P. J. (2022, August 1). *Interview with P.J. Blount* (S. Rodgers, Interviewer) [Video Call, Zoom].

Boley, A. C., & Byers, M. (2021). Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere and on Earth. *Scientific Reports*, 11(1), 10642. https://doi.org/10.1038/s41598-021-89909-7

Brasch, S. (2022, April 21). *Is Xcel Energy making too much money? Colorado voters could get the chance to decide* [News]. Colorado Public Radio. https://www.cpr.org/2022/04/21/colorado-xcel-energy-profits-utilities/

CenturyLink Internet Plans. (2022). [Commercial Referral]. Bandwidth Place. https://www.bandwidthplace.com/centurylink/

Chambers, R. (2009). *Consistent Decision Making by Regulators*. Council on Licensure, Enforcement and Regulation (CLEAR). https://www.clearhq.org/resources/09consistent.pdf

Chao, B., Park, C., & Stager, J. (2020). *The Cost of Connectivity 2020* (The Cost of Connectivity). New America Open Technology Institute. https://d1y8sb8igg2f8e.cloudfront.net/documents/The_Cost_of_Connectivity_2020__.pdf

Chen, B., Liu, D., Chin, T.-J., Rutten, M., Derksenv, D., Martens, M., von Looz, M., Lecuyer, G., & Izzo, D. (2021). Spot the GEO Satellites: From Dataset to Kelvins SpotGEO Challenge. *2021 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW)*, 2086–2094. https://doi.org/10.1109/CVPRW53098.2021.00237

Chow, B. G. (2021). Space Traffic Management in the New Space Age. *Strategic Studies Quarterly, Vol. 14(Winter 2020)*, 74–104.

Christensen, I. (2016, September). *Future Issues for Commercial Space Sustainability Suggested by Space Industry Socio-Economic Trends.* 67th International Astronautical Congress (IAC), Guadalajara, Mexico, Guadalajara, Mexico.

Commercial Space Activities. (2021, August 12). https://spacepolicyonline.com/topics/commercial-space-activities/

Cooper, T. (2022a, May 4). *Annual Report: Europe vs US Broadband Performance 2022*. Fair Internet Report. https://fairinternetreport.com/research/usa-vs-europe-internet-speed-analysis

Cooper, T. (2022b, July 21). Starlink Internet: Coverage & Availability Map [Research]. *BroadbandNow*. https://broadbandnow.com/starlink

Count Evolution by Object Orbit. (2019). European Space Agency. https://www.sdo.esoc.esa.int/environment_report/figures/all_evo_orbit_count.png

Davies, J. B. P., & Woodburn, J. (2021). Approaches to and Loci for Regulation of Large and Mega Satellite Constellations. In A. Froehlich (Ed.), *Legal Aspects Around Satellite Constellations: Volume 2* (pp. 47–81). Springer International Publishing. https://doi.org/10.1007/978-3-030-71385-0_3

Department for Business, Energy, and Industrial Strategy. (2022, July 26). *OneWeb merger with Eutelsat*. GOV.UK. https://www.gov.uk/government/news/oneweb-merger-with-eutelsat

Detrekoi, Z. (2018, January 26). *Net Neutrality: Current State of Affairs and Main Players — CMDS* [University]. Central European Univeristy Democracy Institute's Center for Media, Data and Society. https://cmds.ceu.edu/article/2018-01-26/net-neutrality-current-state-affairs-and-main-players

Downes, L. (2015, October 19). How to Understand the EU-U.S. Digital Divide. *Harvard Business Review*. https://hbr.org/2015/10/how-to-understand-the-eu-u-s-digital-divide

Dr. Brian Weeden — Secure World Foundation. (n.d.). Retrieved August 19, 2022, from https://swfound.org/about-us/our-team/dr-brian-weeden/

Dr. Darren McKnight LeoLabs Bio. (n.d.). LeoLabs. Retrieved August 19, 2022, from https://leolabs.space/team/dr-darren-mcknight/

Duffy, K. (2022, May 11). *Elon Musk says Russia has stepped up efforts to jam SpaceX's Starlink in Ukraine* [News]. Business Insider. https://www.businessinsider.com/elon-musk-spacex-russia-ramps-up-efforts-jam-starlink-ukraine-2022-5

Eschner, K. (2017, May 18). *Here's How FDR Explained Making Electricity Public*. Smithsonian Magazine. https://www.smithsonianmag.com/smart-news/heres-how-fdr-explained-making-electricity-public-180963286/

Eutelsat and OneWeb to combine: A leap forward in satellite connectivity. (2022, July 25). OneWeb. http://oneweb.net/resources/eutelsat-and-oneweb-combine-leap-forward-satellite-connectivity

Fimea, V. E., & Mann, T. (1986). Intelsat Recent Developments in International Organizations. *American University Journal of International Law and Policy*, 1, 413–424.

Foust, J. (2021a, September 19). *Space community ponders right-of-way rules for space traffic*. SpaceNews. https://spacenews.com/space-community-ponders-right-of-way-rules-for-space-traffic/

Foust, J. (2021c, December 14). *Satellite operators criticize "extreme" megaconstellation filings*. SpaceNews. https://spacenews.com/satellite-operators-criticize-extreme-megaconstellation-filings/

Gerhardt, N. (2022, July 29). *Starlink Reviews: Plans, Prices And Speed 2022* [News]. Forbes Home. https://www.forbes.com/home-improvement/internet/starlink-internet-review/

Gruber, H., Hätönen, J., & Koutroumpis, P. (2014). Broadband access in the EU: An assessment of future economic benefits. *Telecommunications Policy*, 38(11), 1046–1058. https://doi.org/10.1016/j.telpol.2014.06.007

Herkert, J., Borenstein, J., & Miller, K. (2020). The Boeing 737 MAX: Lessons for Engineering Ethics. *Science and Engineering Ethics*, 26(6), 2957–2974. https://doi.org/10.1007/s11948-020-00252-y

Hitchens, T. (2020, April 22). *Most Satellite Operators Fail to Follow Space Debris Rules: NASA*. Satnews. http://www.satnews.com/story.php?number=16788917

Institute for Local Self-Reliance. (2021, September). *Community Network Map* [Institutional]. Community Networks. https://muninetworks.org/communitymap

International Telecommunications Union Radiocommunications Sector Mission Statement. (2022). [Government]. ITU. https://www.itu.int:443/en/ITU-R/information/Pages/mission-statement.aspx

Jones, A. (2021, May 26). *China establishes company to build satellite broadband megaconstellation* [News]. SpaceNews. https://spacenews.com/china-establishes-company-to-build-satellite-broadband-megaconstellation/

Kahn, A. (2021, June 17). *A New Chapter for Space Sustainability*. MIT Media Lab. https://www.media.mit.edu/posts/a-new-chapter-for-space-sustainability/

Kahn, A. E. (1988). Surprises of Airline Deregulation. *The American Economic Review*, 78(2), 316–322. JSTOR.

Kessler, D. J., Johnson, N. L., Liou, J.-C., & Matney, M. (2010). *The Kessler Syndrome: Implications to Future Space operations*. 16. https://threecountrytrustedbroker.com/media/kesseler_syndrome.pdf

Kulu, E. (2022). *Satellite Constellations*. NewSpace Index. https://www.newspace.im/index.html

Kunstadter, C. (2022, July 6). *Interview with Chris Kunstadter* (S. Rodgers, Interviewer) [Video Call, Zoom].

Lag, S. (2019). *Reusable rockets: Revolutionizing access to outer space*. Det Norske Veritas. https://www.dnv.com/to2030/CH_Page/Default

Lazarus, D. (2020, October 23). *The pandemic makes clear it's time to treat the internet as a utility* [News]. Los Angeles Times. https://www.latimes.com/business/story/2020-10-23/coronavirus-internet-is-a-utility

Levy, S. A. (1975). INTELSAT: Technology, Politics and the Transformation of a Regime. *International Organization*, 29(3), 655–680. JSTOR.

Lewis, H. G. (2020). Understanding long-term orbital debris population dynamics. *Space Debris: The State of Art*, 7(3), 164–170. https://doi.org/10.1016/j.jsse.2020.06.006

Litan, R. (2014). Regulating Internet Access as a Public Utility: A Boomerang on Tech If It Happens. *The Brookings Institute*, 4.

Lohr, S. (2008, October 13). *U.S. not always averse to nationalization, despite its free-market image*. The New York Times. https://www.nytimes.com/2008/10/13/business/worldbusiness/13iht-nationalize.4.16915416.html

Low Earth Orbit (LEO) Satellites Global Market Report 2022 (Low Earth Orbit (LEO) Satellites Global Market). (2022). [Business]. The Business Research Company. https://www.reportlinker.com/p06241265/Low-Earth-Orbit-LEO-Satellites-Global-Market-Report.html?utm_source=GNW

Lowery, G. (2020). *The Rise of the Democratic Socialists of America: A Qualitative Analysis of the Contributing Factors to Insurgent Mobilization* [Doctoral, University of Tennessee, Knoxville]. https://trace.tennessee.edu/cgi/viewcontent.cgi?article=7115&context=utk_graddiss

Macaire, A. (2017). *Space Management of Launch Operations* (T. Flohrer & F. Schmitz, Eds.). ESA Space Debris Office.

Net Neutrality and Broadband Justice Act of 2022, S. 4676, 117th Congress, 2nd Session (2022). https://www.congress.gov/bill/117th-congress/senate-bill/4676/text?r=1&s=1

Matignon, L. de G. (2019, March 27). The Kessler syndrome and space debris. *Space Legal Issues*. https://www.spacelegalissues.com/space-law-the-kessler-syndrome/

McDowell, J. C. (2020). The Low Earth Orbit Satellite Population and Impacts of the SpaceX Starlink Constellation. *The Astrophysical Journal*, 892(2), L36. https://doi.org/10.3847/2041-8213/ab8016

McKnight, D. (2022, August 18). *Interview with Darren McKnight* (S. Rodgers, Interviewer) [Video Call, Zoom].

Milano, B. (2021, April 20). *Should the internet be treated like a public utility?* [University]. Harvard Law School. https://hls.harvard.edu/today/should-the-internet-be-treated-like-a-public-utility/

Mitigating space debris generation. (2022). European Space Agency. https://www.esa.int/Safety_Security/Space_Debris/Mitigating_space_debris_generation

NextLight Residential Internet Plans. (2020, October 12). [Commerical]. NextLight: Longmont's Gig Internet. https://mynextlight.com/residential/

Oltrogee, D. (2022, July 21). *Interview with Daniel Oltrogge* (S. Rodgers, Interviewer) [Video Call, Zoom].

Open Internet — Shaping Europe's digital future. (n.d.). Retrieved May 25, 2022, from https://digital-strategy.ec.europa.eu/en/policies/open-internet

Our History. (n.d.). [Government]. Tennessee Valley Authority. Retrieved July 26, 2022, from https://www.tva.com/about-tva/our-history

Pardini, C., & Anselmo, L. (2021). Evaluating the impact of space activities in low earth orbit. *Acta Astronautica*, 184, 11–22. https://doi.org/10.1016/j.actaastro.2021.03.030

Patel, N. (2019, September 24). *Do satellite mega-constellations really have to be so big?* MIT Technology Review. https://www.technologyreview.com/2019/09/24/102603/do-satellite-mega-constellations-really-have-to-be-so-big/

Pelton, J. N. (2017). History of Satellite Communications. In J. N. Pelton, S. Madry, & S. Camacho-Lara (Eds.), *Handbook of Satellite Applications* (pp. 31–71). Springer International Publishing. https://doi.org/10.1007/978-3-319-23386-4_35

PJ Blount Cardiff University Bio. (n.d.). [University]. Cardiff University. Retrieved August 19, 2022, from https://www.cardiff.ac.uk/people/view/2596741-

Pollard, K., & Martinez, M. (2021, December 15). *Digital Divide in High-Speed Internet Access Leaves Rural Areas Behind* [Non-Profit Research]. Population Reference Bureau. https://www.prb.org/articles/digital-divide-in-high-speed-internet-access-leaves-rural-areas-behind/

Public Service Company of Colorado Electric Tariff Index . (2022). The Public Utilities Commission of the State of Colorado.

Radio Regulations—Articles—Edition of 2020 (Radio Regulations). (2020). [Regulatory]. International Telecommunications Union.

Rahman, K. S. (2017a). Regulating Informational Infrastructure: Internet Platform as the New Public Utilities. *Georgetown Law Technology Review*, 2(2), 234–251.

Rahman, K. S. (2017b). The New Utilities: Private Power, Social Infrastructure, and the Revival of the Public Utility Concept. Cardozo Law Review, 39(5), 1621–1692.

Rao, A. (2019). *The Economics of Orbit Use: Theory, Policy, and Measurement* [Doctoral]. University of Colorado Boulder.

Memorandum on International Communications Satellite Systems, no. 85–2, Presidential Determination (1984). https://www.reaganlibrary.gov/archives/speech/memora ndum-international-communications-satellite-systems

Regulation of Global Broadband Satellite Communications (Broadband Series). (2012). [Governmental]. International Telecommunications Union. https://www.itu.int/ITU-D/treg/broadband/ ITU-BB-Reports_RegulationBroadbandSatellite.pdf

The Patient Protection and Affordable Care Act, H.R. 3950, House of Representatives, 111th Congress (2010). https://www.congress.gov/111/plaws/publ148/PLAW-111publ148.pdf

Report of the World Commission on Environment and Development: Our Common Future. (1987). [Governmental]. United Nations Brundtland Comission. http://www.un-documents.net/o ur-common-future.pdf

Requirements on Space Debris Mitigation for ESA Projects. (2002). The European Space Agency.

Roll On Columbia the Documentary. (2005). UO Media Services. https://library.uoregon.edu/ec/wguthrie/controlofutilities.html

Sampaio, J. C., Wnuk, E., de Moraes, R. V., & Fernandes, S. S. (2014). Resonant Orbital Dynamics in LEO Region: Space Debris in Focus. *Mathematical Problems in Engineering*, 2014, 1–12. https://doi.org/10.1155/2014/929810

Satellite Warfare: Undoing Intelsat's Monopoly. (1991, January 21). *Bloomberg.com.* https://www.bloomberg.com/news/articles/1991-01-20/satellite-warfare-undoing-intelsats-monopoly

Services – EU SST. (2022). [Government]. European Union Space Surveillance and Tracking. https://www.eusst.eu/services/

Silbert, D., Borgeson, M. D., Peterson, G., Jenkin, A., & Sorge, M. (2010, September). *Operational Impact of Improved Space Tracking on Collision Avoidance in the Future LEO Space Environment.* Advanced Maui Optical and Space Surveillance Technologies Conference, Wailea, Maui, Hawaii.

Singh, K. (2022, October 1). Elon Musk to provide Florida with Starlink satellites in response to Hurricane Ian. *Reuters.* https://www.reuters.com/world/us/elon-musk-provide-florida-with-starlink-satellites-response-hurricane-ian-2022-10-01/

Smith, M. (2018). A Space Law Primer for Colorado Lawyers Part 2: U.S. Space Law. *The Colorado Bar Journal*, 47(45), 15.

Snapshots of Municipal Broadband: A much-needed part of America's digital ecosystem. (2021). *Institute for Local Self-Reliance*, 2.

Snow, M. S. (1987). Natural monopoly in INTELSAT: Cost estimation and policy implications for the separate systems issue. *Telematics and Informatics*, 4(2), 133–150. https://doi.org/10.1016/0736-5853(87)90007-4

Soulier, S. (2018, October 11). 40 Years Later: How the Airline Deregulation Act Came to Pass – Part I [Interest Group]. *Industry Insight.* https://www.airlines.org/40-years-later-how-the-airline-deregulation-act-came-to-pass-part-i/

Space debris by the numbers. (2022, April 4). [Government]. European Space Agency. https://www.esa.int/Safety_Security/Space_Debris/Space_debris_by_the_numbers

Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, RES 62/217, Committee on the Peaceful Uses of Outer Space, 44th Session of The Committee and its Scientific and Technical Subcommittee (2007). https://www.unoosa.org/pdf/publications/st_space_49E.pdf

Space Sustainability: Preserving the Usability of Outer Space. (2022). Secure World Foundation. https://swfound.org/space-sustainability-infographic/

Space-Based Broadband Internet Market — A Global and Regional Analysis: Focus on Application, End User, Frequency, Component, Orbit, and Country Analysis and Forecast: 2021-2031. (2021). [Market Report]. BIS Research; EMIS Intelligence. https://www-emis-com.colorado.idm.oclc.org/php/url-sharing/route?url=90179ff266238137

Start-Up Space 2020: Update on Investment in Commerical Space Ventures (Start-Up Space). (2020). Bryce Space and Technology. https://brycetech.com/repor/report-documents/Bryce_Start_Up_Space_2020.pdf

Talbot, D., Hessekiel, K., & Kehl, D. (2017). Community-Owned Fiber Networks: Value Leaders in America. *Berkman Klein Center for Internet & Society Research Publication*. https://doi.org/10.2139/ssrn.3099626

Toh, S. B. (2020, June 17). *Council Post: The Argument For The Internet As A Utility: Is It Time To Change How It's Delivered?* [News]. Forbes. https://www.forbes.com/sites/forbestechcouncil/2020/06/17/the-argument-for-the-internet-as-a-utility-is-it-time-to-change-how-its-delivered/

Treaty on the Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, RES 2222 (XXI), General Assembly 21st session (1966). https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html

Triedman, C., Lukens-Day, E., Hinh, A., & Ball-Burack, N. (2021). *Can State Utility Commissions Lead in the Clean Energy Transition? Lessons from Six States*. Brown University Climate and Development Lab.

Undseth, M., Jolly, C., & Olivari, M. (2020). *Space sustainability: The economics of space debris in perspective* (OECD Science, Technology and Industry Policy Papers No. 87; OECD Science, Technology and Industry Policy Papers, Vol. 87). OCED Science, Technology and Industry Policy Papers. https://doi.org/10.1787/a339de43-en

United Nations Office for Outer Space Affairs 2021 Annual Report (Annual Report, pp. 49–68). (2022). [Governmental]. United Nations Office for Outer Space Affairs.

U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update. (2019). National Aeronautic and Space Administration. https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf

Weeden, B. C. (2022, July 12). *Interview with Brian Weeden* (S. Rodgers, Interviewer) [Video Call, Zoom].

Weinzierl, M. (2018). Space, the Final Economic Frontier. *Journal of Economic Perspectives*, 32(2), 173–192. https://doi.org/10.1257/jep.32.2.173

Whipple, M. (2021, March 15). *We Already Knew Broadband Should Be A Public Utility. The Pandemic Made It Obvious*. [Activist]. Public Knowledge. https://publicknowledge.org/we-already-knew-broadband-should-be-a-public-utility-the-pandemic-made-it-obvious/

Xfinity Internet Plans. (n.d.). [Commercial Referral]. Bandwidth Place. Retrieved August 31, 2022, from https://www.bandwidthplace.com/xfinity/

Yoo, C. S. (2014). U.S. vs. European Broadband Deployment: What Do the Data Say? *Univ. of Pennsylvania Institute for Law and Economics*, 14–35, 65.

Young, K. (2007, January 20). *Anti-satellite test generates dangerous space debris* [News]. New Scientist. https://www.newscientist.com/article/dn10999-anti-satellite-test-generates-dangerous-space-debris/

Appendix A

Appendix A: Additional Background Research

This appendix will cover topics not discussed in the main thesis which I reviewed in preparation for this thesis. My literary review helped focus my thesis's topic, narrowing its scope and particular argument, as well as filling in the intellectual gaps needed to address monopolistic regulation.

A.1 First-Mover Advantage and Common Resources

I began my literary review with a deep dive into the first-mover advantage, institutions for governing common resources, and how the two interacted. The first-mover advantage is the idea that those who first enter a market have a sizeable advantage compared to later enterprises. This idea follows a logical thought: those who first discover a new technology, market, product, or resource often get the first attempt at capitalizing on its value. There are instances where those who enter a market at a later date and grow to dominance, such as Sony and Microsoft with the PlayStation and Xbox pushing out legacy acts like SEGA. There is a concern that first movers can use their favorable position to engage in anti-competitive behavior, particularly with common pool resources. As the internet LSC is a recent development in LEO, and LEO is a shared global commons, I wanted to improve my understanding of the intersection between the first-mover advantage and common pool resources. The resources below provided that information and informed the explanation above (note: some of these sources I cite in the thesis and can be found in my bibliography):

A.1.1 References

Adams, W. M., Brockington, D., Dyson, J., & Vira, B. (2003). Managing Tragedies: Understanding Conflict over Common Pool Resources. Science. https://doi.org/10.1126/science.1087771

Cottrell, T., & Sick, G. (2002). Real Options and Follower Strategies: The loss of real option value to first-mover advantage. The Engineering Economist, 47(3), 232–263. https://doi.org/10.1080/00137910208965035

Davies, J. B. P., & Woodburn, J. (2021). Approaches to and Loci for Regulation of Large and Mega Satellite Constellations. In A. Froehlich (Ed.), Legal Aspects Around Satellite Constellations: Volume 2 (pp. 47–81). Springer International Publishing. https://doi.org/10.1007/978-3-030-71385-0_3

Frynas, J. G., Mellahi, K., & Pigman, G. A. (2006). First mover advantages in international business and firm-specific political resources. Strategic Management Journal, 27(4), 321–345. https://doi.org/10.1002/smj.519

Galappaththi, E. K., & Berkes, F. (2014). Institutions for managing common-pool resources: The case of community-based shrimp aquaculture in northwestern Sri Lanka. Maritime Studies, 13(1), 13. https://doi.org/10.1186/s40152-014-0013-6 Hardin. (1968). The Tragedy of the Commons. Science, 162(3859), 1243–1248.

Ostrom, E. (1992). Institutions and Common-Pool Resources. Journal of Theoretical Politics, 4(3), 243–245. https://doi.org/10.1177/0951692892004003001

Ostrom, E. (2010). Beyond Markets and States: Polycentric Governance of Complex Economic Systems. American Economic Review, 100(3), 641–672. https://doi.org/10.1257/aer.100.3.641

Ostrom, E. (2015). Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press; Cambridge Core. https://doi.org/10.1017/CBO9781316423936

Suarez, F. F., & Lanzolla, G. (2005, April 1). The Half-Truth of First-Mover Advantage. Harvard Business Review. https://hbr.org/2005/04/the-half-truth-of-first-mover-advantage

Thierer, A. D. (1994). Unnatural Monopoly: Critical Moments in the Development of the Bell System Monopoly. Cato Journal, 14(2), 267–286.

Vollan, B., Prediger, S., & Frölich, M. (2013). Co-managing common-pool resources: Do formal rules have to be adapted to traditional ecological norms? Ecological Economics, 95, 51–62. https://doi.org/10.1016/j.ecolecon.2013.08.010

A.2 Natural Monopolies in Low Earth Orbit

Next I researched the concept of natural monopolies and their potential in LEO, leading to an investigation into public utilities. Natural monopolies are monopolies that grow from economies of scale, where as a company's customer base expands its service becomes cheaper to provide. These monopolies are considered natural because they could theoretically arise without government interference because of consumers seeking the least expensive product. The most common example of this are public utilities such as water, gas, sewage, and electricity. Once a company has erected the required infrastructure to provide a utility service, each additional household serviced lowers the average shared cost of maintaining the infrastructure. This literary review illuminated that most utilities came to be because competing infrastructure led to a sub-optical allocation of resources,

enough so that the government directly manages particular utilities. It was this discovery combined with a growing cultural shift for internet to be treated like a utility that led me to suggest internet as a utility in this thesis. Furthermore, with LEO's orbital space being a limited resource, the infrastructure restriction of LEO introduced an argument for a single internet LSC within the U.S. Readings can be found below:

A.2.1 References

Baumol, W. J. (1977). On the Proper Cost Tests for Natural Monopoly in a Multiproduct Industry. The American Economic Review, 67(5), 809–822.

Brasch, S. (2022, April 21). Is Xcel Energy making too much money? Colorado voters could get the chance to decide [News]. Colorado Public Radio. https://www.cpr.org/2022/04/21/colorado-xcel-energy-profits-utilities/

Depoorter, B. W. F. (1999). REGULATION OF NATURAL MONOPOLY. University of Ghent, 35.

Joskow, P. L. (2007). Chapter 16 Regulation of Natural Monopoly. In Handbook of Law and Economics (Vol. 2, pp. 1227–1348). Elsevier. https://doi.org/10.1016/S1574-0730(07)02016-6

Litan, R. (2014). Regulating Internet Access as a Public Utility: A Boomerang on Tech If It Happens. The Brookings Institute, 4.

Lohr, S. (2008, October 13). U.S. not always averse to nationalization, despite its free-market image. The New York Times. https://www.nytimes.com/2008/10/13/business/worldbusiness/13iht-nationalize.4.16915416.html

Milano, B. (2021, April 20). Should the internet be treated like a public utility? [University]. Harvard Law School. https://hls.harvard.edu/today/should-the-internet-be-treated-like-a-public-utility/

Mosca, M. (2008). On the origins of the concept of natural monopoly: Economies of scale and competition. The European Journal of the History of Economic Thought, 15(2), 317–353. https://doi.org/10.1080/09672560802037623

Posner, R. A. (1978). Natural Monopoly and Its Regulation Competition and Regulation 21 Stanford Law Review 548 (1969). Journal of Reprints for Antitrust Law and Economics, 9(2), 767–864.

Public Service Company of Colorado Electric Tariff Index (p. 457). (2022). The Public Utilities Commission of the State of Colorado.

Rahman, K. S. (2017). Regulating Informational Infrastructure: Internet Platform as the New Public Utilities. Georgetown Law Technology Review, 2(2), 234–251.

Smith, M. (2018). A Space Law Primer for Colorado Lawyers Part 2: U.S. Space Law. The Colorado Bar Journal, 47(45), 15.

Snow, M. S. (1987). Natural monopoly in INTELSAT: Cost estimation and policy implications for the separate systems issue. Telematics and Informatics, 4(2), 133–150. https://doi.org/10.1016/0736-5853(87)90007-4

Symonds, E. (2019). COMPARING AND CONTRASTING SPACE AND CYBER GOVERNANCE IN MULTILATERAL FORUMS AND U.S. POLICY INITIATIVES. Univeristy of Maryland - School of Public Policy, 68.

Thierer, A. D. (1994). Unnatural Monopoly: Critical Moments in the Development of the Bell System Monopoly. Cato Journal, 14(2), 267–286.

Toh, S. B. (2020, June 17). Council Post: The Argument For The Internet As A Utility: Is It Time To Change How It's Delivered? [News]. Forbes. https://www.forbes.com/sites/forbestechcouncil/2020/06/17/the-argument-for-the-internet-as-a-utility-is-it-time-to-change-how-its-delivered/

Triedman, C., Lukens-Day, E., Hinh, A., & Ball-Burack, N. (2021). Can State Utility Commissions Lead in the Clean Energy Transition? Lessons from Six States. Brown University Climate and Development Lab.

Wells, T. (2016). Exploring the Space for Antitrust Law in the Race for Space Exploration Notes. Washington University Global Studies Law Review, 15(2), [i]-402

Appendix B

Appendix B: Script and Interview Briefs

B.1 Script

Introduction

Thanks for participating in this project. I will be asking you a set of questions regarding regulating large satellite constellations and whether regulating them as monopolies could be an effective manner at encouraging sustainable practices in low Earth orbit. Prior to this interview I sent you the frameworks for two possible regulatory approaches, one modeled after the US public utilities structure and one modeled after the European internet structure. I will be asking you questions regarding the general concept as well as these two specific frameworks. Feel free to ask any clarifying or follow-up questions anytime during this interview, as I will be doing the same.

For the record, could you please state your name, your current occupation, your area of expertise, and whether you are speaking on your own behalf or on behalf of another organization.

Questions

Q1: Absent of the two frameworks presented to you, what are your thoughts on monopolies in space?

Q1.1: Are LSC's "natural" in the sense that the more customers served, the less expensive they become to operate (are they economies of scale)? Q1.2: Are artificial barriers needed to create a monopoly in space?

Q1.2B: What are your thoughts on internet as a utility?

Q2: Turning to the two concepts laid out, what are your general thoughts on each?

Q2.1: What are the strengths/fast paths of each concept?

Q2.2: What are the weaknesses/roadblocks of each concept?

Q3: Regarding the sustainability goals, which of the two concepts do you think will better implement these goals overall?

Q3.1: Are certain goals better suited for one of the two concepts?

Q4: Are there any specific large constellation uses that you see this approach working well for other than internet?

Q5: Which of the two concepts seems more viable in today's setting?

Q5.1: What would need to be changed to make the other more viable?

Q5.2: Are there any other frameworks you think might be applicable or worth investigation?

B.2 Interview Briefs

These interview briefs are a combination of direct quotes and paraphrases. Whenever possible I tried to include the original quote, however the back-and-forth nature of these interviews made it so many important data points are best presentable as paraphrases.

Question 1: Absent of the two frameworks presented to you, what are your thoughts on monopolies in space?

CK: "Monopolies in any regime are inevitable". However, if they actively seek to avoid competition, blocking potential competitors who present no issues of safety or danger to systems and/or people from entering the industry, then regulation should step in. If a monopoly arises as a natural occurrence of the domain and doesn't prevent competition or stifle innovation, then there is no problem.

BW: In short, "They're hard". There are only really two historical monopolies, GPS and Space Surveillance Network (SSN). Despite multiple attempts by the U.S. to make GPS a monopoly, other countries developed their own GPS systems, with a multitude of systems existing today. The story is similar to the SSN, except this network had private competition as well as other governments, causing further disruption of the monopoly.

DO: "I am not convinced that new large constellation operators automatically become a monopoly, as other large constellation operators would be able to field similar systems that could compete. But as a practical matter, there are aspects of taking up the "capacity" of the space environment"

PJB: "That depends on what [I (Mack)] mean as a monopoly in space." If you are treating one company as a monopoly, giving them granted rights, there might be some problems. We give monopolies to utility companies because competing infrastructure is damaging to the public. The cable-internet monopoly limits infrastructure but not competition. A company could offer 5G broadband streaming as an alternative. There is nothing to keep others out of the space market, you can easily launch into space. With Starlink, they have claimed certain orbits, but other orbits are available. The "question would become whether or not this monopoly thing can hold in the sense that... it doesn't accomplish the same ends that we seek when we [instate monopolies for] public utilities."

DM: "Sounds bad." To him it means that people get their way unconditionally. "That's not what we want in space, we want people to work as a community." Gut is bad, but could be convinced.

Q1.1: Are LSC's "natural" in the sense that the more customers served, the less expensive they become to operate (are they economies of scale)?

CK: From the point of view of the satellite operator, "LSCs do have economies of scale".

BW: In one way they are: servicing range. Imagine a satellite company just serving the U.S. Because LEO satellites are orbiting the entire surface, 80% of the time the satellites are not going be over the US, meaning this time goes wasted. In that context, if you get customers in other countries to sign up, you now get additional revenue and service for no additional infrastructure costs. Conversely, the opposite is true with regards to service density. Getting more customers in the same geographic area doesn't scale, instead you get "capacity strain" (slower speeds). Density of users in the same area are a problem. Geographic diversity gives economy of scale, service density

does the opposite.

DO: "Yes, I believe they are economies of scale, in that once you have fielded a large constellation with global coverage, it can likely easily accommodate global need. This would then serve to reduce the cost burden for any replacement satellites or ground infrastructure enhancements are upgrades."

PJB: "They depend on an economy of scale". The question is: do you have the market for your service. Rural America has a market, while NYC will never have a market for people who need StarLink. He is not positive that we are seeing enough customers for StarLink to have an economy of scale. Unless we partition orbital space according to uses, we will have enough space for competition. He agrees with Mr. Oltrogge's idea of monopolies by orbital. This would be natural in terms of infrastructure. This would have to go through the ITU or some international body.

DM: "It depends." It varies depending on the matter and the problem being addressed. It might make more sense for earth imaging but not necessarily for internet satellites (due to technological refresh/improvement costs). You need to look at the field in question, it is not an assumed economic law for all constellations.

Q.1.2.A: Are artificial barriers needed to create a monopoly in space?

CK: If there is only one organization that wants to engage in a particular activity, that is a monopoly by default. There is bound to be a dominant or a few dominant actors among the rest, along with smaller operators, due to the complexities of space operations.

BW: Yes. Under the OST countries are able to freely use space; internationally there are no monopolies. Within a country a government can choose who they license, creating the needed barriers.

DO: "When you look at the technology required to design, build, launch, operate, and dispose of large constellations, barriers already exist that can prevent less mature or advanced space faring countries from using space at a large constellation level. That's not to say that artificial barriers do not already exist, but there are enough technological and financial barriers that naturally occur which can lead to monopolies in space."

PJB: Yes, see response regarding the need for international agreement in Q1.1

Q1.2.B: What are your thoughts on internet as a utility?

CK: No response to this question.

BW: He doesn't think the US will treat internet as a public utility in its entirety. There are existing proposals in Congress for net neutrality,[1] should they pass he believes this would be the closest the US would get to regulating internet like a utility. However, if the US did regulate internet accordingly, he's not sure if it would have a huge impact on overall internet LSCs.

DO: "There are places in the US where the public utility is not well thought of, and customers are frustrated by the lack of capabilities and unreliability."

PJB: There would need to be a justification based on infrastructure restrictions, where the development of multiple internet networks would harm society. It could help balance the urban-rural broadband access.

DM: We are moving that direction already in terms of communal use. You don't get charged for the internet, light, water at Starbucks. "If you go to Starbucks and use the internet. it's like

1. *Net Neutrality and Broadband Justice Act of 2022*, 2022

using light: you don't get charged for light, you don't get charged for water, for using the toilet!" However, he is not inherently onboard with the lack of competition from a utility-based regulatory approach. Competition in cable TV lowered the prices, competition improves performance and services. "Competition is what usually improves performance and improves service."

Question 2: Turning to the two concepts laid out, what are your general thoughts on each?

CK: He doesn't think the PU approach is appropriate for space. Looking at the example of airlines in the 70s and 80s, the intense regulation with fixed profit margins proved to be a barrier to lower prices and better service. "The heavy regulatory layer... didn't help civil aeronautics". He believes regulating an internet LSC like a public utility would run into the same problems as the airlines did.

Regarding the EI approach, it will be hindered by the speed of the government; Nothing in the government moves quickly". Why should every taxpayer pay a general user-fee for a service they do not use?

BW: Overall, both have significant drawbacks. However, "there may be a benefit from not having duplicate efforts." Having a single constellation would increase the chance that the constellation would be a success, whether privately (as in the PU) or publicly (as in the EI) operated. He doesn't want the satellites of folded companies staying in orbit, as that would only further the congestion problem. Moving onto the drawbacks, a U.S. providers only approach would present the capacity problem mentioned in Q1.1, urban population density would struggle. Furthermore, the U.S. has already issued licenses for multiple private internet LSCs, revoking or buying out those licenses may not be possible. "We've already said yes to all this stuff [permits to orbit]. So, if we were going to adopt either of these two solutions we would essentially have to go and tell the other companies to remove their stuff from space. That's a huge regulatory and political challenge. I'm not even sure the U.S. government has the authority to do this after giving them a yes"

DO: "The question would be how you might take these two frameworks and somehow incorporate the existing large constellations which already have a lot of inertia, customer sets, capabilities, and VC engagement."

PJB: Regarding the PU approach, there needs to be a compelling reason behind infrastructure restriction. One would have to "create the reason in order for there to be a monopoly." Congress could do this, giving authority to the FCC. The US is a lassie faire government by nature with regards to business. Looking at the failure of net neutrality, he's not sure whether the US has the appetite for regulating internet.

The EI concept could be a thing. A government satellite could be equipped with multiple transponders for various service providers. One of the big problems with EI in space is innovation. We see crazy satellites competing in orbit. Will the government put up a satellite that meets my needs as a service provider? Can I deliver the kind of service I want with the government satellite? Companies want to sell services from their satellites, a safer investment for each company.

DM: He leans more towards the U.S. version vs. the European version, fearing government oversight. "I want it to be owned by the private companies." Excessive government oversight could lead to a few problems: they would be slower at adapting technological advancements (delays in procurement process), and fear of lack of quality (looking at Veteran Affairs). But it also means

that the technology would be safer than if commercially used.

Q2.1: What are the strengths/fast paths of each concept? CK: For the PU and EI approach, strengths could include assuring availability and access to customers. It ensures that a system will be in place, not ensuring it will be a quality system however.

BW: Blessing one company as the sole provider in exchange for restrictions on profit (the PU approach) may be the natural occurrence if the demand for satellite internet is not as robust as people imagined; a monopoly could occur purely from lack of demand. Other countries are taking this approach (Canada with TeleSat,[2] China with the China Satellite Network Group,[3] OneWeb's minority ownership by the British Government[4]). Dr. Weeden refers to this as the "National Champions" approach, where one company gets exclusive support and licenses from a country to be their provider. This could grow to where each country has their company compete on the international stage to service, going the profit route, or restrict just to in-country access based off security reasons.

Regarding the National Champions approach, he sees this as plausible both commercially and as a way to enact sustainability norms. If countries agree to have one national champion who competes on the international internet providers market, all agreeing to sustainability standards, then this would preserve competition as well as improve the sustainability of the LEO environment.

DO: "The strength of the US Public Utilities approach could be that we already have a large constellation in existence, and if the US government could succeed in convincing that operator [SpaceX with StarLink] to become the operator for the LSC, then potentially it could be quickly realized... A potential strength of the European model could be that it would promote innovation, competition, and choice amongst the user community."

"Concept 2A:[5] There could be benefits to a slightly different "flavor" of this European model for the LSC topic, whereby the government provides an interoperability framework that allows multiple LSC operators to live within that framework but in constrained and pre-coordinated ways. One might think that this is effectively what we have in place today with the FCC approving large constellations submitted by different operators. But the difference could be that the government in concept 2A would first define the framework which defines the interoperability between approved large constellations satellites, rather than having them being separate, standalone entities and capabilities. And orbits, and inter-constellation interplay, would be coordinated and orchestrated." The government allots orbitals. This framework could include standards of communications, crosslinks between orbit regimes, different altitudes serving different parts of infrastructure, etc. There needs to be a way to prevent excessive fees, prove that the fees/rates you are charging are reasonable and not exploitative.

PJB: "The US has a broadband infrastructure problem." These ideas could solve this rural-

2. *Approval in Principle — Telesat Canada (COMMSTELLATION)*, 2015
3. Jones, 2021
4. Department for Business, Energy, and Industrial Strategy, 2022; *Eutelsat and OneWeb to Combine*, 2022
5. Dr. Blount expressed support for a similar version of this idea. His take on the 2A concept goes as follows: the U.S. recognizes we need better broadband infrastructure so they put out proposals to companies to fill in the gaps. Companies compete for these contracts. This could also solve a tangential issue. In the U.S., regulation and licensing is bifurcated and fractured; The FAA, FCC and others all have different processes. Through this contractual competition concept the U.S. could streamline their regulatory structure and install controlled privately operated domain monopolies, taking the 2A approach Mr. Oltrogge laid out for orbital space and expanding it across all broadband gaps.

urban connection divide, being connected is crucial to modern day life. "this [satellite monopoly] could help solve this broadband issue by spreading connectivity across the nation... that is something of value to the U.S. and in particular to the U.S. economy." Another benefit is its ability to reduce the number of LSCs in orbit, we need more orbital space. "It does allow us to reduce the number of these megaconstellations in orbit... which is good for orbital space." Treating internet like a common carrier, especially with satellites, could level the price difference between rural and urban areas. By taking the costs and spreading them across different areas, you might get a better infrastructure. Within the U.S., the only legal barrier is finding the legislative momentum. We can have Congress create a monopoly, but it's likely that this would be unpopular with the current Congress. "That law is not going to be easily forthcoming."

DM: PU approach keeps it somewhat capitalist, where the private company owns the system, making the process cost effective and efficient. "I want it to be owned by the private companies" He wants to keep the system under private control, and the PU approach allows for this in some capacity.

Q2.2: What are the weaknesses/roadblocks of each concept?

CK: For the PU approach, "The weaknesses are the burden of government oversight, the regulatory infrastructure... definitely stifling competition, not just in operators but in satellite manufacturers".[6] Also, a big risk of vertical monopoly unintentionally forming. How do you make sure that the operator is charging a fair price when there is no yardstick to compare the price against? What do you do when someone says they can operate an internet LSC for less?

Many of the same problems will plague the EI framework. There will be a stifling of competition, an immense cost to operate, and a slower speed of operation than a privately-operated LSC.

BW: No response, answer reflected in Q2.

DO: "One obvious weakness of the U.S. Public Utilities approach is that it can stifle innovation and... limit the quality of service that the customer is able to obtain, precisely because competition has been eliminated... A potentially big weakness of the European approach... is that the government would develop and operate the large constellation, and the government is often not very efficient, timely, or innovative in deploying such technically complex systems. We would likely anticipate very large cost overruns, issues with legal battles contesting the award of such systems to a single contractor, and administrations that could change every four years that prioritize and then subsequently deprioritize such a project."

PJB: A problem could be the "free space" issue, with other constellations outside of the U.S. abusing the U.S.'s self-restriction. "just because we do this thing with internet doesn't mena that other satellites will come into this orbital space" The National Champions model could solve this. Furthermore, not everything fits the common carrier qualification. Federal legislation could solve this, but the U.S. lacks the political momentum at this time.

DM: EI approach could lead to over-budgeted costs and loss of efficiency.

Question 3: Regarding the sustainability goals, which of the two concepts do you think will better implement these goals overall?

6. Mr. Kunstadter argues that we already see this occurring with SpaceX, who can produce the satellite and the launch vehicle while operate both. This combined with their favorable government position and existing infrastructure has resulted in a lack of vertical competition.

CK:

(1) Risk tolerance: The government may come up with standards, but these standards may become outdated in a few years, "Developments in space happen very quickly." Case and point, "look at the 25-year rule." You don't want to force a standard; they should be developed by industry. "Not a matter of public policy." Neither is advantageous.

(2) Transponder tracking: "Having this government monopoly... will bring down the cost of these transponders" as they become mass produced; "it will make [the transponders] ubiquitous and a de facto standard." Either one would do that. In PU, the operator may ask the government to pay for it. In EI, the government would definitely pay for it, bringing down the cost of production and purchase.

(3) Deorbiting: The pressure of crowded space is going to drive people to reduce the 25-year. rule. In the second case (EI) the government could influence the deorbiting timeline by setting a precedent. Should the government deorbit all their satellites within a set timeframe, then this could become the industry standard.

(4) Reduction in debris creation/propagation: Reusable rockets are the new standard. However, there is more we can do, improving later stages. This is a development occurring regardless of whether a government-backed or government-owned LSC goes into orbit.

(5) Propulsion requirements: Similar to transponders, through the EI model the government can demonstrate propulsion effectiveness by using the systems themselves. This would build confidence in the technology as well as reduce the cost of purchasing and developing in-orbit propulsion systems. For PU: most LSCs will have propulsions; they are too big to not have it. We already see propulsion systems on StarLink and OneWeb, though there could be improvements in these systems.

BW: Neither one has an inherent advantage over the other regarding sustainability norms. The PU approach may be slightly more plausible as it removes industry as a middleman for standard setting, but "governments haven't always been great stewards of space". He's not convinced that the government operating constellations (EI) themselves will be more effective than the government supervising a private company (PU).

DO: "Because both of your proposed approaches advocate for a single LSC, I don't necessarily see a benefit to sustainability for one approach versus the other."

PJB: "The PU model... is more suited for sustainability... it actively reduces the number of satellites in orbit". The PU approach can accommodate for competition so long as we keep the infrastructure the same. Meanwhile, the EI model can better reduce the price of services, having the government swallow the infrastructure bill. However, the EI system may not inherently contribute to a reduced capacity. Does it precludeother satellites or just bring the cost of internet down?

DM: End of Life and tracking are the two most important, and he would like to add remediation/active debris removal (ADR) to that list. These goals, in particular ADR, may not best be solved with my regulation, wrong tool for the job. This should be left to the market but encouraged by reclamation credits or funding for private companies to remove debris. If the government wanted

to enact ADR via regulation, the EI approach may be more viable. However, the PU approach could allow private innovation with ADR technology.

Q3.1: Are certain goals better suited for one of the two concepts?

CK: Goals centered around the proliferation of sustainability technology will be best suited to the EI approach, as the purchase and usage of such technology will lower the cost for others. The implementation of deorbiting/end-of-life procedure might also be easier to implement through the EI approach. The other, more standard-based goals (reduction in debris, risk tolerance) are equally suited for both concepts, though.

BW: Neither concept has a comparative advantage.

DO: "Again from the perspective of overall capability to the end user and innovation, the European approach helps facilitate at least some level of competition, which I see as a necessary aspect of a healthy regime."

PJB: It all comes down to legislative momentum. If the U.S. pursues the PU route, then it would demonstrate that private companies can be sustainable. The EI route may not. Internationally, if sustainability is the concern, I'm not sure if a single nation restricting themselves will solve the capacity issue. We will run into the flag of convenience problem. Sustainability is not possible unless everyone signs on.

DM: Gave no answer for this question, instead stressed the importance of ADR. "You could potentially give companies credits for going and removing 5,000 or 10,000 lbs of debris, which they could sell to these new constellations" to make space for their new constellation."

Question 4: Are there any specific large constellation uses that you see this approach working well for other than internet?

CK: While not an LSC, there is precedent for a PU setup with launch vehicles. Before the entrance of SpaceX and other launch providers, the United Launch Alliance (ULA) provided launch vehicles to the U.S. government at fixed rates, having a monopoly over launch services.

BW: He could see both approaches working for scientific objectives. There have been ideas floated of an EI-style constellation where scientists could equip sensors for public use. This follows precedent of governments sponsoring scientific research, which is not inherently profitable. Regarding commercial endeavors, the U.S. Government would need to find an infrastructure that the economy provides.

If we investigate a model where a utility is provided, such as imaging and weather prediction, there could be a national security justification for such an LSC. This somewhat exists with NOAA weather imagery: the government owns and operates the satellites, releasing the data to the public for other governments and companies to use as they please. There is a similar situation with Maxar Technologies, which holds a technological advantage over high-resolution space imaging. This advantage is weakening, the rapid innovation in the imaging/remote sensing field combined with the growing variety in demand and application has made the idea of a monopoly less and less appealing. A common-cause LSC that grows as other companies innovate could be a partial solution.

DO: "Potentially mapping and earth observing, however both of these aspects depend heavily upon the users requirements and a single system may not be able to meet individual user requirements."

PJB: To some extent we have this model with weather satellite right now (not privately operated). The government operates the weather satellites, the data is sent out as a public good. This doesn't prevent other operators from collecting and selling private data, but they cannot compete with satellites providing free data. People don't want to pay for this data, it is in the public interest to keep weather satellites free (better situational preparedness, information, access to models). Outside of telecom and internet, applications may be limited.

DM: Earth Imaging is a direct commodity to Google Maps, but not a direct commodity to the average person. However, the average person uses Google Maps in their daily life. "Constellations that support voice communications probably would work." In general, if you don't know the infrastructure is in space, it could potentially work as a government-managed space-based utility. If we don't think that it's from space, you're not aware, then it has become an infrastructure success; the utility is ubiquitous.

Question 5: Which of the two concepts seems more viable in today's setting?

CK: EI seems more viable as PU is anticompetitive. Government will support industry by buying products from industry. He doesn't like it though, as private companies can do better than the government. The EI approach seems more viable but not ideal.

BW: The PU approach, specifically in the form of National Champions, could be viable, however he doesn't see the EI approach working in the U.S.

DO: "Both of these approaches have a huge roadblock in terms of figuring out how to address these existing large constellations. I don't really see a single large constellation as having the flexibility to meet all user requirements, which calls into question the efficacy of both approaches.

That said, given what I believe is a requirement for healthy competition and options for the end user, I believe the European approach is better suited to an LSC framework, but only if that competition exists at the LSC level (2A), as opposed to your current proposal of the government developing and operating the LSC itself."

PJB: The PU Model seems more realistic unless you do EI Concept 2A. If you want broadband to be affordable, and satellite is the key to that, the government needs to have a hand in organizing infrastructure. They can bring prices down to an affordable point and establish a more diverse and accessible internet infrastructure.

DM: "It's very culturally dependent." The PU approach is best for the US, the EI is best for other countries which are more interested in government involvement.

Q5.1: What would need to be changed to make the other more viable?

CK: "PU approach could only be more viable if you allowed more providers". This would be a bloodbath; a lot of lobbying efforts and constituency issues would complicate and entrap this process. Regarding the EI approach, the government would have to let commercial operators operate it, then CSOs could provide feedback on operation methods.

DO: "Potentially a [contract competition] between a couple of LSC's might help ensure that the US Public Utilities approach meets user requirements and gets us the capabilities we all would like to see."

PJB: We need a cultural shift in how we view governance in order to make the EI model work or to bring any international agreement on applying these concepts globally.

DM: "From the utility perspective... does it have to all be based on a monopoly approach

or really can 85% be that way [commercial] and can 15% be dedicated government?" There could be a national security imperative to have internet protected from external stimuli as a PU. "Does it have to be all one or the other?" Internet is great for everything, but in the case of space weather, hacking, security, it might be wise to have 15% owned and operated (reserved) by the government for emergency internet access. During times of significant turmoil, you will want a secure government pipeline.[7] It could be through this national security imperative that the government installs sustainability norms and helps to mediate internet prices, as they themselves would be a customer. "There's probably always something you're going to want to have a bit of a pure government play on." For the EI approach, the U.S. would need a cultural shift in the US towards socialism.

Q5.2: Are there any other frameworks you think might be applicable or worth investigation?

CK: He would want to take the government out of operations, giving control to commercial industries, but promote new technologies, thereby providing competition and preventing a monopoly from forming. Today, we are ending up with a monopoly (StarLink) due to their technological advantage. Anyone can copy StarLink, but few have the resources to do so. So long as they don't use their monopoly position to screw the customer, this should be fine.

DO: Option 2A, mentioned above (Q2.1).

PJB: "There is going to be a need at some point for the ITU to address carrying capacity." The ITU has authority over frequencies and associating orbital slots for certain frequencies. The ITU tightly regulates frequency in GEO as this is a shared orbit, but they are more relaxed in LEO due to its multiple orbits. Frequencies are beginning to overlap, however. Soon there will need to be a regulatory shift, applying the stricter regulation seen in GEO to LEO.

DM: The idea of vouchers could be a market-based way to encourage ADR. Assume that US/China/Russia aren't going to do anything about their junk. Have companies receive vouchers based off how much debris they remove. For example, should a company remove 1 kg of debris from orbit they may receive a voucher to leave up 0.5 kg of their own debris, thereby net-reducing total orbital debris. Another option could be requiring companies to remove debris before orbiting their own satellite and to remove the satellite you intend to replace. Overall, we need a net-decreasing amount of mass in space. Leave no trace principle.

7. For an example of this importance, look at the hacking and jamming of StarLink satellites servicing Ukraine (Duffy, 2022)

Appendix C

Appendix C: Presented Frameworks and Consent Form

C.1 Presented Framework:

Objective: To see if large satellite constellations can be regulated in a similar manner to monopolies, and if so, if this regulatory framework would be more or less effective at implementing modern sustainability norms.

Defining criteria: I will judge based of three criteria: Efficiency, equity, and sustainability.

- Efficiency pertains to how well these regulations can maximize the productive use of LEO
- Equity focuses on ensuring fair access to space and to the products space can offer
- Sustainability indicates how durable these regulations are in keeping LEO a viable, safe, and marketable operating domain in the long run

Test constellation: a U3 CubeSat constellation (10x30 cm) on the order of 104 in size offering a set service within the United States. For this study, the service is internet. There are two possible setups that I will be considering: the US public utilities approach and the European internet approach. Regardless of the approach, the LSC will be the same.

The Regulation: Depending on the approach the regulations will differ. The two approaches being considered are the US public utility approach and the European internet approach. These regulations are more holistic and avoid full detail, as that is beyond the scope of this study. Therefore, they will stay frameworks. Both feature a single LSC offering exclusive services, it is the delivery methods that differ. The two regulatory approaches will be discussed in greater detail later. Both regulations will be part of an internet-as-utility network, approaching internet as a non-profit enterprise. The satellite network would complement terrestrial-based infrastructure, acting as one appendage of a larger internet infrastructure.

Sustainability Goals:

- Maximum risk tolerance regarding conjunctions, standardizing risk assessment.
- Transponder tracking, requiring that all satellites have active transponders attached so their location can be precisely determined.

- Stricter deorbiting protocol, i.e., reducing the 25-year rule to five years or less, decreasing net congestion.
- Reduction in debris propagation, having more secure satellites that shed fewer parts and reusable launches.
- Propulsion requirements, all satellites must have a base-level of maneuverability to avoid debris and collisions.

C.1.1 The US Public Utilities approach

Overview: A single company would develop and operate the LSC. Service would be organized around a public utilities commission, very similar to what occurs at the state level. The commission would act at a "union" for citizens to establish fair usage rates as well as fulfill other duties. This would work in tandem with terrestrial internet infrastructure.

The Monopoly: One company would be selected to develop, launch, and operate the LSC. This company would have exclusive rights to provide LEO-based satellite internet within the US. The company would be responsible for maintaining this network and upgrading it as needed. However, their profits would be tied to a percentage of the revenue, not based off of the development of new infrastructure as is the case with most US public utility agreements. This change in incentive works towards the sustainability goal of this approach, protecting LEO from overcrowding. The rates and percentage profit would be determined by a national public utilities commission.

The National Public Utility Commission: Modeled after state public utility commissions, the commission (as I will refer to it) will monitor, regulate, and evaluate the monopolist. Its duties would encompass the tasks below among others:

- Determine the market price for services, calculating operational costs
- Monitor and evaluate the monopolist, ensuring they abide by the required sustainability and equity standards along with other regulatory requirements
- Determine the profit percentage the monopolist can charge relative to the break-even price
- Negotiate and regulate the break-even price plus the profit percentage
- Perform audits as to where the LSC needs maintenance, upgrading, and adjust the percentage profit depending on the success or neglect of the monopolist

The monopoly should be contingent on providing a base level of utility and internet speed, ensuring it remains competitive with land-based internet. Furthermore, access should be nation-wide, providing the same quality internet to all regions and community. This follows the requirements of space activity to be on a basis of equality, per Article I.

The commission would have an odd number of members, be appointed by the President, approved by the Senate, and hold positions for a set number of years.[1] The commission's members should be a mix of scientists, engineers, policy experts, and economists.

Expected Problems:

This approach runs the risk of falling into similar traps as existing state public utilities commissions. In particular, any Presidentially appointed, Congressionally approved commission risks becoming politicized and partisan or falling under the sway of lobbyist. The commission should be advocates on behalf of American citizens, the consumers, but if not properly set up and protected, could fall under the influence of the monopolist, leading to inefficient outcomes in terms of sustainability and market efficiency. Some other possible problems include:

- Congressional deadlock creating a commission lacking full membership
- Existing satellite constellations providing similar services
- Broadband congestion in urban areas
- Accurate auditing of the monopolist and fair price negotiations

C.1.2 The European Approach

Overview: This model pulls from the precedent sent by European countries on how they manage terrestrial internet. While the large size of America may have proved a blockage to this approach in the past, the flexibility of space may alleviate this restriction. This network would work in tandem with terrestrial internet infrastructure.

The Monopoly: The US government develops and operates the LSC, being liable for its maintenance and relevant updates (new technology, higher speeds, greater reach, etc.). The taxpayer would pay for the development and launch with an expected return on investment via taxes for service usage. Since the government is controlling the LSC, sustainability standards can be enforced upon itself by law and policy, much akin to the standard mitigation practices that Us missions currently follow. This would likely fall under the FCC's control. **The Agreement**: Companies can use this LSC under an "open access" agreement. Open access means that internet access providers can use the infrastructure to provide internet services to consumers and businesses. However, the open access agreement means no throttling or blocking traffic and following a non-discriminatory traffic management.[2] Companies can use the LSC infrastructure to offer internet services without having to put forward the money to build, maintain and operate the network, instead with a percentage of revenue going to the government for usage. This tax would go towards system maintenance and updates. Some other important points:

- Contract for the LSC usage would include clauses to restrict ballooning of prices

1. There are concerns surrounding presidential appointments and public service companies, so suggestions on more effective membership selection processes are welcome. Concerns rise from the politicization of the Postal service and the Postmaster General.

2. Note that in the EU's regulation there are three exceptions to these requirements: "compliance with legal obligations; integrity of the network; congestion management in exceptional and temporary situations" *Open Internet — Shaping Europe's Digital Future*, n.d.)

- The aim is for the open access to allow greater competition, keeping prices low, as there is a lower barrier to entry. The monopoly is used to prevent a monopoly.
- Since the government is operating the satellite, they can force themselves by law to follow the criteria below, setting the standard.

Expected Problems:

Most of the European approach's anticipated problems come from the difference in market culture. Americans place the free market at a premium, not wanting government interference. Americans historically have preferred venture-capitalist backed endeavors, not opposed to government money, but wanting the private sector to maintain control of revenue and costs. Below are some additional problems this approach may encounter:

- Desire for private sector control
- Competition with other public/taxpayer funding for development and launch; it would need a secure way to gain back expenditures
- US government's historical inefficiency and history of cancelling projects
- Contracting vs in-house for development, risk of NASA-like contracting reliance, large financial burden

C.2 Script

University of Colorado Boulder

Permission to Take Part in a Human Research Study

Title of research study: Can Regulating Large Satellite Constellations like Natural Monopolies Effectively Increase Sustainability Standards

Investigator: Samuel Rodgers

Purpose of the Study

The purpose of the study is to determine whether regulating large satellite constellations (LSC) like natural monopolies can allow policy makers to implement and enforce sustainability standards more effectively. The growth of LSCs in Low Earth Orbit (LEO) has raised concerns surrounding overcrowding, space debris proliferation, and increased risks of collisions and conjunctions. The regulatory body has not evolved to match LEO's population growth, and companies have little incentive to act sustainably with respect to this increase. Pulling from how governments handle terrestrial economies of scale (utility companies being an example, or internet in European companies), approaching the development of LSCs from this economy of scale perspective may allow governments to implement greater sustainability standards.

I will be drafting up two draft frameworks for regulating natural monopolies in space at the national (US) level. I will be using satellite internet as the service of choice for this research. The first will be for a privately developed and operated LSC with exclusive internet providing rights, regulated through a national public utilities commission (the American utilities model). The second will be for a government developed and owned LSC through which private companies can offer internet services. These two approaches will be judged based off 5 sustainability goals:

1. Standardized risk assessment, including maximum risk tolerance
2. Transponder tracking
3. Debris propagation standards
4. Propulsion and maneuverability requirements
5. Stricter deorbiting protocol

Judging the potential of this regulatory approach will either add an additional tool to solving the space sustainability issue or eliminate an ineffective option.

We expect that this interview will last between 30-45 minutes. This interview will be recorded and non-anonymous. We expect about fifteen people will be in this research study.

I have read the section above and understand the basis for this study: (initial here) _____

Explanation of Procedures

Three weeks prior to the interview we will send you the draft frameworks to be read and reviewed along with the questions that will be asked in the interview.

The interview will begin with a statement marking the beginning of the recording, reminding you that you have the right to strike a comment from the record at anytime. Following this, the interviewer will ask you who is being interviewed, their profession, and whether you speak as an individual or on behalf of an organization. The interviewer will then walk through each question, taking notes and comments, allowing for you to ask clarifying questions, and follow up questions from the interviewer to clarify comments. At the end of the interview the interviewer will announce the end of the recording and ask you if you wish to change any comments or strike anything from the record.

After the interview we will send you a transcript of the interview and provide you with 72 hours to correct, clarify, or strike any comments from the record.

I have read the section above and understand the interview's procedures: (initial here) _____

Voluntary Participation and Withdrawal

Whether or not you take part in this research is your choice. You can leave the research at any time, and it will not be held against you.

At any time, you may request to be removed from the study. If so, all of your comments will be discarded and deleted, and your name will be removed from the study.

The person in charge of the research study can remove you from the research study without your approval. Possible reasons for removal include: change in occupation, loss of authority, inappropriate comments, conflicts of interest.

I have read the section above and understand my right to withdraw my participation at anytime: (initial here) _____

Confidentiality

This is a **non-anonymous** interview. Your name, occupation, and title will be used in the final publication, as it is your expertise and authority on the subject matter that is critical to this research. What you say in the interview may be quoted and used as evidence for this study's final conclusion.

Information obtained about you for this study will be kept confidential until presentation of this honors thesis. Research information that identifies you may be shared with the University of Colorado Boulder Institutional Review Board (IRB) and others who are responsible for ensuring compliance with laws and regulations related to research, including people on behalf of the Office for Human Research Protections. The information from this research may be published for scientific purposes.

I have read the section above and understand that this study will be non-anonymous and that what I say in the interview may be cited: (initial here) _____

Payment for Participation

You will not be paid to be in this study.

Contact for Future Studies

We would like to keep your contact information on file so we can notify you if we have future research studies we think you may be interested in. This information will be used by only the principal investigator of this study and only for this purpose.
Please initial your choice below:

___ Yes, you may contact me for future research studies. The best way to contact me is: (enter preferred telephone number and/or email address)
_____

___ No, you may not contact me for future research studies.

Questions

If you have questions, concerns, or complaints, or think the research has hurt you, talk to the research team at zachary.donohew@colorado.edu and/or lauren.blum@lasp.colorado.edu

Signatures

Your signature documents your permission to take part in this research.

_____
Signature of subject Date

_____
Printed name of subject

_____
Signature of person obtaining consent Date

_____
Printed name of person obtaining consent