Analysis of the Challenges in Enforcing Effective Space Legislation in an Expanding Space Economy

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

In October of 1957, the first man made object was launched into space. The Sputnik 1, launched by the Soviet Union, set a milestone that would set off a human revolution in exploring and utilizing outer space (*A Brief History of Space Exploration*, n.d.). Today, there are over 100 million man made objects in space, which comprises both spacecraft as well as space debris. In 2021, NASA's activities provided over $70B in economic output (Brukhardt, 2022). This exponential growth of space access has been the result of innovations in the internet, cell phones, and telecommunications, resulting in infrastructure in the geostationary region above Earth (less than 1200 miles above) (Weeks & Faiyetole, 2014). During this initial wave of development from the 1960s to the 1990s, this orbital region became occupied by equipment to facilitate technologies that drive the world today. Additionally, this "space race" began in order to build national prestige amid the Cold War to project both power, military significance, and serve commercial and geopolitical interests ("Chapter 5. Crowding and Competition in Space", 2022). These early space activities were funded by the public sector, where educational efforts influenced school curricula to involve space, and international coordination resulted in ventures like the international space station ("Chapter 5. Crowding and Competition in Space", 2022).

In the early stages of space development, there was some legislation that attempted to govern and promote responsible space activity. The 1967 Outer Space Treaty was created by the United Nations to mitigate the risk of potential clashes, by limiting nuclear weapons in space, and keeping outer space free for exploration ("Treaty on Principles", n.d.). However, this treaty contains extremely vague terms, which leads to nations defining them according to their own interests. Subsequently, there is a lack of updated international rules and regulations, which poses a risk to modern space activities. Five internationally recognized treaties govern space law, none

of which contain any terms about how to manage space debris once it's present, how to determine how it should be dealt with once in orbit, and how orbits can be claimed in an equitable manner (Space Foundation Editorial Team, n.d.). The challenge in all of this is that space property access is becoming difficult to regulate, and the lack of effective legislation is going to result in misallocations of orbits. There is a pressing need to regulate this system, while ensuring that the net economic benefits are maximized. By looking at the previous history of space development, and where it is headed, through a technological momentum lens, this paper will uncover social and economic issues that have risen in outer space, as well as issues that will need to be addressed in the future to ensure safe, beneficial use.

The Future of Space Development

Currently, a second “wave” of space development is underway, with an increasingly large share of contributions coming from the private sector for resources, goods, and services, such as commercial space tourism (Weeks & Faiyetole, 2014). The onset of various private companies such as SpaceX and Blue Origin, as well as multiple startups, combined with the vast amount of research has raised billions of dollars for the industry. It has also decreased the cost of launch systems and payload costs, allowing more companies to get a chance at launching satellites and constellations ("Chapter 5. Crowding and Competition in Space", 2022). By decreasing costs, more actors are incentivized to test their technologies and attempt to become profitable, which has created a momentum that is hard to reverse, and will be discussed further in the next section.

In a world with growing geopolitical tensions, governments are relying more on private space ventures to expedite and implement technologies through the distribution of government contracts. In developing space policies on top of national and foreign policies, the commercial

possibilities of space play a significant role in their strategies. These ventures are aimed at establishing territorial orbital claims in Low Earth and Medium Earth regions, to enhance nations' military and defense presences ("Chapter 5. Crowding and Competition in Space", 2022). With the overall cost of space launches going down as a result of technological advancements (like reusable rockets) coupled with growing government investment into space companies, this cost-friendly access to space is going to open up new opportunities in fields such as energy harvesting, space mining, and tourism. These new fields, combined with the growth of the already expansive broadband infrastructure, is going to bring many more players into space ("Chapter 5. Crowding and Competition in Space", 2022). By the year 2035, it is expected that the global space economy is going to be valued at nearly $2T dollars, which is almost three times greater than the $600B it was valued at in 2023. This huge sum accounts for applications such as satellites, global positioning systems, and telecommunications, as well as certain "reach" applications that are going to play a large role in the space economy in the near future (Acket-Goemaere et al., 2024).

Technological Momentum in Space

To uncover issues that have risen up from the history of outer space development, and potential problems that may arise in the future, the sociotechnical framework of technological momentum can be utilized. By talking about this framework in the context of the space race and modern space industry, certain issues can be seen that would otherwise not be apparent.

Technological momentum is a framework that describes how technological systems gain stability and more inertia as they are further implemented and adopted, making their development hard to stop (Baker, 2018). By attracting more investments and having

infrastructure built for a certain technology, it becomes more entrenched and harder to change. In this context, space systems like satellites and rockets that have been used for primary purposes have created a precedent that is now difficult to alter, such as using outer space to communicate and monitor weather, other nations, and agriculture (Logsdon, 2025). Once governments realized that communicating through space and observing Earth from above was useful for both military purposes and the general public, it kicked off a trend that has not looked back since. On top of this, as space capabilities have gotten stronger, they can be applied for military and civilian use as well. Another catalyst for this momentum was the Cold War competition between the United States and Soviet Union (Logsdon, 2025). In order to prove to the other power that they were more superior, each side began developing and testing technologies that showed how capable they were. Once the Soviet Union sent the first astronaut, Yuri Gagarin, to space, the Americans soon followed. It then went from sending one person into orbit to multiple people. A few years later, in 1969, the first humans escaped the orbit of Earth and landed on the moon (Logsdon, 2025). Today, companies like SpaceX are trying to send astronauts to another planet, Mars, with the hopes of terraforming it one day. This has been facilitated by the continuing development and investment into space systems, which have played a pivotal role in allowing these feats. Thus, this race to go farther is a testament to how the momentum of the first few technologies in space, and the catalyst of the Cold War, have created a fervor that has not slowed at all. Humans are continuing to expand into space and install more technology.

An additional aspect of the technological momentum in space has been the trend with reusable rockets. When the space program began in 1972, it was created with the intent of becoming partially reusable, so that it could complete hundreds of missions with a lower cost than sending a new spacecraft each time. Up until 2011, this space shuttle would be used to send

astronauts and equipment to the International Space Station, and would eventually be succeeded by the private SpaceX family of rockets called the Falcon. The Falcon is more feasible because it has a reusable first stage, unlike the space shuttle, which is driving down launch costs further (Logsdon, 2023). However, in this transition, there were plenty of bureaucratic and technological challenges that delayed the initial use of the Falcon for NASA, illustrating how the quick momentum growth stunted the ability of NASA to adapt.

As mentioned prior, the onset of private corporations and investments has led to an increase in the efficacy of space infrastructure, which has made going to space easier, and allows for more parties to be involved in space. To demonstrate the facets of this momentum, the world launched 165 objects into space in 1985. In 2022, the number increased to 2,477 objects, showing how growing investments and research have enabled more space access ("Annual Number of Objects", n.d.).

Although this growth into outer space has caused space to become more accessible and allowed for humans to benefit more from space via certain technologies, legislation has been slow to keep pace with the rate at which space is evolving. Nowhere in the five internationally recognized treaties is there information on how private companies play a role, and if nation-states are liable for them. Also, there seems to be no writing on how potential collisions will be managed, and how to keep other infrastructure safe from potential debris ("Space Law Treaties and Principles", n.d.). As there are many benefits to the planet from the growing presence of humanity in space, there are various associated challenges with this increasing use of outer space and orbits.

Challenges

In both the past and present day space industry, both have been driven by the technological momentum of more benefits for society, lower costs, and national prestige, there have been various issues as a result of the unchecked growth. On top of this, legislation has not been as successful or wide-ranging as it has hoped to be, and that is going to cause more issues as the legal domain will be so far behind that lawmakers will not have much to build off of.

One of the largest challenges that will arise from this extended period of momentum driving space exploration is that since private companies have gained lots of resources and investments, more profit and production is going to shift towards the private sector (Weeks & Faiyetole, 2014). From this, national space policies and economic initiatives will also be placed towards the private sector. Regulating space use is going to be even more difficult, as less of space will be under government control. Additionally, with specialized private sector growth, resources will be concentrated towards companies awarded the most lucrative contracts and with the most infrastructure. As a result, the momentum that the biggest companies have will give rise to economic disparities not only across the world, but even within countries, where bigger corporations can control the broader industry and market (Weeks & Faiyetole, 2014).

A second issue from the continuing technological momentum is that more players in Low Earth and Medium Earth Orbits is going to result in more congested orbits. With more occupied orbits comes an inherent risk of collisions, which can multiply the number of local space debris that already pose a threat to orbits ("Chapter 5. Crowding and Competition in Space", 2022). The world tracks over 35,000 pieces of space debris along with satellites, but most of the debris is too small to detect, even though they still pose threats to satellites. The number of undetected debris is estimated to be around 100 million, and with more collisions, it only impedes future space

missions. Another consequence is that satellites will need to be equipped with the ability to maneuver away from debris in the likelihood of a collision, which can then disrupt other orbiting satellites, starting a chain reaction. These sorts of collisions may be detrimental to future space development and the implementation of new technologies. An extreme amount of debris can render an orbit unsafe for operation of a satellite, which can slow down the growth of technologies in space, which will cause society to benefit less ("Chapter 5. Crowding and Competition in Space", 2022). Finally, with collisions come the problem of exacerbating international relations and causing global tensions over sovereign objects. If one country's satellite were to collide with another country's satellite that might be key for their national security or communications, major issues will arise as a result of irresponsible, unregulated use of orbits. As discussed previously, space agreements do not have any sort of authority or governing body that provides oversight for space traffic control and the enforcement of orbits and their claims. This reflects an ever-growing need to have robust tools in place to mitigate these problems before they become too much to deal with ("Chapter 5. Crowding and Competition in Space", 2022).

The third major issue as a result of the technological momentum that has grown the space economy is the lack of inclusive growth that will create economic divides that are reflective of what is seen on Earth. In 2022, only forty one countries out of over 190 in the world have registered space agencies ("Chapter 5. Crowding and Competition in Space", 2022). Out of these forty one, only thirteen countries and the European Space Agency (ESA) have rocket launch capabilities (Buchholz, 2022). The way the current system is, the major companies and nations that are driving the economic growth of outer space are growing larger and larger, and establishing a larger presence in space. Two of these countries have historically dominated the

realm, and have been growing for decades. Presently, the largest players, the United States, China, India, and Japan, already have trillions of dollars in operations. They are growing unchecked, and many space programs and even countries are being left behind, unable to compete in this sector. A crucial aspect of this is that people with stronger industry experiences and technical backgrounds will have an advantage as the larger players grow more ("Chapter 5. Crowding and Competition in Space", 2022). This is known as geographical polarization, where the most attractive and profitable positions become accumulated in regions where development is most successful and apparent. A negative impact of this is that those from other countries with less developed space programs, will leave their nation to go work for one of these big countries' space programs or a private company. Their home country has now lost out on viable talent, and the same fate will be seen with other countries, until all the talent is concentrated for the bigger players.

Furthermore, should technologies from more developed space programs want to be transferred to another country to spread the societal benefits from a technology that has been tested and implemented, the transfer may be limited ("Chapter 5. Crowding and Competition in Space", 2022). This will be due to limited infrastructure development and the lack of technical talent to build systems to house these space technologies. Involving more than just space programs, but various people as well, these technologies that have the potential to benefit the world, such as agricultural monitoring, may not be as effective as originally thought. One solution to this is that treaties should be created to ensure that infrastructure is also prioritized in nations that could benefit from having space technologies, such as remote island nations who could use the technology to improve residents' lives.

With the private sector becoming an integral part of the development in outer space, combined with more developed space programs concentrating talent and infrastructure, a difficult road lies ahead in ensuring that unchecked growth does not happen. The lack of regulations and laws that govern spatial orbits, as well as the distribution of space infrastructure of resources around the world, can cause lots of potential concerns for both the safety of outer space and the technological inequalities that exist.

Analysis and Discussion

When considering the impact that technological momentum has had on the growth of the space industry, both public and private, and both past and present, it is important to look at the challenges that this high-caliber growth is providing–not only the challenges pertaining to the global economy and space as a whole, but also the legal challenges that are going to come about as well. Currently, the five major pieces of space legislation are not nearly sufficient enough to govern space use today, due to the wide variety of private companies and challenges associated with regulating orbits and dealing with collisions. More policy needs to be created to deal with a domain that is becoming more privately run each year. However, some of the shortcomings result from the inherent nature of private companies. These entities are kept private because they are more focused on their research and development efforts, and do not face responsibility to stakeholders and external forces. Instead, they move and operate at the discretion of directors and align themselves to where they want investment from. For that reason, private companies often prioritize profit in the short run, to be competitive. This is the case even when their products/data may be more valuable to the public. In contrast, public companies operate and develop ideas to spread them to the public faster (Corrado et al., 2023). This is the reality seen with space

companies in the present day: NASA is funded by the government and therefore operates in line with what the government necessitates, and has less freedom to pursue tasks because they have to get approved by the government. On the other hand, companies like SpaceX can operate without approval, as they are privately funded, and can operate as their board sees fit. The lack of approval and legal hurdles required allows them to develop and innovate faster than public companies. This momentum that allows private companies to continue innovating and bring in profit is what has gained them multiple lucrative contracts.

It stems from this idea that one of the most important needs for space policy in the future is to uncover how private companies can be incentivized to still undergo research and development and continue innovating. Instead of operating with profit as the primary purpose, however, the production and diffusion of information related to space technology developments should be paramount. This way, the entire industry can grow as a whole (Corrado et al., 2023). There is also a potential counter argument for this, where prioritizing the dissemination of findings will not promote innovation, as there is less competition overall. Policy makers will have to consider the nature of competition as well. New legislation must ensure that competition is still spurring innovation, while industry leaders are not monopolizing their creations. By studying how competitive behavior has implications in outer space and its resources, policy makers can make more informed decisions.

The next important need for future legislation is to understand the best way to allocate resources in space. This topic is precarious because misallocating orbital space will lead to more debris and collisions, hindering the viability of future space missions (Corrado et al., 2023). To go about this, more research needs to be done on these large scale systems where satellite constellations range in the thousands. Occupying significant amounts of orbital space, the

operators of these massive constellations are not great in number–only a few companies have the capacity to control them. Therefore, placing too little regulation on the finite orbital resource will cause constellations to minimize cost and reduce the effort needed to continue growing the constellations and selling their services (Corrado et al., 2023). More overcrowding of orbits can be a negative result of this. The main issue with allocating resources that are not physically tied to a country or land, in this case orbits, is that there is no clear indication of who should oversee the regulation. From this, the regulations should be based on national regulations and allow countries to protect their interests and rights. Additionally, rules should be created so as to not repel new players and technologies entering the realm (Aglietti, 2020). Due to the fact that countries with historic space programs are already occupying many of the existing orbits, legislation should ensure that orbital disparities can be reduced for newer spacefaring nations.

A fine balance needs to be struck between allowing already prominent spacefaring nations and companies (public and private) to continue developing and innovating in outer space yet not discouraging new players from entering the scene and taking advantage of the capabilities of outer space technology. Additionally, regulations should not inhibit the current infrastructure and capabilities such as satellite constellations, but they should also not be too stringent so that new nations and technologies implement themselves in space readily. As there is not much prior legislation on resources that no sovereign power has physical ties to, tackling these challenges in this domain is going to be pivotal to ensure that inequalities between legacy and newer powers do not grow past repair.

Conclusion

By looking deeper into the challenges posed as a result of the technological momentum

and the growing privatization and expansion of the space industry by a few key players, many insights can be gained as to how to shape future legislation. Through balancing various needs and promoting economic growth while allowing for new parties to make an appearance, outer space use can be managed effectively so that all of humanity can continue benefiting from technologies such as communications, agriculture, and weather. Through key legislation that focuses on certain policies outlined in this paper, the "second" space race taking place in modern times can be molded to not only ensure safe and responsible use, but controlled, shared use of a vital resource.

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