Across the Universe:
Commercial Space Companies and International Cooperation

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Abstract

The space industry has grown exponentially since the end of the Cold War, and with it, the quantity and quality of commercial space companies. While past space enterprises were undertaken by national governments through joint and individual efforts, commercial space have permeated the industry. In this study, I research whether these commercial companies influence international cooperation in space, hypothesizing that increases in commercial space revenue will lead to fewer positive negotiations over space law. To research this, I analyzed changes in international legislation sentiment (hand coded to reflect sentiment towards international cooperation), dependent upon several variables to measure commercial revenue, including national space budgets, commercial infrastructure and support, commercial space products and services, launch attempts, and military expenditure. I included controls for international cooperation changes due to other causes via proxy variables, aggregate trade per capita and intergovernmental organization membership. The results found that commercial infrastructure and support industries often had a positive relationship with international cooperation, providing evidence against my hypothesis. This provides a foundational insight into the role of commercial space companies in international cooperation and the positive role that they may play.

Introduction

After the United States won the Space Race against the Soviet Union, space innovation rapidly became a distinctive trait in American culture. This innovation eventually led to an entire industry, with the United States becoming home to nearly 5,600 space-focused companies (out of almost 10,000 globally).[1] Big names include Boeing, United Launch Alliance, and Blue Origin. As of November 2024, SpaceX, a private space company owned by billionaire Elon Musk, has successfully launched a Falcon 9 rocket one-hundred and fifteen times, with sixteen launches planned for the rest of the year. While the U.S. is a significant actor in the space industry, commercial space companies are growing internationally. These include groups such as Arianespace (France), Airbus (France) Thales Alenia Space (France/Italy), iSpace (Japan), and Magellan Aerospace (Canada).

With the introduction of these new players, however, comes a new problem. Although national governments frequently contract commercial companies for missions, these companies have the capability to conduct launches independently. Commercial launches have changed the landscape of the space industry, with only six percent of satellite launches being conducted by the civil government (ninety percent being commercial and the final four percent being military).[2] This is a drastic change from the beginning era of space, where most of the activity was being conducted by a national space agency.[3]

Despite the exponential increase in commercial companies, their role in diplomatic relations is a rarely studied topic, with existing research mainly noting the substantial lack of space law regulating commercial company activity. This is most likely due to the newness of the industry. Some propose legal frameworks based on similar laws (for example, maritime law). Very few explore how commercial companies have affected the role of space diplomacy in international relations. The more mainstream study of space and space law is in its relationship to the military and defense industries. Security studies scholars primarily examine how satellites, missiles, and other launched objects play a role in military conflict.

My goal was to help fill the gap in research about space by investigating how commercial space companies affect international cooperation, hypothesizing that increases in commercial

[1] John Koetsier, "Space Inc: 10,000 Companies, $4T Value ... And 52% American," *Forbes*, June 28, 2021, https://www.forbes.com/sites/johnkoetsier/2021/05/22/space-inc-10000-companies-4t-value--and-52-american/#:~:text=Elon%20Musk's%20SpaceX%20might%20get,the%20UK%2C%20which%20has%20615.

[2] Space Foundation Editorial Team, "The Space Report 2023 Q4 Shows Record Number of Launches for Third Year in a Row, Technological Firsts, and Heightened Focus on Policy."

[3] Barton, "Technology and the History of Commercial Spaceflight."

space revenue will lead to fewer positive negotiations over space law. I began by creating a foundation for my research using literature from law, economics, and philosophy to create a picture of the commercial space industry and the role of space in diplomacy. I then conducted analyses using supervised machine learning and regression analyses on datasets I constructed. I presented and analyzed the results, then discussed them within the context of current events. Finally, I considered the limitations of the tests.

Background and Existing Literature

International cooperation in the realm of space has been an ongoing effort since the Cold War. Despite the obvious rivalry between the Soviet Union and the United States, there later existed joint efforts between the two, notably through the Apollo-Soyuz mission.[4] After the war ended, cooperative efforts in space became more prominent, culminating in the creation of the International Space Station. These efforts have continued strongly to this day. However, a new actor has been introduced into the international space realm: commercial space companies. As commercial space companies increasingly participate in international space activities, their role in shaping diplomacy, legal frameworks, and economic policies has become more significant. This research aims to understand the relationship between space diplomacy and commercial space businesses. This includes examining key aspects of commercialization, such as private property rights, liability concerns, launch regulations, and governance frameworks. To do this, I approached the relationship using multiple different schools of thought. These include diplomatic efforts, current ideas on the related international laws, debates around commercialization, and finally, philosophical perspectives. All the contributing scholars and ideas in these fields provide a key foundation for understanding the commercialization of space and the relationship to international cooperation. The following provides an overview of the related literature.

Diplomatic Efforts

While diplomacy and international cooperation have long been highly studied subjects, the niche field of space diplomacy is considered far less with many of the efforts being concentrated in security studies. The concepts examined include science diplomacy and economic diplomacy. However, despite the different usage, these ideas can still be applied to space and the relative role of international cooperation.

[4] History.com Editors, "The Space Race."

Science Diplomacy

Science diplomacy is described as the use of science-based cooperation to further international relationships, often to address common problems.[5] This includes mechanisms such as the sharing of scientific research or international collaborations on projects, such as the Human Genome Project.[6] In terms of space research, there have been multiple cooperative efforts; particularly the ISS. A lesser-known example would be the International Gemini Observatory, located in Hawai'i and Cerro Pachón, Chile. With six participating countries (U.S., Canada, Chile, Brazil, Argentina, and Korea) researchers have access to two 8.1-meter telescopes.[7] Depending on the type collected, data will become available after a proprietary period of varying lengths. This is a key characteristic of science diplomacy; researchers in any of the participating countries can apply for time on Gemini, and researchers of any country can utilize the data. Another consideration of science diplomacy in space is how it affects countries with lesser space capacity. In an article researching space capacities in the Asian-Pacific, the authors describe how Japan, with greater access to space-based remote sensing, could form a diplomatic relationship with the Association of Southeast Asian Nations (ASEAN). Through this, ASEAN countries would gain access to remote sensing technology that could assists with disaster management and Japan would gain some level of normative power. Although the non-scientific benefits are open to interpretation, it's been found that scientific protectionism has considerable consequences, including slowing innovation, hurting international research capabilities, and restricting researchers' international opportunities.[8] Therefore, it is evident that science diplomacy plays a crucial role in fostering international cooperation, and that space diplomacy plays a similar role.

International Laws

One notable point that nearly everyone who researches international space cooperation agrees with is this: current legislation has fallen far behind the times. When the original five space treaties were created, they were made with the intent of dealing with international governments. Since then, however, commercial space companies have evolved far more than ever anticipated. With this new consideration of space companies, there are several gaps in international space law to be examined. As a result, experts often propose original suggestions and draw comparisons to similar regulations to address these gaps in international space law.

[5] Ruffini, "What Is Science Diplomacy?"
[6] National Human Genome Research Institute, "Human Genome Project Fact Sheet."
[7] aadamson, "About."
[8] Van Langenhove and Piaget, "Leveraging Science Diplomacy in Times of Conflict | GJIA."

Gaps in Laws

In analyzing the potential of commercial companies, scholars have noted that there is little to no regulation for this industry. Currently, there are five major treaties regarding space activities: the Outer Space Treaty (1967), the Rescue and Return Agreement (1968), the Liability Convention (1972), the Registration Convention (1975), and the Moon Agreement (1979), all of which have varying states of ratification between nations. However, these are outdated, having been written when there were only two states significantly involved.[9] This has left much uncertainty as more actors have gotten involved including non-state private entities. The only treaty that mentions private property is the Moon Treaty, which just states that no one country can own celestial bodies.[10] Because of its strict stance against private ownership, states that engage in space exploration have not ratified it. The Outer Space Treaty, the foremost of space treaties, fails to describe how ownership of extraterrestrial property is to be treated.[11] There is significant ambiguity between what the Outer Space Treaty decrees and what it's successor, the Moon Treaty decrees. Furthermore, the U.N. has not clarified things further, only suggesting that each state consider enacting laws and regulations of non-governmental space entities as they see fit.[12] There is not a universally accepted 'edge of space' (where Earth airspace ends and outer space begins); the Kármán line is widely used, but not internationally agreed upon.[13] Finally, there is not even a universal definition of a space object.[14]

This has led to legitimate problems between state and commercial actors before. One such example is the 2009 collision of an Iridium Communications (formerly Iridium Satellite) and an unused Russian satellite.[15] More recently, several of SpaceX's Starship launches have resulted explosive failure, resulting in hazards to populated areas as well as the environment.[16] With the rise in commercial companies, they pose an increasing danger to other companies, international missions, and people who happen to live near a launch site. It's clear that there is room and need in current law for more regulations.

[9] Reynolds, "International Space Law: Into the Twenty-First Century."
[10] Iliopoulos and Esteban, "Sustainable Space Exploration and Its Relevance to the Privatization of Space Ventures."
[11] Gorove, "Interpreting Article II of the Outer Space Treaty."
[12] United Nations General Assembly, "A/RES/59/115."
[13] Davalos, "International Standards in Regulating Space Travel: Clarifying Ambiguities in the Commercial Era of Outer Space."
[14] Boczek, *International Law.*
[15] Iannotta, "U.S. Satellite Destroyed in Space Collision."
[16] Hollingham, "When Rockets Go Wrong – Protecting the Environment from Catastrophe"; Wattles, "SpaceX Calls off Starship's First Flight Attempt after January Explosion of Flight 7 | CNN"; Goodwin, McFall-Johnsen, and Niemeyer, "All the Times SpaceX's Starship Has Exploded into a Giant Fireball."

Compliance and Effectiveness

Due to their nature, the outer space treaties are binding, and countries are obligated to comply with them (inasmuch as they consent to the obligations).[17] However, the ambiguity of the treaties means that compliance is far easier in this realm than others of international interest. Liability, interestingly, has become a principle of customary international law, and is now a part of liability negotiations which can be applied to states that have not ratified the related convention.[18]

Examples of Previous Laws and Regulations

Many scholars argue that future space laws and regulations should be based off the structure of similar situations. One such argument puts forth the idea of modeling the space industry using Open-Skies-Agreements, multinational agreements to allow foreign powers within sovereign airspace. Because they're negotiated by governments, they may not work for all countries. However, for those that it does, it has been shown to help commercial opportunities grow (for better or for worse).[19]

Others encourage mimicking maritime law, particularly in terms of liability. Due to the long, international history of maritime exploration, there is a considerably larger body of law to refer to. There are several treaties and agreements regarding maritime liability, including the 1976 convention on Limitation of Liability for Maritime Claims, which stemmed from the Limitation Liability Act of 1851.[20] In terms of space, there is only one regulation that discusses liability: the 1972 Space Convention on Liability, which gives absolute liability of a launched object to the state from which it's launched from, but do not consider damage involving commercial companies or damage to celestial bodies.[21] It's recommended by scholars to adapt at least a portion of maritime law, to help fill a piece of the missing chunk of law.[22]

[17] United Nations, "Understanding International Law."
[18] Davalos, "International Standards in Regulating Space Travel: Clarifying Ambiguities in the Commercial Era of Outer Space."
[19] Levers, "Star Trek, Star Wars, or Battlestar Galactica—the Occurring Privatization of Space Exploration, and the Need for 'Global' Regulations."
[20] Rogers, "The Sea of the Universe."
[21] Davalos, "International Standards in Regulating Space Travel: Clarifying Ambiguities in the Commercial Era of Outer Space."
[22] Iavicoli, "The Legal Regime of Outer Space in Light of the Law of the Sea."

Suggested Laws and Regulations

There are a multitude of regulations suggested by scholars in the field. Very few, however, recommend specific codes; most simply recommend ideologies of which to use as a guide for future regulations. One source argues for the development of space appropriation regulations based on tenets of property law, capitalism, and a strong free market approach. Under this model, space appropriation would be staked in traditional property jurisprudence (i.e. discovery, claim, and possession).[23] Others advocate for a technological approach; rather than focusing on human interactions, regulations should consider the interoperability of space-based infrastructures and technologies. Using the 1975 Apollo-Soyuz orbital docking as an example, they advocate for this model because it would help foster innovation and co-operation.[24] Finally, there is an argument for a multilateral and adaptive approach. Scholars argue that nations need to work together multilaterally in order to prevent the militarization of space caused by the privatization of space.[25] In doing so, they must also develop a framework of adaptive governance that allows the laws and regulations of space to change. These include resource information, values, environmentalism, equity, and institutions.[26]

Commercialization

Commercialization is defined as the process of bringing goods or services to the public market.[27] In the context of the space industry, commercialization has significant implications for technological advancement, economic growth, and societal progress. In the following, I explore the literature of both the advantages and disadvantages of commercializing the space industry.

Advantages

There are several considerable advantages to commercial space companies. The first and foremost is the benefit of financial efficiency. Without the bureaucratic government oversight, companies can achieve goals both faster and more affordably. Commercial companies work under a stringent risk assessment, resulting in products that are financially beneficial.[28] The United States a primary example of this. In 2018, the cost for NASA to launch 27,500 kg to low-Earth

[23] Thomas, "Privatization of Space Ventures: Proposing a Proven Regulatory Theory for Future Extraterrestral Appropriation."
[24] Stewart and Dittmer, "More-than-Human Space Diplomacy."
[25] Salin, "Privatization and Militarization in the Space Business Environment."
[26] Migaud, Greer, and Bullock, "Developing an Adaptive Space Governance Framework."
[27] Kenton, "Commercialization."
[28] Iliopoulos and Esteban, "Sustainable Space Exploration and Its Relevance to the Privatization of Space Ventures."

orbit (LEO) was about $1.5 billion. In stark comparison, SpaceX's Falcon 9 could launch 22,800 kg for a mere $62 million, a reduction by a factor of 20.[29] One possible explanation for commercial companies' ability to lower costs so significantly is market competition. Up until the recent commercialization of space, the United Launch Alliance (ULA) had a significant monopoly on the space equipment market, with customers consisting of NASA, and the U.S. military. The only goal that clients had for equipment was high reliability, regardless of the price.[30] This lack of competition led to a plateau of launch shuttle costs. With the presence of competitors however, companies are encouraged to decrease costs for themselves and the client to win contracts. In addition, market competition encourages research and development innovation, leading to faster technological growth.[31]

Another financial advantage of commercialization is that taxpayers may pay less in funding for state-sponsored space programs.[32] While organizations like NASA don't face economic incentives to lower cost, they still respond to public incentives. If the public believes that too much money is being wasted on an impractical project, government leadership may pull some portion of the funding, resulting in a lack of any programs. By subcontracting space work, governments can reduce project risks by sharing them.[33]

Disadvantages

Much of the research explored regarding the disadvantages of commercialization was done within the context of science research. One article suggests that the commercialization of scientific research from universities results in pressure on researchers. This in turn results in the possible misrepresentation of steps in the scientific research process.[34] Additionally, under a commercial model, scientists may face more demand for their time, increased secrecy, and changed research interests.[35] These factors may also harm the research process by forcing scientists to take on the role of entrepreneur, rather than just researcher. In social sciences, there are ethical concerns about worsening societal issues as a casualty.[36]

Another disadvantage of commercialization, from the perspective of technological innovation.

[29] Jones, "The Recent Large Reduction in Space Launch Cost."
[30] Jones.
[31] Cobb, *Privatizing Peace: How Commerce Can Reduce Conflict in Space.*
[32] The Economic Lowdown Podcast Series, "Fiscal Policy - The Economic Lowdown Podcast Series."
[33] Hinz Consulting, "Exploring the Benefits of Government Subcontracting."
[34] Caulfield and Ogbogu, "The Commercialization of University-Based Research: Balancing Risks and Benefits."
[35] Buenstorf, "Is Commercialization Good or Bad for Science? Individual-Level Evidence from the Max Planck Society."
[36] Komp, "The Commercialization of Sociological Research: On the How and Why (Not)."

Before technological capabilities develop, they often are forced to depend on and cooperate with other countries in order to maintain technological standards. However, as their capabilities increase, both statewide and commercially, they become more self-sufficient and begin to prioritize international cooperation less.[37] This phenomenon has happened before; in military cooperation between Germany and the Soviet Union post-World War I, and in liberal democratic states that accept Chinese investment and technology.[38] While commercialization may be good for international cooperation initially, it may run the risk of devolving into competition.

Non-U.S. Commercialization

While the U.S. is the main champion of private space companies, other countries are beginning to see the creation of private space companies as well. China, a notable rival of the United States, has been encouraging the growth of private space companies by allowing them to participate in the space industry (previously, there were only two significant space companies, state-owned China Aerospace Science and Industry Corporation (CASIC) and China Aerospace Science and Technology Corporation (CASTC) with a handful of private firms being allowed to function)[39]. As of 2021, over 100 private space companies have been created.[40] Additionally, the aerospace and commercial industries are projected to be worth more than $900 billion (USD) by 2029.[41] Alternatively, Russia, America's competitor during the Space Race, has stalled out in terms of space program progress, with any research and equipment being utilized for their ongoing war with Ukraine.[42] Prior to the February 2022 invasion, they had been making progress towards designing and building a new space station alternative to the International Space Station.[43]

There are also many countries with increasing space industries. Japan, for example, has a handful of private space companies supported by government funding.[44] While traditional firms like Mitsubishi Heavy Industries have traditionally dominated the Japanese space industry, new private firms, such as iSpace and Astroscale are beginning to appear in the market.[45] India has

[37] Zúñiga et al., "The Geopolitics of Technology Standards."
[38] Center and Bates, "Tech-Politik."
[39] Patel, "China's Surging Private Space Industry Is out to Challenge the US"; Nie, "Space Privatization in China's National Strategy of Military-Civilian Integration: An Appraisal of Critical Legal Challenges."
[40] Adriaensen et al., "Priorities in National Space Strategies and Governance of the Member States of the European Space Agency."
[41] Interesse, "China's Space Economy."
[42] Levers, "Star Trek, Star Wars, or Battlestar Galactica—the Occurring Privatization of Space Exploration, and the Need for 'Global' Regulations."
[43] Luzin, "Russia's Space Program After 2024."
[44] Hobbs, "Nation in Review."
[45] Borowitz, "Global Workforce Growth Shows Annual Overall Gains."

experienced a similar increase in private firms, becoming home to almost 400 space businesses.[46] National governments are also planning to form partnerships in future commercial companies; South Korea's Korea Aerospace Research Institute (KARI) and Korea Advanced Institute of Science & Technology (KAIST) have created a contract with companies to use government satellite assets.[47]

Philosophical Perspectives

There are many philosophical lenses to consider in the commercialization of the space industry, but the most important to my research are environmentalism and equity.

Environmentalism

Unlike space diplomacy, there has been more prior research on this topic. 'Astro environmentalism', an idea that combines environmentalist ideals to space exploration, is not a new concept.[48] It takes multiple physical concerns into consideration: celestial body conservation (other planets, the moon, etc.), potential extraterrestrial contamination, atmospheric pollution, greenhouse gas emission from launch exhaust, and ozone depletion from high temperature launch and re-entry events.[49] In addition, there are ethical considerations that note the protection of alien life, equity in space exploration (countries with the resources are crowding space with mega-constellations, such as Space-X's Starlink), and the prevention of international conflict over private property.[50] Most scholars agree that environmental protections should be factored into future international agreements. Some offer solutions, such as granting celestial bodies juridical rights (environmental personhood).[51] Others believe that the solution lies in the economy, arguing for a circular economy approach to the space industry.[52] In terms of commercialism, it's likely that commercial companies may not prioritize environmental safety and concerns, choosing instead to prioritize profit.[53] This may lead to significant effects of the aforementioned physical concerns, including increasing space debris, atmospheric pollution, and overcrowding. Regardless of differing approaches to solving this issue, almost all scholars agree that it is imperative that environmentalism plays a significant role in space law.

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[46] Borowitz.
[47] Hobbs, "2022 TSRQ1 - Nation in Review."
[48] Miller, "Astroenvironmentalism."
[49] Goldstein, "The Environmental Impacts of the New Space Race."
[50] Marino and Cheney, "Centring Environmentalism in Space Governance."
[51] Altabef, "The Legal Man in the Moon: Exploring Environmental Personhood for Celestial Bodies."
[52] Jah, "Space Environmentalism - Toward a Circular Economy Approach for Orbital Space."
[53] Axelrod, "Corporate Honesty and Climate Change."

Equity

Another major concern in the growing space industry is equity, particularly regarding access to space and the distribution of its benefits. As space exploration (and exploitation) become increasingly dominated by wealthy states and commercial corporations, the benefits of space activities become disproportionately concentrated. This raises concerns about the equitable use of space resources, as low-income and developing nations are often left out of the decision-making processes and technological advancements. For example, countries like the United States, China, and Russia dominate the space industry, while smaller nations struggle to gain access to critical space-based technologies such as satellite communications and Earth observation services.[54] Without comprehensive space legislation, the growing divide between space nations and others, reinforcing global inequalities and limiting opportunities for the wider international community to benefit from space exploration.

Research Design

My research aims to determine what effect, if any, the commercialization of space has had on international cooperation. My hypothesis is the following:

> H_1: Increases in commercial space revenue will lead to fewer positive negotiations over space law.

In this, I defined "positive negotiations" as space legislation being created with an outcome that fosters international cooperation in space, rather than competition. I theorized that as national space agencies lose influence (due to reduced funding or weaker presence in space) and commercial companies gain influence, positive international space cooperation will decline. First, companies cannot directly negotiate international law. Second, as companies gain a significant foothold in the space industry, states may feel less incentive to create and ratify positive space legislation.[55] This is because as countries increase their space capabilities, they look to prioritize their national interests over international cooperation.[56] Finally, as commercial revenue increases, national space agencies would lose power, and international cooperation (through government entities) would decrease. I interchangeably refer to positive negotiations as 'positive cooperation'.

[54] Finch, "How Activity in Outer Space Will Affect Regional Inequalities in the Future"; Tepper, "Space Commercialization Is Closing the Digital Divide, but Expanding Global Economic Inequality."
[55] Durkee, "The Business of Treaties."
[56] Zúñiga et al., "The Geopolitics of Technology Standards."

To investigate this, I created two main datasets: one consisting of agreements concerning space, and the other consisting of predictors of international cooperation and commercialization. The space agreements are the measure of international space sentiment, the text of which may tilt towards cooperation or commercialization. The variables are measures of commercialization, as well as several proxies for state behavior. To analyze these, I divided six countries with clearly different types of space behavior into three different categories: cooperative (Italy, France), pro-commercial (United States, Japan), and military (Russia, China). I presented the initial descriptive statistics and then the regression results for an international model, and then each case study.

Data

To begin, I collected a list of international and domestic legislation and recommendations concerning space. First, I constructed a dataset of forty-three pieces of legislation (found via the United Nations Office for Outer Space Affairs database)[57] to train a logistic regression supervised machine learning model on. This consists of space legislation from Japan, Canada, the United States, and the five space treaties (the Outer Space Treaty, the Liability Convention, the Rescue Agreement, the Moon Treaty, and the Registration Convention)[58]; each one was manually coded as positive towards international cooperation (1) or not positive/negative (0). My criteria for coding these was whether they were featured strong statements of positive feelings towards working with other countries (cooperation, 1) or whether they focused on supporting domestic space efforts, often through commercialization. Each line of data consisted of the year of legislation, country of origin, title, text, and sentiment score. I also created another dataset, made of exclusively international space agreements and recommendations originating from the United Nations, to use as my response variable.[59] This consisted of the same components, but with an empty score column. This is my dependent variable, to be used to measure international cooperation. While some would believe that international agreements are inherently cooperative, I argued that while they may be technically cooperative, they must also be substantively cooperative; that is, the actual text of the document must have a stance of some kind, which dictates whether the agreement is cooperative or pro-commercial. This is why I'm using these documents as my measure of international cooperation. They may be interchangeably referred to as treaties, agreements, or legislation throughout the rest of this paper.

[57]United Nations Office for Outer Space Affairs, "ASTRO National Space Law Database."
[58]See Appendix 1A
[59]See Appendix 1B

I chose to utilize supervised machine learning to analyze legislation this way. First, I wanted to ensure that my grading of legislation was consistent throughout all of the legislation and avoid any false results stemming from inconsistent grading. Second, my original method of grading legislation (word scores) was not comprehensive enough to capture the nuances of the legislation (i.e. homographs and homophones, such as United [Nations] vs united [as one], or object [noun] vs object [verb]). Supervised machine learning would be able to detect the nuanced patterns in legislative text that ordinary text analysis would be unable to.

To create my second main dataset, I combined data from The Space Foundation's "Space Report". I used the individual datasets "Launch Attempts by Category, 2014-2023"[60] and "Global space activity by category, 2005-2023"[61] as measures of space activity. Finally, I used a dataset from the World Bank of countries' military expenditures as a measure of government military activity and state behavior. These variables were used as independent predictors of space commercialization. The variables 'U.S. Government Space Budgets' and 'Non-U.S. Government Space Budgets' were used as a measure of government spending on space. In country-specific models, these were both replaced by a single measure of that state's national space budget. The variables 'Commercial Infrastructure and Support' and 'Commercial Space Products and Services' were both used as measures of commercial revenue, stemming from different areas of commercial space businesses. I used these variables in all the models because the data was captured internationally. I originally included three sets of launch attempts (commercial, civil, and military) as another measure of waning government and commercial power but later used only the commercial launch variable.

Independent Variables	
U.S. Government Space Budgets	How much the United States government (civil and military) spent on space infrastructure, research, etc.
Non-U.S. Government Space Budgets	How much governments (civil and military) outside the U.S. spent on space infrastructure, research, etc.

[60] Roeder, "Led by Sharp Uptick in Commercial Demand and U.S. Space Launches, All-Time Records Topple for Attempts and Successful Space Flights in 2023."
[61] Hobbs, "Global Space Economy Steadily Grows to $570 Billion."

Independent Variables	
Commercial Infrastructure and Support	Revenue generated by products and services from the private sector to support development, launch, and successful operation of commercial space assets. This includes ground stations and equipment, insurance, space situational awareness products and services, on-orbit servicing, and commercial human spaceflight revenues.
Commercial Space Products and Services	Revenue generated by satellites and other products to provide services for people on Earth (i.e. navigation systems, satellite imagery and data, television and radio systems, broadband connections).
Civil Government Launch Attempts	Orbital launch attempts (successful and failed) executed by civil governments internationally.
Military Launch Attempts	Orbital launch attempts (successful and failed) executed by militaries internationally.
Commercial Launch Attempts	Orbital launch attempts (successful and failed) executed by commercial companies internationally.
Military Expenditures	Percent of GDP that countries spend on military expenditures, including peacekeeping forces, defense ministries, paramilitary forces, military space activities, etc. Data collected for each of the six countries.

I also used the Cross-National Time-Series (CNTS) archive as an additional measure of international cooperation to be used as a control.[62] I isolated the top five contributors to the

[62] Banks and Wilson, "Cross-National Time-Series Data (CNTS)."

European Space Agency (France, Germany, Italy, Belgium, the United Kingdom),[63] as well as the United States, the USSR/Russian Federation, China, Japan, and South Korea. I used the annual aggregate trade (total imports/exports per capita, normalized via population) of these countries per year as a proxy for the general state of international cooperation each year in the overall international model. I used the same formula for each of my six case study countries. Additionally, I utilized the Correlates of War International Organization dataset as another control to show the state of diplomacy of any given country in my individual models.[64] Finally, I narrowed the dataset to the years 1963-2023 to include as many observations (years) as possible. The observations of interests for all models were years, but for the categorical models, it was years for a particular country, whereas the international model was years for all countries.

Control Variables	
International Trade	Total imports and exports per capita for each country
IGO Membership	Contains a list of every intergovernmental organization (that has at least three members) and whether a state has membership in it.

Methods

In terms of the qualitative data, I began by pre-processing the data for both sets, which included transforming all words to lowercase, removing punctuation, removing stop words, and stemming. I then partitioned the first dataset (referred to as the 'testing' set) via an 75/25 split. Given the high number of features and the relatively low number of samples, I trained the model using repeated cross-validation and up sampling. This resulted in a model with an accuracy statistic of 0.59, which I then used on the second dataset (referred to as the 'actual' set). The resulting prediction (probability of a treaty being 0 (not positive/negative or 1 (positive)) I then used as the quantitative variable for international space agreements. To fill in a dataset from 1963-2023 when legislation is not created every year, I took the score of the previous year of legislation as the score for each year following until new legislation.

[63] ESA, "Funding."
[64] Pevehouse et al., "Intergovernmental Organizations (v3) – Correlates of War."

Because of the limited timeframe of each quantitative dataset, I chose to backfill the data to 1963. I used an exponential backfill (at a 0.05 rate) due to the exponential growth that each variable shows in the timeframe it's available for. While the model doesn't necessarily capture some of the specific nuances of the data (particular increases or decreases per year), it does capture the general growth that has occurred in the space industry since the Space Race.[65] To backfill the "US Government Space Budget" variable from the "Global space activity . . ." dataset, I used a linear regression model with complete data of NASA's budget from 1959-2021.[66]

Figure 1: Space budgets before and after exponential back fill

(a) (b)

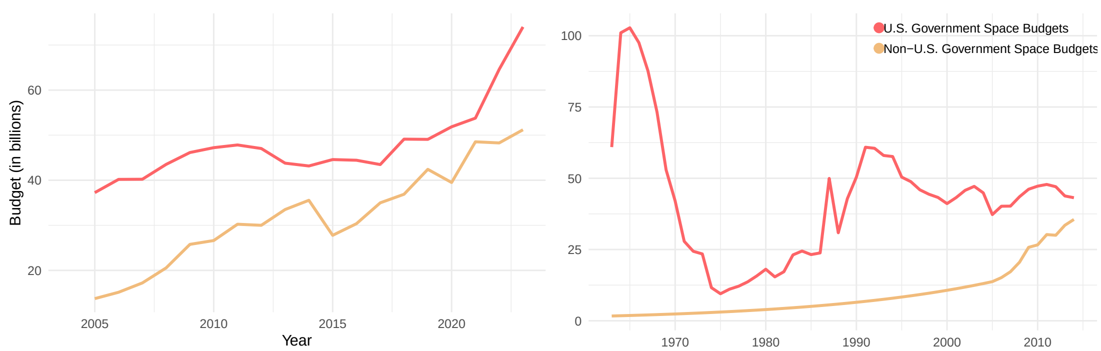
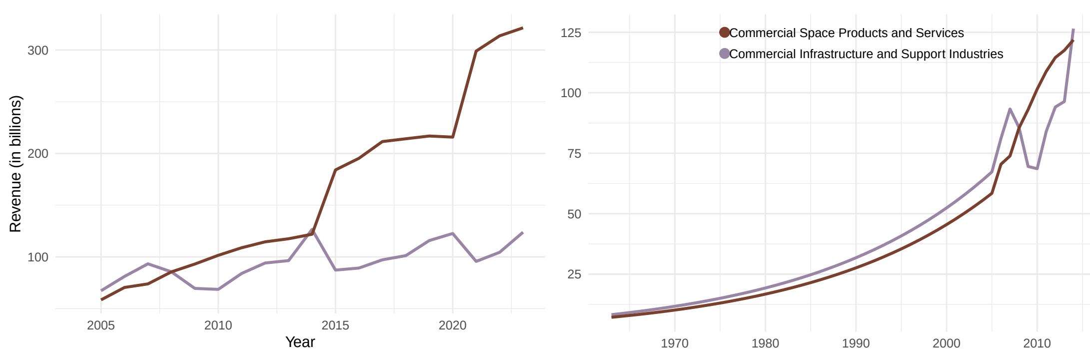


Figure 2: Commercial Revenue before and after exponential back fill

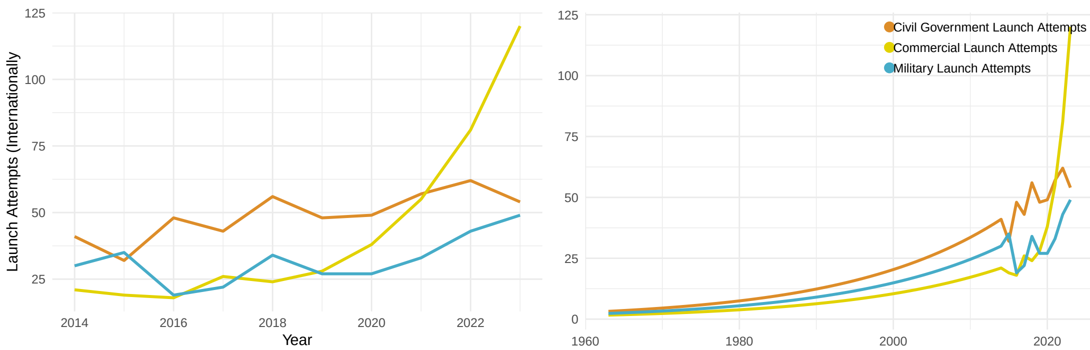
(a) (b)



[65] Corrado, Cropper, and Rao, "Space Exploration and Economic Growth."
[66] The Space Report, "NASA Budget, 1959-2021."

Figure 3: Launch attempts before and after exponential back fill

(a) (b)



One limitation of this method to induce values into the data are that it may introduce assumptions (such as sudden policy shifts resulting in unexpected changes in values) or regression overfitting. However, in this situation, this was the best method to produce a robust model and comprehensive analysis using small and incomplete datasets. It matches the general trend of growth occurring in the space industry; without the added values, the model would have been too sparse to capture meaningful patterns or trends, limiting the ability to draw reliable conclusions about the relationship between commercial space activity and international cooperation. In addition, I ran the models without the imputed data, and while they were siginificantly weaker, they possessed the important characters of the backfilled models (significance, direction), indicating that the results were accurate.

Using this new dataset, I utilized linear regression. First, I created a model on an international scale, using the international legislation data as my dependent variable, and the following as predictors: U.S. government space budgets, non-U.S. government space budgets, commercial infrastructure and support industries, commercial space products and services, civil government launch attempts, commercial launch attempts and military launch attempts. In this model, I included the U.S. government space budget and non-U.S. government space budgets due to the considerable role the U.S. plays in the past and present space industry.[67]

To analyze the international effects further, I considered six case studies, divided into three categories by their behavior in and with the space industry. The intent of these was to determine whether international cooperation is affected by a state's space industry behavior, or whether the international effects are a genuinely international phenomenon. The first category I describe

[67] Chatzky, Siripurapu, and Markovich, "Space Exploration and U.S. Competitiveness."

as cooperative states: France and Italy. While both have their own individual space agency (Centre National d'Etudes Spatiales and Agenzia Spaziale Italiana), each country contributes considerably to the European Space Agency (ESA), an intergovernmental space agency consisting of twenty-three members. France and Italy were chosen specifically because they are the two highest contributors to the ESA budget.[68] Additionally, a significant number of projects and activities conducted by France and Italy are in cooperation with the ESA.[69] Finally, both countries have a relatively small body of law, generally working under EU laws and national aviation regulations.[70] Similar to the international model, I used the legislation data as the dependent variable, and France/Italy's space budget, commercial infrastructure and support industries, commercial space products and services, civil government launch attempts, commercial launch attempts, military launch attempts, military expenditure (as a percent of the overall country GDP), total trade per capita (specific to France and Italy individually), and membership in intergovernmental organizations. I included variables from the international model because they were measured internationally, and capture data from every country available. I used military expenditure as a measure of state behavior, and trade and IGO membership as controls.

My next category were pro-commercialization countries, which are the United States and Japan. These countries have both a relatively strong commercial space industry, as well as governments that support them. For example, in a memo from the U.S. Department of Commerce, they advocate for the U.S. to remain the leader in space commerce.[71] The U.S. also has created multiple laws governing the growing commercial industry, including the Commercial Space Act of 2023 and Commercial Space Launch Competitiveness Act. Japan has also become a leader in the space industry. With support from Japan's space agency, JAXA, commercial companies like iSpace and Interstellar Technologies have become substantial entities in the commercial space industry. Japan also has legislation for commercial space companies (Act on the Promotion of Business Activities Related to the Exploration and Development of Space Resources (the Space Resources Act)).[72] For analysis, I used the same model as the cooperative states but tailored to the U.S. and Japan.

My final category of countries is those with a military/defense focus in the space industry,

[68] ESA, "Funding."

[69] ESA, "ESA and CNES Collaborate towards a European Space Transportation Hub"; ESA, "Agenzia Spaziale Italiana (ASI)."

[70] Mikalef, "A General Introduction to Space Law in France"; Théard-Jallu et al., "Space Law 2024 - France"; Iaboni, "A Brief Outlook on the Announced Comprehensive National Law Regulating Space Activities in Italy"; Iaboni.

[71] U.S. Department of Commerce, "Space Commerce."

[72] Okubo et al., "Space Law 2024 - Japan."

which are Russia and China. Prior to the 2022 invasion of Ukraine, Russia had a fledgling commercial space industry, with a few companies possessing launch capabilities.[73] However, after the invasion and throughout the ongoing war, government support of commercial companies has been redirected towards the defense industry. In addition, commercial capabilities have been diminished due to international sanctions.[74] Russia has a few laws pertaining to space, but the most notable one is an act that establishes their space agency, Roscosmos. Additional laws generally describe what is within Roscosmos's purview. Somewhat similarly, China does not have any space laws, but does have two regulations pertaining to the launching and registration of space objects.[75] There are Chinese commercial space companies, but a good portion of the Chinese space industry is focused on cyber and information warfare capabilities (particularly since the election of Xi Jinping).[76] I analyzed these two states using the previous model for the other categories. All of this work was done using R.

Results

While my research cannot conclusively prove a causal relationship, there were some correlational relationships to note. A recurring pattern throughout my models was that few of my included variables had a statistical significance. For the international model, there were two significant predictors of international space cooperation. The cooperative model included three significant predictors. Within the commercial model, the United States was an outlier with seven significant variables, but Japan remained consistent with two. From the military model, Russia possessed four significant variables, and China had two.

International Model

Figures 4 and 5 display the results of the international regression model. In it, commercial infrastructure and support industries as well as non-U.S. government space budgets both have a statistically significant relationship on international cooperation. Commercial infrastructure and support industries show a marginally positive relationship with international cooperation (0.02), whereas non-U.S. government space budgets have a similarly small negative relationship (-0.07). Both variables were significant at the $p<0.05$ level. When adding a control for total

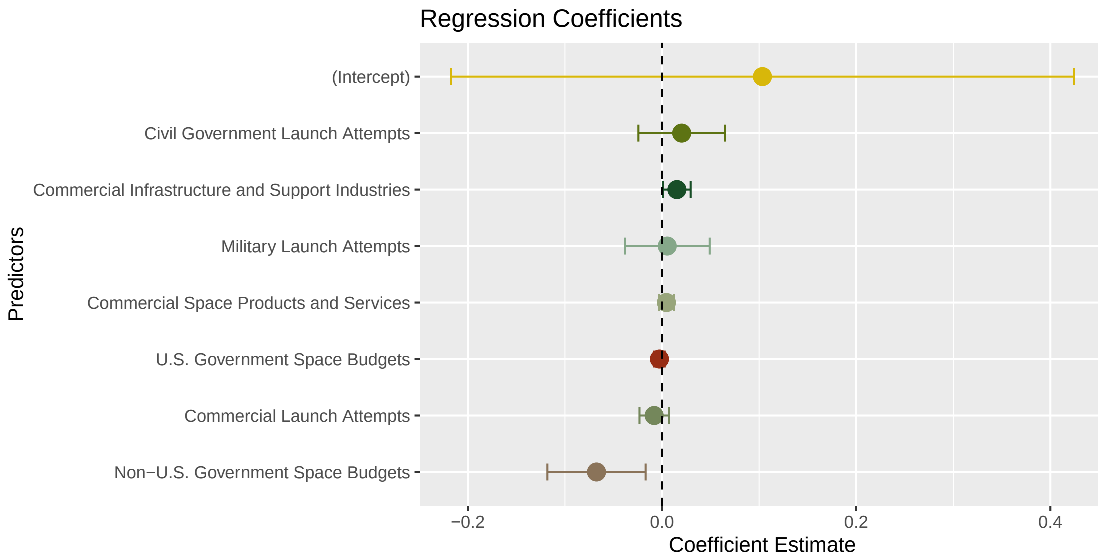
[73] CNBCTV18, "A Look at Countries with Commercial Space Missions and Their Private Players."
[74] Grunert, "Sanctions and Satellites."
[75] Tronchetti, "Space Law and China."
[76] Jones and Palmer, "China Outpacing U.S. Defense Industrial Base"; Ding and Tang, "Xi Jinping Has Further Boosted the Military-Industrial Group of China"; Husain, "China's Fast Growing Military Space Capabilities"; Cheng, "China and Space."

Figure 4: International Regression Model

	log_preds	
Predictors	Estimates	p
(Intercept)	0.10	0.521
USGovernment Space Budgets	-0.00	0.323
Commercial Infrastructure and Support Industries	0.02	**0.034**
NonUS Government Space Budgets	-0.07	**0.010**
Commercial Space Products and Services	0.00	0.239
Civil Government Launch Attempts	0.02	0.367
Commercial Launch Attempts	-0.01	0.288
Military Launch Attempts	0.01	0.807
Observations	61	
R^2 / R^2 adjusted	0.381 / 0.299	

	log_preds	
Predictors	Estimates	p
(Intercept)	0.07	0.669
USGovernment Space Budgets	-0.00	0.308
Commercial Infrastructure and Support Industries	0.02	**0.027**
NonUS Government Space Budgets	-0.07	**0.008**
Commercial Space Products and Services	0.00	0.454
Civil Government Launch Attempts	0.03	0.253
Commercial Launch Attempts	-0.01	0.152
Military Launch Attempts	0.02	0.443
total trade per capita	-0.05	0.321
Observations	61	
R^2 / R^2 adjusted	0.393 / 0.300	

Figure 5: International Regression Plot



international trade, the results are very similar, suggesting that it doesn't have a significant effect on the model. The remainder of the variables were statistically insignificant. The model had an R^2 value of 0.39 which indicates that only 39 percent of variance in the model is explained by the variables. The model also had an F-statistic of 4.207 (unlikely that observed differences are due to chance) and p-value of 0.0006116 (statistically significant), indicating that this model is a relatively strong fit.

Cooperative Model

Figures 7, 8, 9, and 10 display the results of the regression analysis for France and Italy, the two cooperative states. France did not possess any significant variables, but the model was marginally significant ($R^2 = 0.34$, $F = 3.312$, p-value = 0.006429). This indicates that none of the included variables have a significant relationship with international space cooperation. The Italy model shows three statistically significant values: the intercept, commercial infrastructure and support industries, and IGO membership. The intercept predicted a baseline negative value (-3.15), and commercial infrastructure and support industries predicted a small positive relationship (0.02) with international cooperation. IGO membership had a similar relationship, with a coefficient of 0.03. These were all significant at the $p<0.05$ level. In addition, the model was significant: $R^2 = 0.4266$, $F = 4.676$, p-value = 0.0005526.

Figure 6: France Regression Model

	log_preds	
Predictors	Estimates	p
(Intercept)	-2.26	0.275
France Budget	0.26	0.845
Commercial Infrastructure and Support Industries	0.02	0.171
Commercial Space Products and Services	-0.03	0.138
Commercial Launch Attempts	0.12	0.465
france total per capita	-0.02	0.620
france Military Expenditure	0.20	0.375
france igo	0.01	0.220
Observations	52	
R^2 / R^2 adjusted	0.345 / 0.241	

* p<0.05   ** p<0.01   *** p<0.001

Figure 7: France Regression Plot

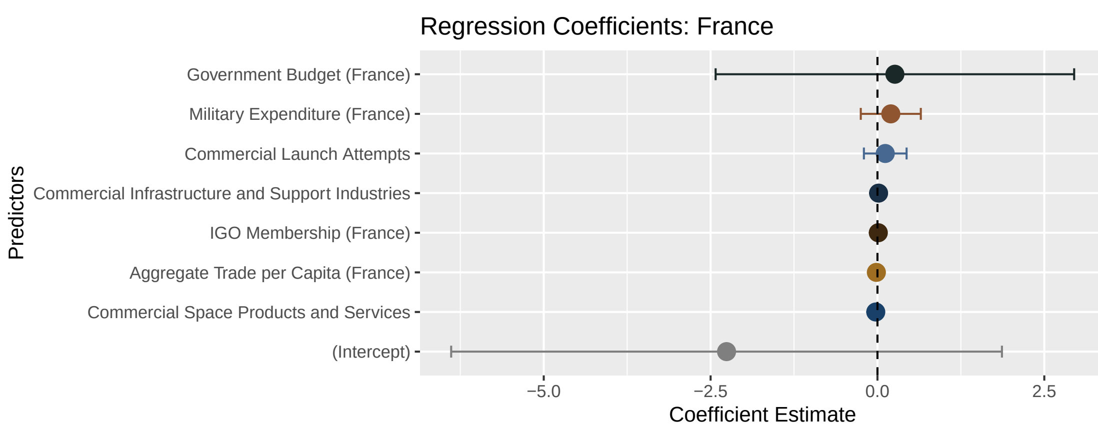
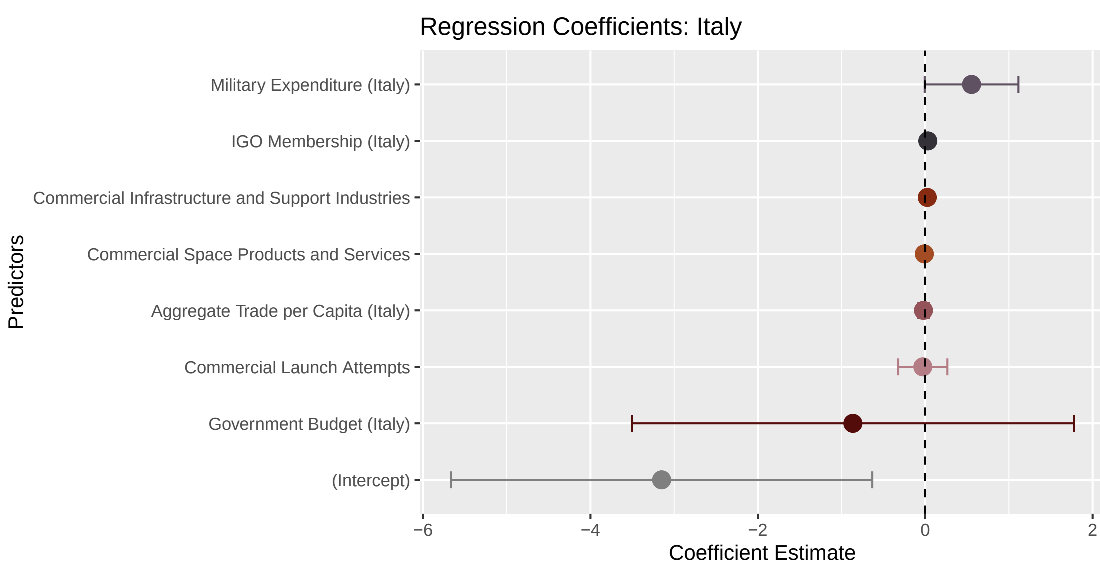


Figure 8: Italy Regression Model

	log_preds	
Predictors	Estimates	p
(Intercept)	-3.15 *	**0.015**
Italy Budget	-0.86	0.513
Commercial Infrastructure and Support Industries	0.02 *	**0.038**
Commercial Space Products and Services	-0.01	0.485
Commercial Launch Attempts	-0.03	0.846
italy total per capita	-0.02	0.521
italy Military Expenditure	0.55	0.052
italy igo	0.03 *	**0.014**
Observations	52	
R^2 / R^2 adjusted	0.427 / 0.335	

* p<0.05   ** p<0.01   *** p<0.001

Figure 9: Italy Regression Plot



Commercial Model

Figures 11, 12, 13, and 14 show the results of the regression analysis for the commercial states, the United States and Japan. For the U.S. model, all the predictors (except total per capita trade) as well as the intercept were statistically significant. The intercept predicts baseline international cooperation being negative (-5.01). U.S. government space budgets and commercial space products and services both predict negative relationships with international cooperation, at estimates of -0.01 and -0.06 respectively. Commercial infrastructure and support industries, commercial launch attempts, military expenditure, and IGO membership all predicted positive relationships with international cooperation with coefficients of 0.03, 0.36, 0.37, and 0.04 respectively. Four of the seven significant variables were significant at $p<0.001$, while the other three were significant at $p<0.05$. The R^2 for this model was 0.608, meaning that 60.8 percent of variance was explained by this model. The F-statistic for this model is 9.732 with a p-value of 0.0000002949, which is statistically significant.

Japan had one significant variable as well as the intercept. The intercept predicated a baseline negative state of international cooperation (-3.22). Military expenditure predicted a considerable positive relationship (3.89) with international cooperation. Both the variable and the intercept were significant at $p<0.05$. The R^2 for this model was 0.439, indicating that 43.9 percent of variance was explained by predictors. The F-statistic was 4.929, with a p-value of 0.0003581, meaning that the overall model was statistically significant.

Figure 10: United States Regression Model

	log_preds	
Predictors	Estimates	p
(Intercept)	-5.01 ***	**<0.001**
USGovernment Space Budgets	-0.01 ***	**<0.001**
Commercial Infrastructure and Support Industries	0.03 *	**0.017**
Commercial Space Products and Services	-0.06 ***	**<0.001**
Commercial Launch Attempts	0.36 **	**0.008**
us total per capita	-0.65	0.052
us Military Expenditure	0.37 ***	**<0.001**
us igo	0.04 **	**0.005**
Observations	52	
R^2 / R^2 adjusted	0.608 / 0.545	

* p<0.05 ** p<0.01 *** p<0.001

Figure 11: United States Regression Plot

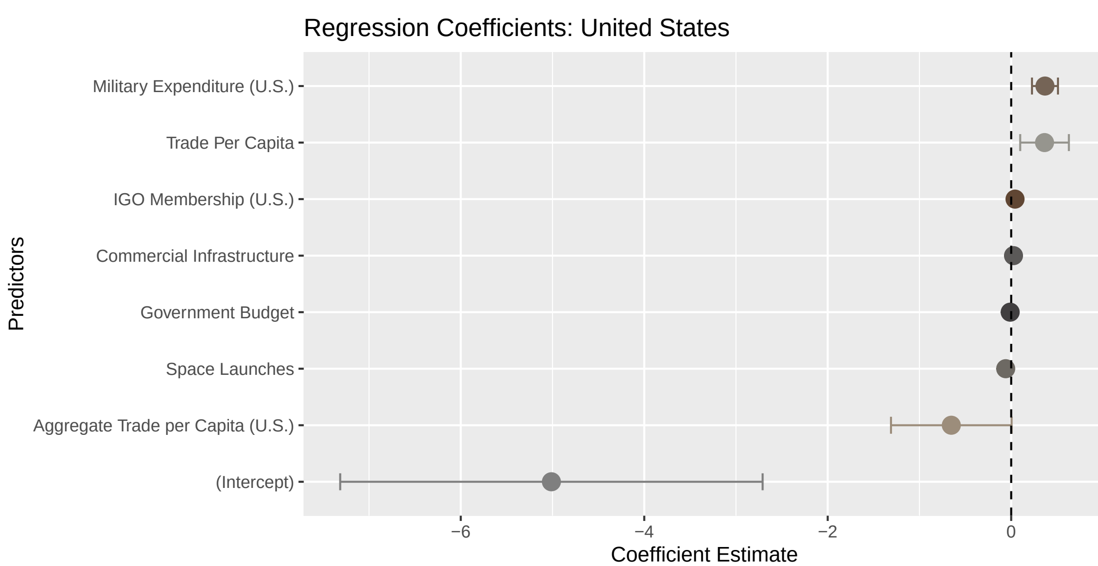
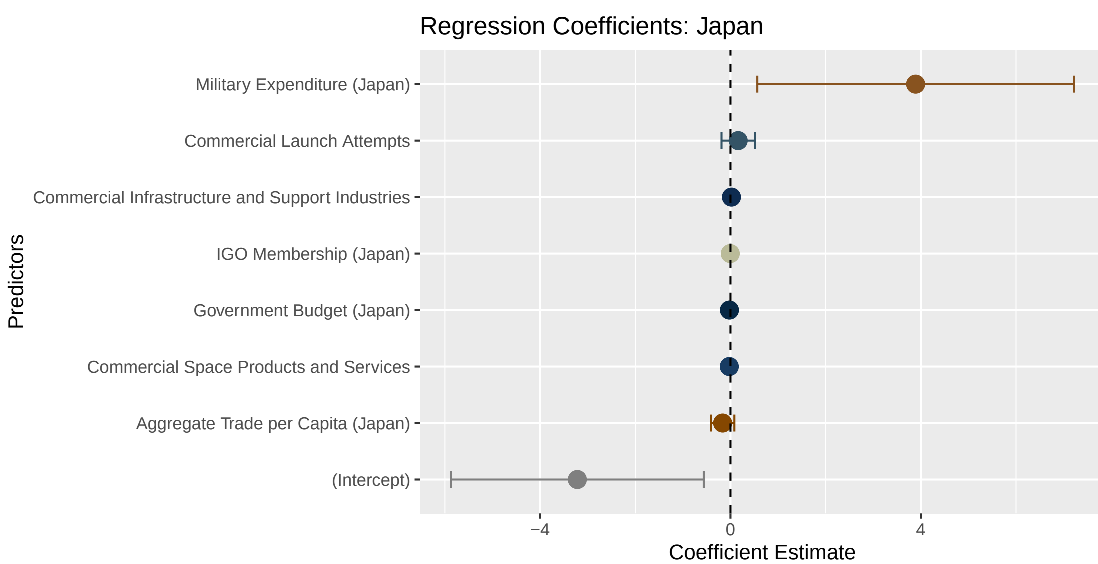


Figure 12: Japan Regression Model

	log_preds	
Predictors	Estimates	p
(Intercept)	-3.22 *	**0.019**
Japan Budget	-0.02	0.479
Commercial Infrastructure and Support Industries	0.02	0.094
Commercial Space Products and Services	-0.03	0.225
Commercial Launch Attempts	0.16	0.357
japan total per capita	-0.16	0.185
japan Military Expenditure	3.89 *	**0.023**
japan igo	-0.00	0.823
Observations	52	
R^2 / R^2 adjusted	0.439 / 0.350	

* p<0.05 ** p<0.01 *** p<0.001

Figure 13: Japan Regression Plot



Military Model

Figures 15, 16, 17, and 18 show the results of the final model, the military states. Russia displayed three significant predictors, all at *p<0.001.* Commercial space products and services predicted a small negative relationship (-0.09) with international cooperation, commercial launch attempts predicted a larger positive relationship (0.88), and Russian IGO membership predicted a small negative relationship (-0.07). The intercept was also significant (*<0.005)* and predicted a baseline positive effect. The overall model was significant, with $R^2 = 0.689$, F = 13.9, p-value = 0.00000000244.

The regression model for China resulted in only one significant value, which was military expenditure. This predicted a strongly positive relationship with international cooperation (1.39) with a significant of *p<0.005.* The intercept was also described as significant. The baseline value for international cooperation was predicted at 3.85, with a significance of *p<0.005.* The overall model was also significant: $R^2 = 0.514$, F = 6.638, p-value = 0.00002249.

Figure 14: Russia Regression Model

	log_preds	
Predictors	Estimates	p
(Intercept)	2.76 **	**0.002**
Russia Budget	0.01	0.833
Commercial Infrastructure and Support Industries	-0.01	0.522
Commercial Space Products and Services	-0.09 ***	**<0.001**
Commercial Launch Attempts	0.88 ***	**<0.001**
russian total per capita	-0.16	0.442
russia Military Expenditure	-0.28	0.083
russia igo	-0.07 ***	**<0.001**
Observations	52	
R^2 / R^2 adjusted	0.689 / 0.639	

* p<0.05 ** p<0.01 *** p<0.001

Figure 15: Russia Regression Plot

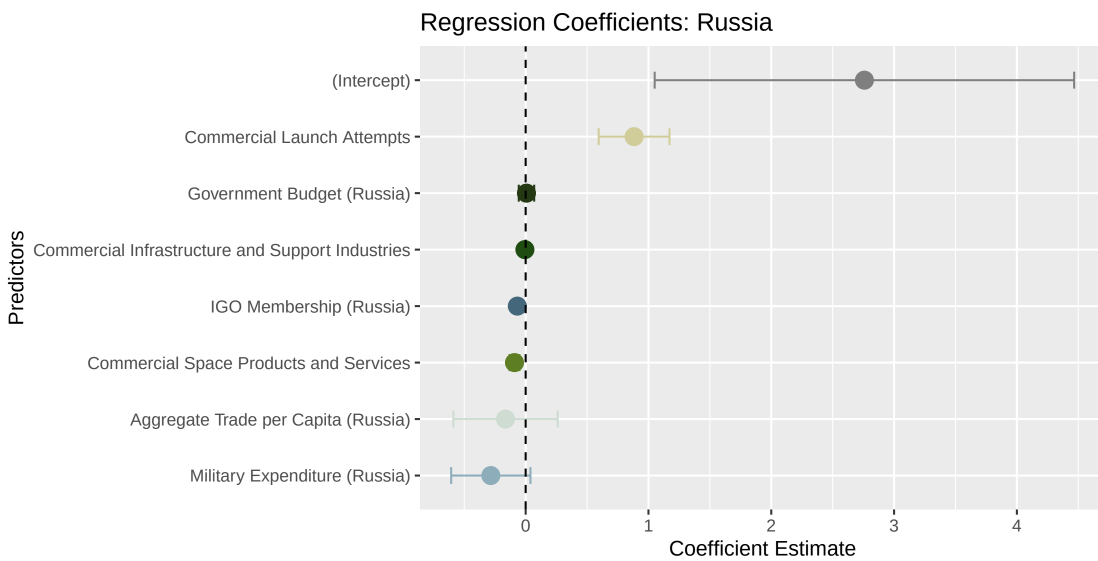
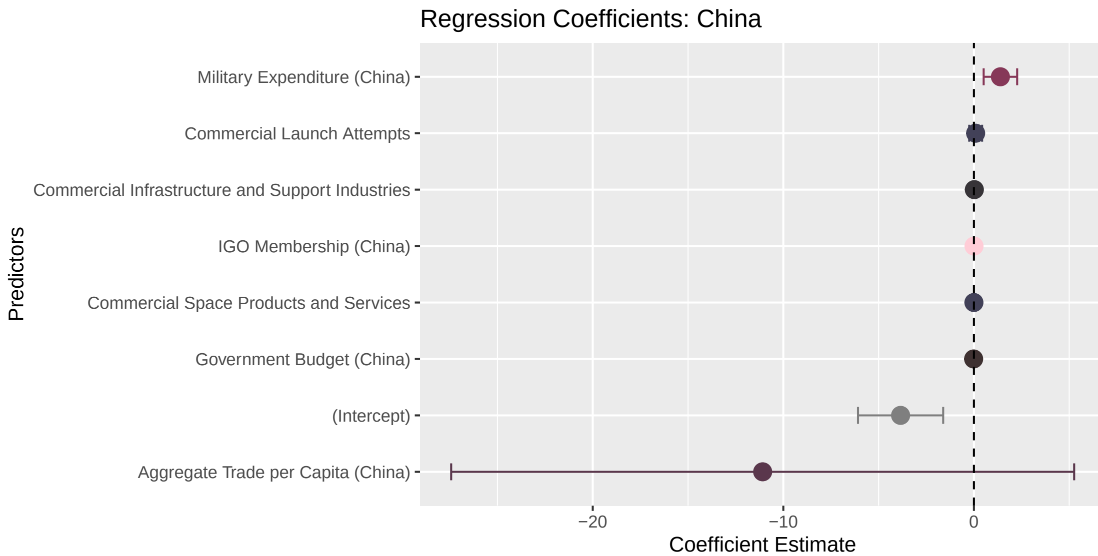


Figure 16: China Regression Model

	log_preds	
Predictors	Estimates	p
(Intercept)	-3.85 **	**0.001**
China Budget	-0.01	0.156
Commercial Infrastructure and Support Industries	0.02	0.054
Commercial Space Products and Services	-0.00	0.996
Commercial Launch Attempts	0.09	0.588
china total per capita	-11.08	0.179
china Military Expenditure	1.39 **	**0.003**
china igo	0.01	0.710
Observations	52	
R^2 / R^2 adjusted	0.514 / 0.436	

* p<0.05 ** p<0.01 *** p<0.001

Figure 17: China Regression Plot



Analysis

The purpose of this study was to investigate the effects of commercial space businesses on international space cooperation, my hypothesis being that increases in commercial space revenue will lead to fewer positive negotiations over space law. While the tests I ran do not conclusively disprove my hypothesis, there were some surprising findings within the models that do provide evidence against my hypothesis. I began with general patterns I saw in the results, and then an analysis of the results of my international model. I did not find any patterns within the individual categories but continue to analyze each categorical model for continuity and ease of comprehension.

The results of this study generally indicate the commercial infrastructure and support industries are often associated with a positive relationship with international cooperation (internationally, Italy, United States significantly). Additionally, IGO membership was generally positively associated with international cooperation, with the exception of Russia, which showed a negative relationship between the two. There was also a generally positive relationship between military expenditure (as a percent of total GDP) and international cooperation. Commercial launch attempts were significant once (United States), meaning that in the larger picture, they don't play a significant role. Finally, the intercept was often significant and negative, meaning that international cooperation starts from a negative baseline, indicating an initial predisposition against international cooperation.

International

Within the international model, commercial infrastructure and support industries showed a significant positive relationship with international cooperation and non-U.S. government budgets showed a significant negative cooperation. The first result was unexpected, the implication being that commercial revenue (of infrastructure and support) is associated with positive international cooperation over space law. This contradicts my hypothesis and theory. One possible explanation for this is that rather than intensifying international competition due to countries looking to expand their power in the industry through domestic businesses, it fostered diplomatic relations because of the universal necessity of space infrastructure.[77] I theorized that this is also a possible reason why the commercial space products and services didn't have the same significance in the models; it's possible individual products are easier to produce than the infrastructure needed to maintain them. Alternatively, infrastructure and support may have resulted in positive cooperation because of commercial actors wanting clearer legislation and thus pushing national governments towards treaty creation ratification.[78]

The second result was less unexpected, indicating that as non-U.S. space government budgets increase, international cooperation decreases. This is also possibly due to the growth of increasingly competitive space programs. Increased funding may allow countries to develop their own space capabilities, prioritizing national businesses, becoming more self-sufficient and relying less on international support. This, in turn, may lead to fewer incentives for international cooperation as countries foster their domestic growth instead.[79] As such, this provides evidence against my hypothesis. My underlying theory was that national space agencies losing influence would result in a decline in international cooperation, with the underlying assumption that the inverse was true, and that gains in influence would result in increases in international cooperation; however, the results show that this is most likely not true.

Cooperative States

The categories of states, cooperative, commercial, and military, were originally introduced to illuminate the nuances of the international model. However, there were no common patterns

[77] Alexander et al., "Build Global Partnerships in Space for Lasting Peace and Security."
[78] Stigler, "The Theory of Economic Regulation."
[79] Center and Bates, "Tech-Politik."

among the categories, which in itself may be a finding. This indicates that space behavior is not restricted by type of government, and that the international model results are caused by all kinds of states. This is significant to note because it means that interactions between commercial companies and international cooperation should be universally predictable. However, I continued to analyze the countries in the order originally presented, to preserve the continuity of the paper.

I originally predicted that France and Italy would have similar regression results due to their shared membership in the ESA, as well their lack of state space law. However, this was not true, and the two states shared zero significant variables. To begin with, France had no significant variables, which was surprising because of its role as largest contributor to the ESA. This is possibly due to an error within the model itself, because it seems that for a country with a relatively strong space industry, there would be some indication of a predilection towards positive or negative international cooperation. One explanation for this may be the limit of data availability; with the newness of commercial space companies, very little data was available prior to 2004.

The model for Italy was considerably different, demonstrating two significant variables and a significant intercept. The intercept indicates then when all else is held at zero, there is a baseline negative value of international cooperation. It's possible that this may be a result of the legislation I used as the measure of international cooperation. The second significant variable is commercial infrastructure and support industries, which shows a small positive relationship with international cooperation. This is likely due to the same reasons addressed in the international model; fostering of diplomatic relations, want for clearer legislation by commercial actors. This thus also provides evidence against my hypothesis. The final significant variable is IGO membership, which increases with international cooperation. I originally used this as a control for the general state of international cooperation. The goal was to be able to isolate the effects of commercial space as much as possible from external diplomatic issues (i.e. wars, sanctions, etc.). However, it's statistical significance implies that may play a role in international cooperation. This is not surprising; it is logical that membership in intergovernmental organizations is correlated with positive international cooperation.

Commercial States

The commercial model experienced the same issue as cooperative states in that there were no cohesive patterns across the two states. They both saw considerable positive relationships between military expenditure and international cooperation, but one significant variable is not enough to discern a pattern.

The United States model contained multiple significant variables. To begin with, the intercept was significantly negative, denoting a baseline negative state of international cooperation. Next, U.S. government space budgets was significant, with a negative relationship with international cooperation, indicating that increases in the budget result in decreases in international cooperation. This is possible due to the aforementioned theories of competition in which countries choose to nurture domestic capabilities rather than limit themselves via international law. Commercial infrastructure and support industries saw a positive relationship with international cooperation similar to that of Italy and the international model. One unexpected part of this model is that commercial space products and services have a significant negative relationship with international cooperation. I theorized that an explanation for this could be that space products and services have accelerated the shift from cooperation to competition by being easier to produce. Commercial launch attempts were positively correlated with international cooperation, indicating a positive relationship. U.S. annual total trade per capita was not significantly associated with international cooperation, but military expenditure and IGO membership were both positive significant variables. A positive correlation between military expenditure and international cooperation may be due to the positive correlation between military expenditure of a country and the military expenditure of its allies (particularly those in the same defensive alliance).[80] IGO membership can be explained the same way as Italy's positive IGO relationship with international cooperation.

The Japan model also found that military expenditure was a significant positive variable, likely for the same reasons as in the U.S. model. This suggests that higher military spending may push countries toward international cooperation, possibly to manage tensions or secure strategic partnerships. The significantly negative intercept means that, at baseline, international cooperation is low, likely due to competition in space and broader geopolitical tensions. Still, the positive effect of military spending hints that, while defense investments often signal competition, they can also drive diplomacy, especially in areas like space security and technology sharing.

[80] Flores, "Alliances as Contiguity in Spatial Models of Military Expenditures."

This model provides evidence against my model, because commercial revenue is both associated and not associated with positive international cooperation, and the budget does not show the directly proportional relationship with international cooperation that I anticipated. One of notable limitations of this model is that a lot of the data collected, while collected internationally, stems from the United States. The U.S. contributes seventy-eight percent of the global space economy, potentially explaining why so many of the variables were significant.[81]

Military States

Once again, the military model did not show any cohesive patterns. Russia saw three significant variables, and a significant intercept. However, the intercept was positive, indicating a baseline positive state of international cooperation. This, similar to the other significant intercepts, is likely due to errors within the model. Similarly to the United States model, space products and services was negatively associated with international cooperation, most likely for the same reasons. Commercial launch attempts were also positively associated with international cooperation. Unexpectedly, IGO membership was significantly negatively associated with international cooperation. This may be due to ineffectiveness of the IGO or other confounding factors behind IGOs, such as policy differences between members.[82] This provides evidence against my hypothesis because while commercial space products are negatively associated, commercial launch attempts are positively associated with international cooperation.

China had one significant variable, and a significantly positive intercept. The intercept indicates a negative baseline value of international cooperation, similar to the other states. The significant variable was military expenditure, which was positively associated with international cooperation. This is likely due to the same reason of the United States. This does not provide evidence for or against my hypothesis because none of the commercial/budget variables were significant.

Altogether, the findings of this study provide limited support for the hypothesis that commercial space revenue negatively impacts international cooperation. While some commercial indicators, such as infrastructure and support industries, were associated with increased cooperation, other variables like commercial space products and services demonstrated a negative relationship in certain cases. Additionally, the relationship between government space budgets

[81] Space Foundation Editorial Team, "Space Foundation Announces $570B Space Economy in 2023, Driven by Steady Private and Public Sector Growth."

[82] Fausett and Volgy, "Intergovernmental Organizations (IGOs) and Interstate Conflict"; Eilstrup-Sangiovanni, "What Kills International Organisations?"

and cooperation varied across states, further complicating my research. The significance of military expenditure and IGO membership in multiple models suggests that traditional geopolitical and institutional factors remain influential in shaping international space relations. Although the results were not uniformly conclusive, they underscore the complexity of the interactions between commercial actors and governmental policies. Ultimately, this study highlights the dynamic nature of the space sector and the need for investigation into the role of commercial enterprises in international space diplomacy.

Discussion

Were I to research this subject again, I would execute the analysis differently. First, I faced considerable data collection limits due to the newness of the subject and limited timeframe in which to conduct the collection and analysis. In the future, I would like to collect data on commercial space companies, and their contracts with their various national governments, both quantity and monetary value. Second, I would like to include more legislation samples. Both France and Russia have a few space laws, but I did not have the resources or skills necessary to translate them from French and Russian respectively. Another solution for this would be to grade individual paragraphs/sections from legislation and combine them into an aggregate score for a more nuanced and in-depth look at legislation sentiment. I would retain my data on national space budgets, military expenditure, and IGO membership because they were useful in my current models. However, I believe this additional data could provide a more nuanced and customized picture of the space industry and its relationship to international cooperation for each country.

There are a number of other studies that can be derived from my research. The results provided an entirely new perspective; I theorized the explanations for many of the phenomena that I found. However, there is little to no previous research done on these occurrences, leaving room for further investigation. Future studies could explore the economic and political factors that drive the relationship between commercial space activities and international cooperation. For instance, research could examine whether the costs and benefits associated with producing space infrastructure, such as ground stations and support equipment, differ significantly from those of space products like satellites and communication systems. Additionally, further investigation into how commercial space companies influence policy through lobbying or public-private partnerships could provide valuable insights.

My research provides valuable insight into how commercial space expansion shapes international cooperation, offering a novel lens to understand current geopolitical developments. As space-wealthy nations navigate environmental and equity concerns, my findings suggest that commercial infrastructure may stabilize international relations and help to encourage diplomatic engagement. This has considerable implications for future negotiations, such as those surrounding the space traffic management.[83] Additionally, the apparent correlation between military expenditures and cooperation highlights the complex relationship between national security priorities and diplomatic efforts, relevant to rising space militarization and defense alliances. By identifying these trends, my research can help policymakers anticipate challenges and opportunities in space governance, contributing to more informed decision-making in a rapidly evolving domain.

When it comes to policies and laws, my recommendation aligns with the prevailing consensus: the need for more comprehensive regulations. Strengthening regulatory frameworks for commercial space companies can help ensure they maintain their stabilizing role in international relations. However, past success does not guarantee future stability, making it crucial for commercial enterprises to remain an inclusive force in the space industry rather than a dominant or exclusionary one that renders geopolitical relationships unstable. One such example is Elon Musk's unelected, highly powerful role in the government, which has granted him increasing influence over NASA, garnering concerns about the undermining of governmental oversight and international cooperation.[84] As such, clear and comprehensive laws are necessary to ensure that commercial space companies continue to contribute to a balanced and cooperative international space environment rather than consolidating power in ways that could limit competition and governmental oversight. Additionally, it's imperative that these laws must take into account diplomatic, environmental, and equitable concerns as well as the strengths and weaknesses of commercialization in order to ensure that space remains a domain for peaceful collaboration rather than unchecked competition, while balancing innovation with responsible governance.

Conclusion

This study set out to explore the relationship between commercial space industries and international cooperation, hypothesizing that increased commercial space revenue would lead to a decline in positive negotiations over space law. However, the results did not fully support this

[83] Bhattacharjee, "Global Push for Cooperation as Space Traffic Crowds Earth Orbit."
[84] Glazer and Maidenberg, "Elon Musk's Mission to Take Over NASA—and Mars."

hypothesis. Instead, the data revealed a more complex and often contradictory relationship between commercial space activities and international cooperation. While commercial infrastructure and support industries were generally associated with positive international cooperation, other commercial variables, such as space products and services, often had a negative relationship. The significance of military expenditure and intergovernmental organization (IGO) membership further suggested that broader geopolitical factors influence space diplomacy.

These findings have important implications for current global space governance. As private companies like SpaceX continue to expand their influence, concerns over regulatory gaps and power consolidation (such as Elon Musk's increasing dominance over NASA's operations) become more pressing. Without clear legal frameworks, commercial actors could shift from being a stabilizing force to a disruptive one, prioritizing national or corporate interests over international collaboration. This underscores the need for comprehensive policies that balance innovation with accountability, ensuring that commercial space advancements support, rather than hinder, global cooperation.

Moving forward, future research should expand on these findings by incorporating more detailed data on commercial contracts, national policies, and legislative developments. Additionally, studying the economic dynamics of space industries, such as the cost-benefit differences between space products and infrastructure, could provide further insights into how commercial activities shape international negotiations. As the space industry continues to evolve, understanding these relationships will be crucial for maintaining a cooperative and sustainable approach to outer space governance.

Appendix A

Legislation used for training supervised machine learning model		
Name	*Year*	*Country*
U.S. Patents Act	1953	United States
The Outer Space Treaty	1967	International
The Rescue Agreement	1968	International
The Liability Convention	1972	International
The Registration Convention	1976	International
Title 22 §3502. Purposes and establishment; policy guidelines and objectives	1979	United States
Title 22 §3503. Functions	1979	United States
The Moon Agreement	1984	International
Radiocommuncation Act	1985	Canada
Canadian Space Agency Act	1990	Canada
Inventions in Outer Space (35 USC Chapter 10, Section 105)	1990	United States
Title 42 §2475. International cooperation	1995	United States
Title 42 §2475b. Foreign contract limitation	1995	United States
Commercial Space Act	1998	United States
Civil International Space Station Agreement Implementation Act.	1999	Canada
Act on the Japan Aerospace Exploration Agency, National Research and Development Agency (Tentative translation)	2002	Japan
Remote Sensing Space Systems Regulations	2007	Canada
Basic Space Act (Tentative Translation)	2008	Japan
Title 51 §20164. International cooperation	2010	United States
Title 51§20102. Congressional declaration of policy and purpose	2010	United States
Title 51 Sec. 101 Findings	2010	United States

Legislation used for training supervised machine learning model		
Title 51 National Aeronautics and Space Capital Development Program	2010	United States
Title 51 §20301. General responsibilities	2010	United States
Title 51 §30306. Small business contracting	2010	United States
Title 51 §30701. Competitiveness and international cooperation	2010	United States
U.S. Commercial Space Launch Competitiveness Act	2015	United States
Act on Launching of Spacecraft, etc. and Control of Spacecraft (Tentative translation)	2016	Japan
Act on Ensuring Appropriate Handling of Satellite Remote Sensing Data (Tentative translation)	2016	Japan
NASA Procedural Requirements	2017	United States
National Space Traffic Management Policy	2018	United States
Space Policy Directive-2, Streamlining Regulations on Commercial Use of Space	2018	United States
USG Orbital Debris Mitigation Standard Practices	2019	United States
Process for Limiting Orbital Debris	2021	United States
Act on the Promotion of Business Activities for the Exploration and Development of Space Resources (Tentative translation)	2021	Japan
Regulation for Enforcement of the Act on the Promotion of Business Activities for the Exploration and Development of Space Resources (Tentative translation)	2021	Japan
FCC 5-Year Rule	2022	United States
NASA Technical Standard for Human-Rating	2023	United States
Framework Agreement Between The Government Of Japan And The Government Of The United States Of America For Cooperation In The Exploration And Use Of Outer Space, Including The Moon And Other Celestial Bodies, For Peaceful Purposes	2023	United States

Legislation used for training supervised machine learning model		
National Aeronautics and Space Act of 1958, As Amended Statement of Purpose	2024	United States
National Aeronautics and Space Act of 1958, As Amended Functions of the Administration	2024	United States
National Aeronautics and Space Act of 1958, As Amended International Cooperation	2024	United States
Code of Federal Regulations, Title 14, § 401.3 The Associate Administrator for Commercial Space Transportation.	2025	United States

Appendix B

Legislation used to measure international cooperation		
Name	*Year*	*Originating Entity*
The Declaration of Legal Principles	1962	United Nations
The Remote Sensing Principles	1974	United Nations
The Benefits Declaration	1982	United Nations
The Broadcasting Principles	1983	United Nations
The Nuclear Power Sources Principles	1993	United Nations
International Cooperation in the Peaceful Uses of Outer Space	2000	United Nations
Recommendations on Enhancing the Practice of States and International Intergovernmental Organizations in Registering Space Objects	2007	United Nations
Safety Framework for Nuclear Power Source Applications in Outer Space	2009	United Nations
Recommendations on National Legislation Relevant to the Peaceful Exploration and Use of Outer Space	2013	United Nations
Declaration on the fiftieth anniversary of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies	2017	United Nations

Legislation used to measure international cooperation		
Artemis Accords	2020	United Nations

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