PROCEEDINGS FOR THE SECOND SYMPOSIUM ON SPACE ECONOMY, SPACE LAW AND SPACE SCIENCES

Editors
Yüksel BAYRAKTAR, Sinan ALİŞ, Verda Neslihan AKÜN

Istanbul University, Faculty of Economics, Faculty of Law, Observatory Application and Research Center

2nd Space Economy, Space Law and Space Sciences Symposium
May 28-29, 2022 / Istanbul, Turkiye

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Editörler / *Editors*
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Sinan ALIŞ
Verda Neslihan AKÜN

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INFORMATION

AIMS AND SCOPE

The Proceedings for the Second Symposium on Space Economy, Space Law and Space Sciences was held by Istanbul University Faculty of Economics together with co-organizers, the Faculty of Law and the Observatory Application and Research Center on May 28-29, 2022 at Istanbul University.

The aim of the Symposium is to bring together experts from different disciplines to share information and to develop a common purpose toward 1) understanding the limitations, opportunities and features of the space industry, 2) analyzing the differences between local and global legislative regulations, and 3) establishing a national strategy of action for research to build the capability of the Turkish space industry.

The scope of the Symposium is multi-disciplinary and includes subjects related to space industry, the sectors enhanced by the space industry, space technology, space sciences, space economy and space law.

EDITORIAL POLICIES

Publication Ethics

All submissions must be original, unpublished, and not under the review of any other publication synchronously.

All submitted papers go through a double blind, non-biased peer review process before publication. Scientific Committee is responsible for the content and quality of the papers and reserve the right to accept or reject a paper in the review process.

Plagiarism, duplication, fraud authorship/denied authorship, research/data fabrication, salami slicing/ salami publication, breaching of copyrights, prevailing conflict of interest are unethical behaviors.

Author Responsibilities

It is authors' responsibility to ensure that the paper is in accordance with scientific and ethical standards and rules. Authors must ensure that submitted work is original and they must certify that the paper has not previously been published elsewhere or is not currently being considered for publication elsewhere, in any language. Any work or words of other authors, contributors, or sources must be appropriately credited and referenced.

All the authors of a submitted paper must have direct scientific and academic contribution to the paper. The author(s) of a research paper is defined as a person who is significantly involved in "conceptualization and design of the study", "collecting the data", "analyzing the data", "writing the manuscript", "reviewing the manuscript with a critical perspective" and "planning/conducting the study of the manuscript and/or revising it". Fund raising, data collection or supervision of the research group are not sufficient roles to be accepted as an author. The author(s) must meet all these criteria described above. The order of names in the author list of an article must be a co-decision.

All authors must disclose all issues concerning financial relationship, conflict of interest, and competing interest.

When an author discovers a significant error or inaccuracy in his/her own published paper, it is the author's obligation to promptly report it.

It is author's responsibility to make final author corrections

Peer Review

Submitted papers that pass preliminary control are scanned for plagiarism using iThenticate software. After plagiarism check, the eligible ones are evaluated for their originality, methodology, the importance of the subject covered and compliance with the scope.

The papers matching the formal rules are sent to at least two referees for evaluation.

Reviewers' judgments must be objective. Reviewers' comments on the following aspects are expected while conducting the review.

- Does the paper contain new and significant information?
- Does the abstract clearly and accurately describe the content of the paper?
- Is the problem significant and concisely stated?
- Are the methods described comprehensively?
- Are the interpretations and consclusions justified by the results?
- Is adequate references made to other works in the field?
- Is the language acceptable?

Reviewers must ensure that all the information related to submitted papers is kept as confidential and must report if they are aware of copyright infringement and plagiarism on the author's side.

A reviewer who feels unqualified to review the topic of a paper or knows that its prompt review will be impossible should excuse himself from the review process.

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Invited Proceedings Paper

PREFACE

Space has always been a subject of intense human curiosity. In recent years, space issues have attracted the attention of many scientists, engineers and entrepreneurs around the world. Space exploration holds great potential for the future of mankind, and to realize this potential, we need to focus on space economy, space law and space science. There are many challenges to space exploration, such as high costs, technological challenges, and physical challenges. Overcoming these challenges requires the cooperation of scientists, engineers, space agencies and private companies from around the world.

This Symposium Proceedings book contains the written versions of most of the papers presented at the II. International Space Economy, Space Law and Space Sciences Symposium held at Istanbul University on May 28-29, 2022. The symposium was co-organized by Istanbul University Faculty of Economics, Faculty of Law and Observatory Application and Research Center.

The aim of the symposium is to learn and support academic studies on space in Turkiye and the world. This symposium has provided an opportunity to discuss the studies and results obtained in the fields of Space Economy, Space Law and Space Sciences, to learn from each other and to carry out joint studies.

Thirty-two distinguished researchers from four different countries, 18 different universities, two different companies, APSCO and the Turkish Space Agency came together at the symposium, where twenty-seven qualified papers were presented in five sessions. The President of the Defense Industry and the Minister of Industry and Technology were invited as keynote speakers. The main objective of the symposium was to promote research and activities in space studies and to exchange information on space laws and space economy for the Turkish Space Policy. The presentations of the speakers were related to the needs and conditions of the sector as well as the trends and developments in the economic, legal and scientific aspects of space.

The symposium papers present a multidisciplinary approach to space studies and provide insightful information for the Turkish Space Program. In terms of disciplines, astropolitics, cooperation opportunities with APSCO, Space 4.0, the impact of space on international security, opportunities in the space economy, responsibilities arising from space activities, legal dimensions of space activities, commercialization of space, objectives of the Turkish Space Agency, rocket technologies, small satellites and ATASAM R&D infrastructure, and the impact of space activities on economic growth were covered. We thank all the participants for their contributions to the symposium program.

The organizing committee of the symposium included Prof. Dr. Sayım Yorgun, Prof. Dr. Ömer Ekmekçi, Prof. Dr. Tolga Güver, Prof. Dr. Yüksel Bayraktar, Prof. Dr. Faruk Kerem Giray, Assc. Prof. Dr. Hakan Bektaş, Assc. Prof. Dr. Suna Muğan Ertuğral, Assc. Prof. Dr. Taha Eğri, Asst. Prof. Dr. Sinan Aliş, Asst. Prof. Dr. Sezgi Gedik Aslan, Dr. Verda Neslihan Akün, Dr. Melikşah Kaçar, Dr. Aziz Dayanır and Oğuz Karasu. The success of the symposium was due to the collective efforts of many individuals. We would like to thank Prof. Dr. Yüksel Bayraktar, Dr. Verda Neslihan Akün and Assist. Prof. Dr. Sinan Aliş who edited the book. We would like to thank the Rector of Istanbul University, Prof. Dr. Mahmut Ak, for his unwavering support and contributions to the symposium. We are grateful to the assistants who skillfully organized the live streaming of the symposium online.

We hope that those interested in space studies will find this Proceedings book interesting and enjoyable.

Prof. Dr. Sayım YORGUN
On behalf of the Organizing Committee of the Symposium
Istanbul University Faculty of Economics
Dean

OPENING SPEECH

Distinguished Guests, Participants, Colleagues and Students,

First Symposium on Space Economics, Space Law and Space Sciences was held at the national level in this hall of Istanbul University as the first multidisciplinary academic meeting in collaboration with the Faculty of Economics, the Faculty of Law and the Observatory Application and Research Centre on the same dates last year. This year, we gather for an international symposium in which, different branches such as astronomy, economics and law feeding each other when the subject comes to space, but, this time, issues related to space are discussed in more depth, and foreign academicians from different countries will enrich us with their contributions.

We are in an effort to strengthen and develop this interdisciplinary academic meeting which shall serve to Turkish Space Policy. Therefore, in this second symposium, we focus on some specific issues of space law, considering that we have already covered the basic issues of space law last year.

Our faculty has taken on a pioneering role as the first law faculty in Turkey to include space law in its curriculum in the 90's. Being as a long standing law faculty of Turkeys, we are competent and ready to make every contribution to the implementation of our National Space Program with our academics trained in international law, in order to protect Turkey's national interests.

In this direction, in order to serve the ninth goal of our National Space Program as "training our effective and competent human resources in the field of space, we aim to train our law students both undergraduate and postgraduate levels, who shall shape space policies of Turkey and protect our rights and interests on the international arena.

Some space activities, which were distant dreams of humanity, recently come true, such as colonization on Mars, asteroid mining, civil space travels; and the era called "new space" not only excites us as lawyers, but on the other hand, the legal problems that may arise in the future worries us. For example, a limited solution to new and big problems such as space debris has been offered with the flexible legal rules called "soft law", which are not yet binding in international law.

On the other hand, in the "new space" era, the involvement of private law entities as a new actor in the field, the commercialization of space activities, reveal the need for new legal amendments, as the space law shaped by international conventions are not sufficient today. It is clear that future legal norms shall not only be limited to international level as a product of mutual agreement, but will also include national legislations. Because, there are issues that the five basic international agreements on space law concluded at the UN cannot meet the needs at some points today or leave them open. Space activities of private law legal entities is one of them. Even if the activities resulting with damage of these legal persons, may be attributed to the state which shall rise the international legal responsibility of the state, it will require the establishment of a recourse system, perhaps the institution of joint responsibility, in domestic laws. In the face of these new problems of space law, uniform regulations in national legislation will be a result of efforts to be made in the international arena. For this reason, the appointment of academics specialized on international space law at the "Legal Subcommittee" within the body of COPUOS at the UN should be an important priority of our country.

Within the framework of our National Space Program announced in 2021, our 4th goal "to provide access to space and to establish a spaceport operation", the efforts of the Turkish Space Agency to establish international cooperation with Russia, Kazakhstan and many countries are issues that need to be regulated by bilateral or multilateral international agreements. In this respect, it would be appropriate to regulate Turkish space activities in our domestic law in accordance with international law, based on the five basic international treaties on space law which we have already bounded. Although it is difficult to keep up with the pace of developments in this area, there is the need for a national legislation package that can cover prospective developments as comprehensive as possible. Contrary to the G-8 countries, although space studies have been carried out by the state with public resources, the interest and contribution of the private sector to this field, particularly at USA, cannot be denied. Initiatives in this field have already started in Turkey. It is time to discuss and work on the formulation of our national legislation regulating the space activities of the public and private sectors.

We believe that our Symposium, which shall serve to “raise space awareness” among the aims of our National Space Program, and which shall attract the attention of our students to space, shall fulfill an important task by providing interaction between all Turkish and foreign academicians working on astronomy, law and economics. Before ending my words with my best wishes for this fruitful weekend, I would like to express my gratitude to some participants. They honour us by acceptance of our invitation and by their presence in this hall. Prof. Larry F. Martinez from California State University, Assistant Professor Tuğrul Çakır from Ankara Yıldırım Beyazıt University Faculty of Law, Merve Erdem Burger Ankara University Faculty of Law. I would like to thank to Prof. Steven Freeland from Western Sidney University who shall connect us from another continent in the very early morning of his location. Also, I would like to thank to my dear colleague Prof. Dr. Turgut Tarhanlı for his moderation in the afternoon who was an old member of our Faculty and served for a long as a Dean at Bilgi University Faculty of Law.

Lastly I would like to thank to the distinguished members of Organisation Committee of this Symposium.

Prof. Dr. Ömer EKMEKÇİ
Dean
Istanbul University Faculty of Law

OPENING SPEECH

Respectful participants,

I would like to welcome you all to the Space Economy, Space Law and Space Sciences Symposium that we organize here at Istanbul University for the second time. As it was stated last year, Space becomes more and more accessible to us all and this creates a large area for multidisciplinary studies.

I personally hope that this symposium and its future versions will help us contribute to all these efforts and provide everyone from economy to law, to sciences, a platform to further improve multidisciplinary studies.

We are lucky enough to be living in times when our government pays special attention space studies. Specifically, this attention has been embodied in the establishment of the Turkish Space Agency, Eastern Anatolia Observatory and several similar initiatives.

For us at Istanbul University all these attempts are even more important because as the University which has the oldest Astronomy and Space Sciences Department and the observatory in modern Turkey, we feel the responsibility to help / contribute in anyway we can to all of these initiatives.

For the idea of the symposium and realization of it, I thank the deans of the Economics and Law faculties Prof. Yorgun and Prof. Ekmekçi and of course to our rector Prof. Ak and everyone in the organizing committee.

Finally, I thank to our very valuable speakers for their participation. I offer my best wishes for a successful symposium.

Prof. Dr. Tolga GÜVER
Director
Istanbul University Observatory Research and Application Center

PROGRAM

2nd SPACE ECONOMY, SPACE LAW AND SPACE SCIENCES SYMPOSIUM

May 28-29 2022

Saturday, May 28, 2022

10.00-11.20	**Opening Speeches** *Prof. Dr. Tolga Güver, Istanbul University, Director of Observatory Research and Application Center* *Prof. Dr. Sayım Yorğun, Istanbul University, Dean of Faculty of Economics* *Prof. Dr. Ömer Ekmekçi, Istanbul University, Dean of Faculty of Law* *Prof. Dr. Mahmut Ak, Istanbul University, Rector* *Prof. Dr. İsmail Demir, President of Defence Industries* *Mustafa Varank, Minister of Industry and Technology*
11:20-11:30	**Coffee Break**
11.30-13.10	**SESSION I** **Moderator:** Prof. Dr. Ahmet İncekara, Istanbul University, Faculty of Economics Assist. Prof. Dr. Korhan Yelkenci – *Istanbul University, Faculty of Science* ***The History of Space Explorations: Yesterday, Today and Future*** Assist. Prof. Dr. Ferhat Fikri Özeren, Deputy Secretary General, APSCO ***"Collaboration Potential and Possibilities with APSCO"*** Prof. Dr. Oktay Tanrısever, Middle East Technical University ***"Securitization of the Outer Space and the Crisis in Russia's Space Cooperation with the West: Implications for International Space Diplomacy"*** Assoc. Prof. Dr. Cüneyt Dirican, Istanbul Arel University ***"Turkiye's Space Economy Preparation Roadmap"*** Dr. Ömer Furkan Kesikbaş, TURKSAT ***"Problematic Regarding the Literature on Astropolitics and Need for an Alternative Approach"*** Şahabeddin Kutlu, Engineer, ASELSAN ***"New Space - Space 4.0" Competition for Turkey"***
13.10-14.25	**Lunch Break**
14.30-16.10	**SESSION II** **Moderator:** Prof. Dr. Turgut Tarhanlı, Istanbul Bilgi University, Faculty of Law Prof. Larry F. Martinez – California State University, Political Sciences ***"The Legal and Policy Dimensions of Cyber-conflict in Outer Space"*** Dr. Aurélie Trur, National Graduate Institute for Policy Studies (GRIPS) ***"Space Sustainability Governance Trends"*** Assist. Prof. Dr. Tuğrul Çakır, Yıldırım Beyazıt University, Faculty of Law ***"Liability of Private Entities Arising from Space Operations"*** Dr. Merve Erdem Burger, Ankara University, Faculty of Law ***"The Ownership Question on the Sources Derived from Space Mining"*** Dr. Verda Neslihan Akün, Istanbul University, Faculty of Law ***"The Military Activities in Space and the Outer Space as a Sphere for Potential Armed Conflicts and Use of Force Conducts"***
16.30-17.10	**Keynote Speaker:** Scott Pace – George Washington University "U.S. Perspectives on National Space Policy"

PROGRAM

17.10-19.10	**SESSION III** **Moderator:** Prof. Dr. Nihal Tuncer, Istanbul University, Faculty of Economics Ari Eisenstat, University of Hawaii at Manoa ***"Astropolitics or Space Innovation"*** Matej Siget, George Washington University ***"LEO Commercialization and Commercial Space Stations"*** George V. Leaua, Ioana Cozmuta, G-SPACE, Inc. ***"In-Space Manufacturing Requires New Acquisition Policies"*** Prof. Steven Freeland – Western Sydney University, School of Law ***"Legal and Governance Issues Regarding Space Resource Activities"*** Kasım İleri, Middle East Technical University ***"From Competition to Confrontation: US Space Strategy in 21st Century"*** Oğuz Karasu, Istanbul University ***"Economic Shocks and International Space Projects: The Russian Invasion of Ukraine"***
	Sunday, May 29, 2022
11.00-13.00	**SESSION IV** **Moderator:** Prof. Dr. Tansel Ak, Istanbul University, Faculty of Science Prof. Dr. İbrahim Küçük, Turkish Space Agency ***"Astronomy in the National Space Program and the Goals of the Turkish Space Agency"*** Prof. Dr. Cahit Yeşilyaprak, Atatürk University ***"Restructuring ATASAM's R&D Capabilities in the Framework of Space Sciences Ecosystem"*** Assoc. Prof. Dr. Arif Karabeyoğlu, Koç University ***"Rocket Technologies"*** Prof. Dr. Emrah Kalemci, Sabancı University ***"Science with Small Satellites"*** Prof. Dr. Alim Rüstem Aslan, Istanbul Technical University ***"Small Satellites"*** Assist. Prof. Dr. Onur Keskin, FSF Işık University ***"Optomechanical Systems and Their Applications in Space Technologies"***
13.00-14.30	**Lunch Break:**
14.30-16.10	**SESSION V** **Moderator:** Prof. Dr. Mithat Zeki Dinçer, Istanbul University, Faculty of Economics Moderator: Prof. Dr. Mithat Zeki Dinçer, Istanbul University, Faculty of Economics Prof. Dr. Murat Azaltun, İsmail Tekbaş, Arzu Aktaş, Ayşe Göksu Atasoy ***"The New Dimension of Accounting in the 21st Century: Space Accounting"*** Assoc. Prof. Dr. A. İnci Sökmen Alaca, Istanbul Arel University ***"First Target in Deep Space Area is Moon and Its Importance"*** Mehmet Fırat Olgun, Prof. Dr. Yüksel Bayraktar, Istanbul University ***"The Relationship between NASA Budget and Economic Growth: The Causality Approach"*** Assoc. Prof. Dr. Hilmi Rafet Yüncü, Anadolu University ***"Travelling Beyond Space' From Fiction to Real: A Conceptual Approach to Space Tourism"*** Assist. Prof. Dr. Cansu Yıldırım, Cansu Soylu, Dokuz Eylül University ***"Space Exploration Logistics"***
16:15	***Closing Remarks***

Proceedings for the Second Symposium on Space Economy, Space Law and Space Sciences

DOI: 10.26650/PB/SS46PS01.2023.004.001

The Relationship Between NASA Budget and Economic Growth: The Causality Approach

Mehmet Fırat OLGUN[1], Yüksel BAYRAKTAR[1]

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1. Introduction

With the launch of Sputnik in October 1957, space has become an industry that concerns the daily life of all people. Space is gaining new dimensions with its developing technology, its own legal system, economic values and international policies. The benefits provided by the technologies developing depending on space activities have led the space industry to gain importance in terms of country policies (İnce, 2020). The global space economy is estimated to be $370 billion in 2021. It is estimated that it will grow by 74% to reach $642 billion by 2030 (Euroconsult, 2022), and this value will reach $1 trillion in 2040 (Morgan Stanley, 2022).

Although the space sector is a sector with high returns, it has high entry barriers to the sector. Entry into the industry requires very high costs. Therefore, the support of the public sector is very important for the development of the sector (Bozkurt and Ercan, 2016). Countries usually exist in the sector by establishing their own space agencies. Because the importance of NASA in the development of the US space industry is an undeniable fact. NASA researches climate, sun, earth and more with 20 centers and facilities nationwide. NASA develops space technologies that will contribute to future exploration and improve human well-being. It also finances. NASA works with academia and the private sector to discover knowledge and contribute to science for the benefit of humanity (NASA, 2022a).

In this study, the effect of NASA's budget on the US economic growth was examined. First of all, NASA budget and the distribution of the budget are given. In the second part, NASA's contribution to the US economy is evaluated by considering the employment and economic output level, and the technology transfers made by NASA and the relevant literature are examined. In the empirical part of the study, the relationship between NASA budget and

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economic growth is discussed with the Toda-Yamamoto causality test. Finally, the empirical findings are evaluated and the conclusion part is given.

2. NASA Budget and Distribution

Space activities in the USA are carried out by NASA. NASA carries out activities with the budget allocated to it. The share of NASA's budget by years in the Federal budget is given in Figure 1.

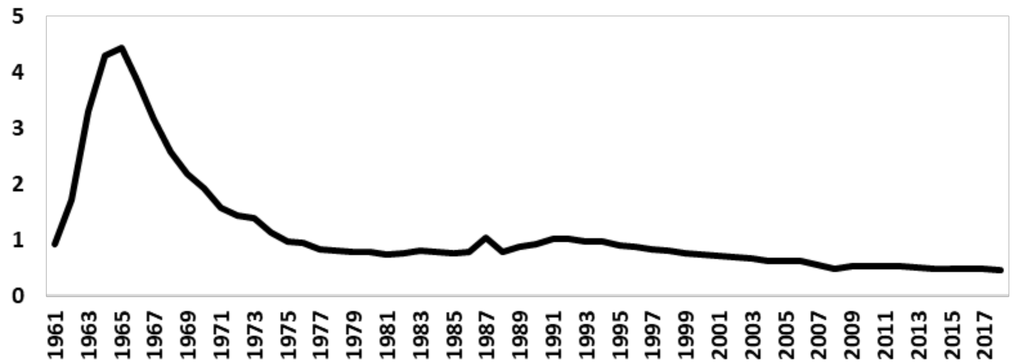


Figure 1. Share of NASA budget in Federal Budget, 1961-2018
Source: The Space Report

More than 27% of NASA spending occurred during the Apollo era (1963-1975). In 1965, the share of NASA's budget in the Federal budget reached its peak with 4.44%.Adjusted for the 2018 price index, this budget is around \$32 billion. During the Apollo era, an average of 2.5% of the federal budget was allocated to NASA. In 1964 and 1965, the share of NASA's budget in the Federal budget exceeded 4%. After the Apollo project, NASA's budget began to decline significantly (after 1975).

After 1975, the share of NASA's budget in all US government spending has varied between 1% and 0.5%. After the Apollo program, the share of NASA's budget in the Federal budget has exceeded 1% only three times (The Space Report).

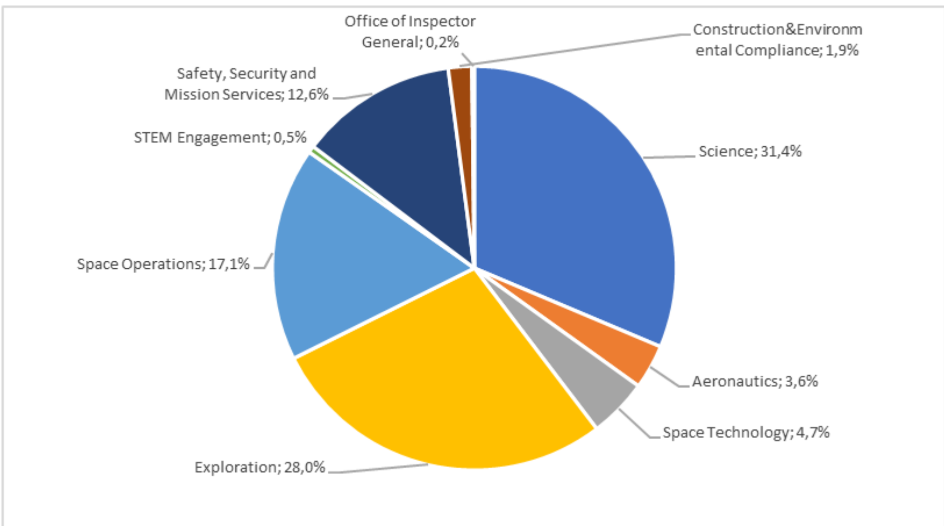


Figure 2. NASA Budget Distribution, 2021

The 2021 NASA budget is $23.3 billion. Figure 2 shows the distribution of the budget by areas. The NASA budget, which varies from year to year, specifies the amount of funding for programs and projects in space science, technology development, manned spaceflight, aviation, and education. NASA prioritizes manned space flights. Approximately 50% of the budget is allocated to this area each year. 30% of the budget is allocated to robotic missions and scientific research (The Planetary Society, 2022).

3. NASA's Impact on The US Economy

NASA has both direct and indirect contributions to the US economy. NASA acquisitions support the economic output process by contributing to the development of businesses in the sector. The effect on the employment level, which can be seen as a direct contribution of NASA, is shown in Table 1.

Table 1. Direct Contribution of NASA Employees to Space Industry Employment

Number of Employees	2012	2013	2014	2015	2016	2017	2018	2019
US Space Industry	354000	362000	357000	359000	359000	360000	352000	354000
NASA	18709	18167	18068	17731	17316	17310	17324	17373
Contribution Rate	5,29%	5,02%	5,06%	4,94%	4,82%	4,81%	4,92%	4,91%
Source: Prepared by the author based on data from Bureau of Economic Analysis and Workforce Information Cubes for NASA (WICN).								

The number of employees in the US space industry varies from year to year. In 2013, this number reached its peak with 362 thousand people. Employment within NASA, on the other hand, reached its highest level in 2012 with approximately 19 thousand people. NASA's direct contribution to the US space industry was also realized in this year with 5.3%. Although the direct contribution of NASA to the US economy varies over the years, it is seen that it contributes to 5% employment on average. But NASA's contribution to the space industry is not limited to its own employees. Data on the total direct and indirect contribution of NASA to the space industry are given in Figure 3.

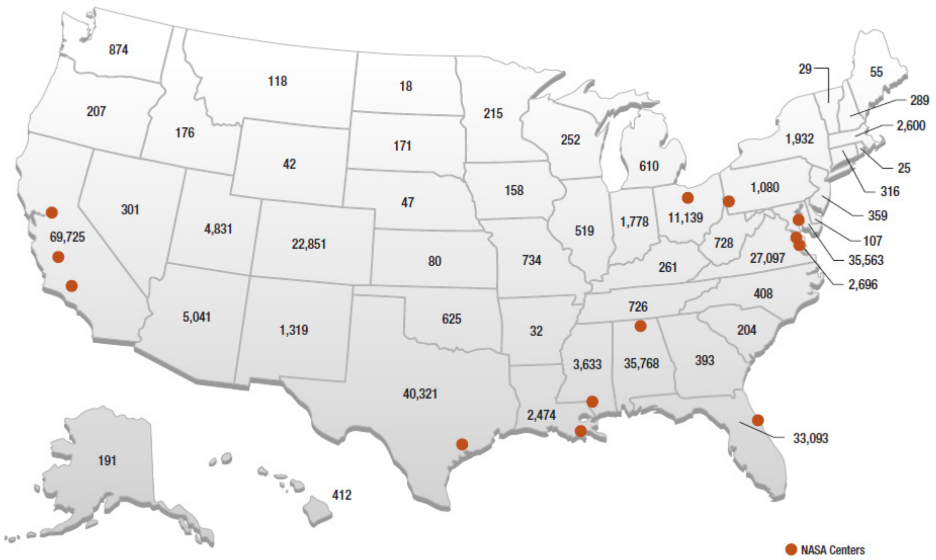


Figure 3. NASA's Contribution to US Employment, 2019
Source: National Aeronautics and Space Administration (2020a).

NASA contributes to the development of businesses both socially and economically by transferring hundreds of new technological products, services and processes every year. In Figure 3, the distribution of NASA's direct or indirect contribution to US employment in 2019 by state is given. NASA contributed to a total of 312,000 jobs in 2019. Impacting different numbers on all 50 states, NASA provided the most employment in California. California employs 69,725 people, accounting for 20% of NASA's total employment in 2019 (NASA, 2020a).

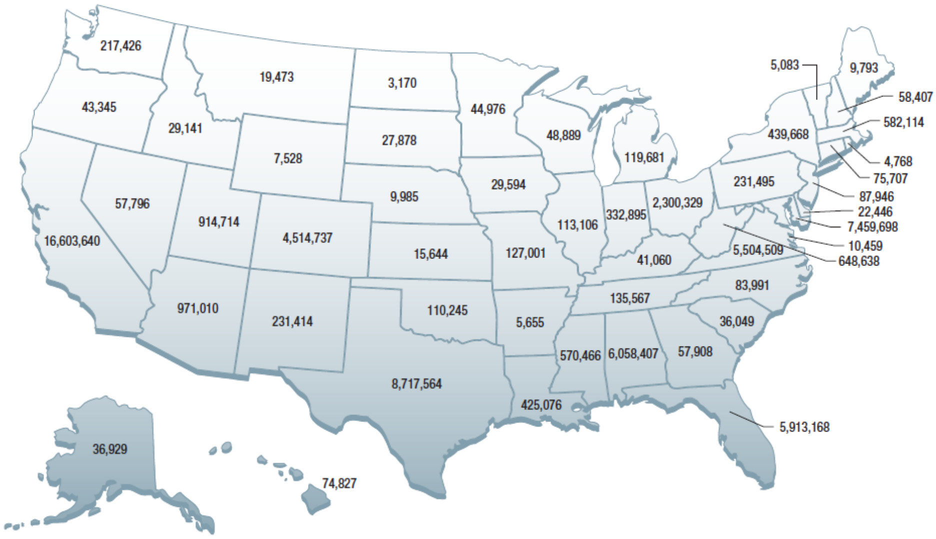


Figure 4. NASA's Contribution to the US Economy, 2019
Source: National Aeronautics and Space Administration (2020a).

Figure (4) shows the output values of NASA's economic contribution to the US economy. In total, NASA contributed $64.3 billion directly or indirectly to the US economy in 2019. The state with the highest economic value is California with $16,603 billion. California obtained 25% of the total economic value. NASA provides the US economy with an average of $23.7 billion in annual labor income. For every full-time job held at a NASA facility, more than 17 jobs are supported in the U.S. economy. Every $1 million in labor income earned by NASA personnel results in $7.7 million in labor income in the United States. In addition to the economic value, NASA transfers hundreds of technologies to the private sector every year and contributes to the country's competitive advantage (NASA, 2020b). The distribution of technology transfer made by NASA in the 1976-2018 period is given in Figure 5.

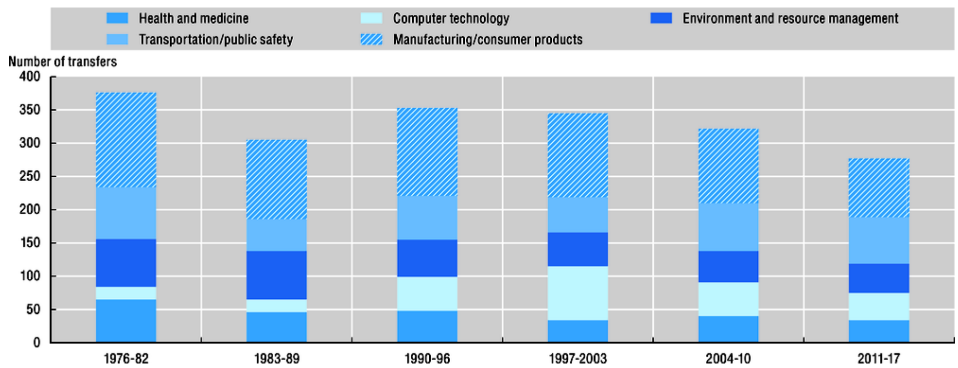


Figure 5. NASA Technology Transfer
Source: OECD (2019, p.56)

NASA transferred more than 2,000 successfully developed commercial products through spinoff companies during the 1976-2018 period. These include different fields such as computer technology, environment, resource management, health. Production and consumption products are the most transferred area with an annual average of 18 products (OECD, 2019).

Results from NASA's research and development activities contribute to the national economy by supporting high-tech industries and creating or maintaining tens of thousands of knowledge-intensive jobs. In addition, NASA is maintaining its country's competitive advantage by investing in economically valuable technologies. Every year, NASA develops hundreds of new technologies and transfers technology by transferring thousands of products, services and processes to private businesses. Technology transfers by NASA increase the productivity of US businesses and contribute to their global competitiveness (NASA 2020b, p. 5).

The benefit NASA has provided is much more than the space sector. NASA every year new technologies, an average of $1 million in annual spinoff income, software use agreements, patent and copyright agreements, developing cooperation with foreign countries, contributing to scientific and technological progress with scientists from 80 different countries, leading a $2 billion scientific and technological program it contributes socio-economically. NASA's socio-economic effects can be grouped under 6 headings. These effects are shown in Figure 6 (Tauri Group, 2013).

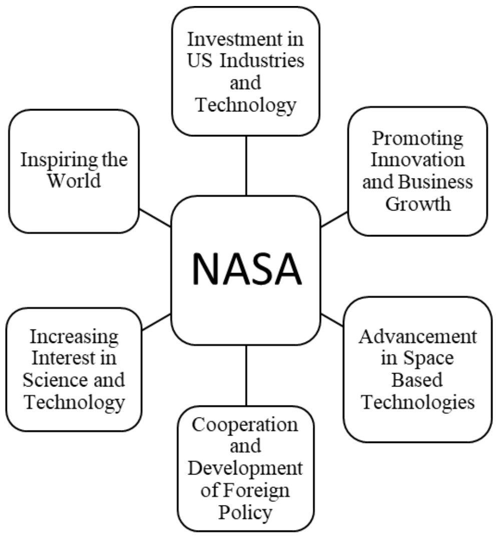


Figure 6. NASA's Socio-Economic Impacts
Source: Tauri Group, 2013.

NASA has a globally significant role in space sector-based technological advancement. It contributes to the increase of welfare in daily life with the inventions it has made in many different sectors such as environment, health, optics, aviation, communication technologies, software, robotics, manufacturing (NASA, 2022b). We owe the freezing techniques that reduce the weight of food and prolong its life to NASA's research. Memory foams, more commonly referred to as visco mattresses today, were first developed by NASA in the 1970s to help pilots feel more comfortable in their seats. Later, these foams started to be used in space shuttles. Robotic developments made by NASA in unmanned or manned vehicles for use in space missions have contributed to more functional prostheses used by the disabled. In the 1960s, a researcher at NASA conducted studies to use computers more efficiently and presented an idea for a technology that could easily manipulate data on the computer screen. This idea led to the invention of today's mouse. In addition, we owe many products we use in our daily lives such as portable computers, smoke detectors, leds, and phone cameras to the activities of NASA (Jet Propulsion Laboratory, 2016). NASA has more than 6800 patents (Espacenet, 2022).

4. Literature

The number of empirical studies dealing with the relationship between the space sector and economic growth is quite limited in the literature. Machay (2012) examined the employment contribution of NASA and the private sector to the space industry and the space economy for the period 1990-2008. OLS estimator was used in the analysis. The findings are that every $1 billion budget regularly allocated to NASA increases the space industry employment by 24,000 people. In addition, it is among the findings of the study that the increase in the level of employment may increase up to 40,000 people in the long run. While presenting the results of this analysis, it was stated that NASA was not in a position to provide employment directly, the employers were the private sector and entrepreneurs, and it was emphasized that NASA provided employment opportunities.

Highfill and MacDonald (2022) examined using input-output analysis the impact of NASA spending and the production of space-related goods and services on the US economy. In the study, the advantages of input-output analysis over income-based economic analysis are given. The data shows that NASA's total economic output in 2019 was $64.3 billion and provided 312,000 jobs. On the other hand, it was concluded that space-related products and services produced $177.5 billion in economic value in 2018. It has been determined that the economic value in 2018 constituted 0.5% of the US GDP.

The contribution of the space sector to the military field is also important for countries. There are studies in the literature that deal with the relationship between military expenditures and economic growth. Yıldırım et al (2005) examined the relationship between defense expenditures and growth for Middle Eastern countries and Turkey. The dynamic panel data model was used in the study, which covers the 1989-1999 period. The findings show that defense expenditures increase economic growth for the Middle East countries and Turkey

Liu et al. (2008) examined the relationship between national defense, human resources, physical resources, net interest payments and other expenditures with growth for 5 sub-categories of the US federal budget, with data for the period 1947-2002. Other expenditure items include space and technology expenditures. The results show that there is a causal relationship from growth to other expenditures. In addition, a 1% increase in other expenditures increases growth by 0.01%. A 1% increase in defense spending increases growth by 0.009%. There is a one-way causality relationship from military expenditures to growth.

Chang et al. (2011) examined the relationship between military expenditures and growth by considering the 1992-2006 period in their study on 90 countries. Countries are classified as low, middle and high income. The findings show that military spending negatively affects economic growth in low-income countries.

Chang et al. (2014) examined the relationship between military spending and growth in

G-7 countries and China. The period of 1988-2010 was discussed and analysis was made with the bootstrap causality approach. The findings show that there is a bidirectional causality relationship between economic growth and military expenditures in Japan and the USA. A causal relationship was found from military expenditures to growth in Canada and UK, and from growth to military expenditures in China. There is no causal relationship between military spending and growth in Italy, Germany and France.

Pan et al. (2014) examined the relationship between military expenditures and economic growth for 10 Middle Eastern countries with the Bootstrap panel causality test. The results show that there is a one-way causality relationship from military expenditures to economic growth in Turkey, while there is a causal relationship from economic growth to military expenditures in Egypt, Kuwait, Lebanon, and Syria. While no causal relationship was found for Jordan, Oman, and Saudi Arabi, a bidirectional causality relationship was found between economic growth and military expenditures for Israel.

Arshad et al. (2017) examined the effect of military expenditures, including space activities, on growth for 61 countries with data for the period 1988-2015. The findings show that military expenditures affect growth negatively.

Abdel-Khalek et al (2019) examined the relationship between military spending and growth in India for the period 1980-2016. According to the findings of the study, there is no causal relationship between military expenditures and growth in India.

The relationship between defense expenditures, which can be considered in relation to the space sector and economic growth, is widely covered in the literature. In this study, which directly deals with the space industry, there are studies that deal with the effects of NASA on the US economy. In addition, limited empirical studies have been observed in the field of space economics. This situation has been decisive in the empirical analysis of the impact of NASA, which pioneered the space sector, on the US economic growth.

5. Dataset and Method

In this study, the relationship between NASA budget and US economic growth is examined. The Toda-Yamamoto causality test was used in the study, which deals with the annual data of the 1961-2021 period. Information on the variables used is given below.

Table 2. Description

Variable	Unit	Source
Growth	GDP Growth (annual %)	World Bank Open Data
lnBudget	Share of NASA Budget in Federal Budget (%)	The Space Report

The time dynamics of the variables used in the model are given in Figure 7.

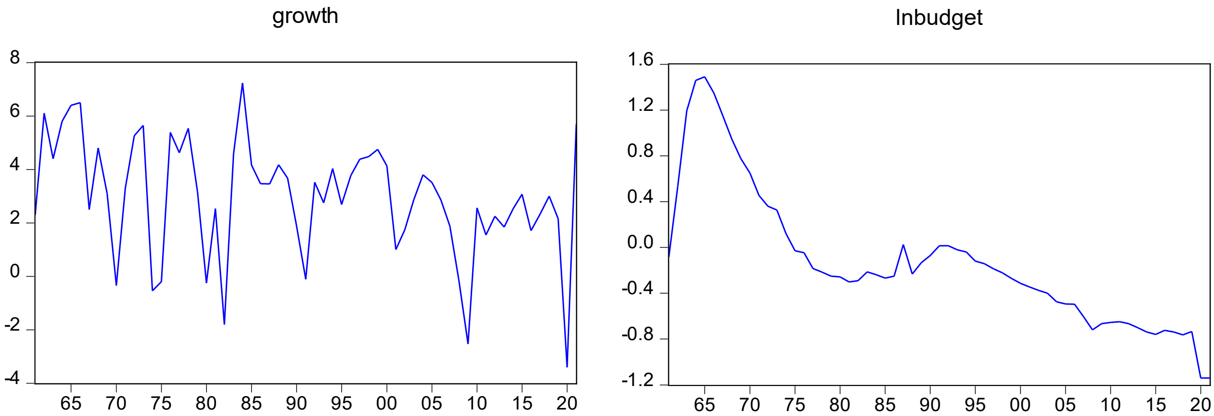


Figure 7. Variable Dynamics

The causality test developed by Toda and Yamamoto (1995) ignores the stationarity level of the series and the cointegration relationship. In the equations below, k represents the lag length of the VAR model and d_{max} represents the maximum degree of integration. After determining the optimum lag length and maximum integration degrees, the VAR model is estimated. The models of the TY extended causality test are as follows.

$$y_t = \gamma_0 + \sum_{i=1}^{k+d_{max}} a_{1i} y_{t-1} + \sum_{i=1}^{k+d_{max}} \beta_{1i} x_{t-1} + e_{1t} \tag{1}$$

$$x_t = \gamma_0 + \sum_{i=1}^{k+d_{max}} a_{2i} y_{t-1} + \sum_{i=1}^{k+d_{max}} \beta_{2i} x_{t-1} + e_{2t} \tag{2}$$

Equation (1) shows whether the variable x is the Granger cause of the variable y, and Equation (2) shows whether the variable y is the Granger cause of the variable x. The main hypothesis in both equations shows that there is no Granger causality. The alternative hypothesis is Granger causality.

$$H_0: \beta_{1i} = 0 \tag{3}$$

$$H_1: \beta_{1i} \neq 0 \tag{4}$$

6. Empirical Findings

In the study, in addition to ADF and P-P traditional unit root tests, Perron (1989) and Zivot and Andrews (1992) break unit root tests, which take into account structural breaks, were used to analyze the stationarity of the series. Unit root test results are given below.

Table 3. Unit Root Test Results

Unit Root Test	Model	Growth	lnBudget
ADF	Constant	-5.927***	-2.674*
	Constant+Trend	-5.705***	-4.034**
	First Difference	-6.568***	-5.663***
Philips-Perron	Constant	-5.882***	-0.946
	Constant+Trend	-6.415***	-3.722**
	First Difference	-24.205***	-5.886***
Perron (1989) Bir Kırılmalı	A (Constant)	-7.256***	-6.301***
	B (Both)	-7.355***	-8.050***
	First Difference (A)	-7.066***	-5.614**
Zivot-Andrews (1992) Bir Kırılmalı	A (Constant)	-6.128***	-5.194**
	B (Both)	-6.472***	-4.071
	First Difference (A)	-6.696***	-5.647***

** and ***; It shows that the series is stationary at 95% and 99% confidence levels.

When the unit root test results are examined, the stationarity of the series differs. However, all series are I (0) or I (1) series. Therefore, Toda and Yamamoto (1995) causality test was used in the causality analysis, which allows for different degrees of stationarity of the series. The results obtained for determining the optimum lag length in the established VAR model are given in Table 4 below.

Table 4. Determining the Optimum Lag Length

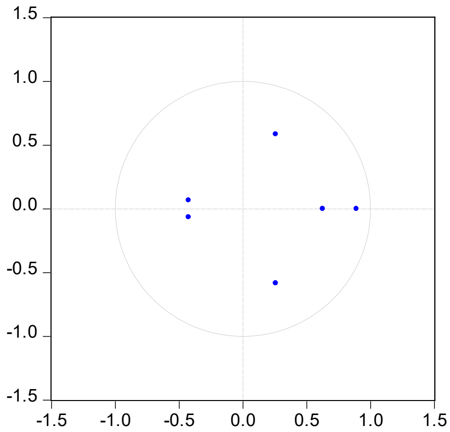
Lag	LogL	LR	FPE	AIC	SC	HQ
0	-174.2454	NA	1.494331	6.077426	6.148476	6.105101
1	-72.65219	192.6767	0.051642	2.712144	2.925294*	2.795170*
2	-67.10703	10.13426*	0.048995*	2.658863*	3.014112	2.797240
3	-63.23218	6.814386	0.049281	2.663179	3.160527	2.856906

The optimum lag length differs according to the information criteria. While the appropriate lag length is 2 according to the Akaike information criterion, the optimum lag length is 1 according to the Schwarz and Hannan-Quinn information criteria. In practice, if the information criteria show different optimum lag length, it is decided by looking at LR (Likeihood ratio) (Akar, 2008, 190). Therefore, in this study, the optimum lag length is taken as 2.

Table 5. Autocorrelation and Heteroscedasticity Test Results

LM Autocorrelation Test		
Lag Length	Test Statistics	Prob.
2	1.409	0.8425
White Heteroscedasticity Test		
2	87.038	0.3032

After determining the optimum lag length, the presence of autocorrelation and heteroscedasticity in the VAR model was investigated for this lag length. The basic hypothesis for the autocorrelation test is that there is no autocorrelation, while the basic hypothesis for the heteroscedasticity test is constant variance. Looking at the estimation results, it is seen that the probe values obtained from the LM test and White test results are greater than 0.1. Therefore, the basic hypothesis cannot be rejected for both tests. In other words, the results show that there is no autocorrelation and heteroscedasticity problem for the VAR model.



Figıre 8. Inverse Roots of AR Characteristic Polynomials

The AR characteristic roots obtained as a result of the VAR analysis are shown in Figure 8. When the figure is examined, it is seen that the characteristic roots are located within the unit circle. The fact that the roots are in the unit circle means that the characteristic roots are all less than 1. Therefore, it can be said that the VAR analysis is stable. The results of the Toda-Yamamoto causality test are given in Table 6.

Table 6. Toda-Yamamoto Causality Test Results

NASA Budgets-Growth		
Test Statistic	Value	Probability
Chi-square	9.8242	0.0201
Growth-NASA Budgets		
Chi-square	0.4951	0.7807

Considering the causality test results, the main hypothesis stating that there is no causality relationship from NASA budget to growth is rejected at the 5% significance level. In other words, there is a causal relationship from NASA budget to growth. However, it is seen that there is no causality relationship from growth to NASA budget. As a result, one-way causality relationship was found from NASA budget to growth.

7. Conclusion

Scientists working within NASA have made more than 6800 technological inventions to date, making life easier in many areas. The space industry is a sector that needs to be supported because of its contributions to research, development, education and innovation, economic growth, creating highly qualified employment, improving the quality of life, protecting nature, and disaster management. Although the space sector seems risky in terms of time, money and resource allocation, it is a sector with a very high return. The risk of financing required public funding of the space industry for many years. However, in the last 20-30 years, the interest of entrepreneurs in the space sector has increased. It is seen that the private sector, which focuses on high return potential, has made significant investments in the space industry. The decrease in NASA's share in the US GDP over the years indicates that new ventures in the space sector are gravitating towards this field and that the private sector is replacing public funding.

In this study, NASA's contributions to the US economy are examined in terms of employment level and output value. Toda-Yamamoto causality analysis was used to determine the relationship between NASA budget and economic growth in the study, which covers the period of 1961-2021. The findings show that there is a unidirectional causality relationship from NASA budget to US economic growth.

Considering the positive relationship between space expenditures and economic growth, it is clear that incentives should be increased to support new ventures in the industry, the industry should be made more competitive, and policies should be developed to increase the interest of entrepreneurs in the space industry.

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LEO Commercialization: Commercial Space Stations and Their Economic Viability

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1. Introduction

Since the beginning of the third millennium, we are witnessing a significant increase in the number of commercial activities happening in space. In fact, commercial actors have outpaced national governments in these activities - the report issued by the Space Foundation notes that the commercial revenue now represents more than 80% of the whole global space economy (Space Foundation, 2021).

Commercial actors have traditionally been active in the field of satellite manufacturing and satellite operations. In recent years there has been a surge in the development and operation of commercial launch vehicles but also manned and unmanned spacecraft. Today, a number of commercial players are also interested in building more advanced platforms for research or technology demonstrations and in the development of whole space stations.

Space stations have traditionally been regarded as the domain of governments, with only a few having tangible experience with designing, building, and operating such manned outposts. This trend is now slowly shifting and there are efforts to engage the commercial sector with the activities happening on the ISS. The private sector conducts experiments, owns research platforms, and even whole modules. Commercial engagement in the field of space station utilization is also visible in the field of space tourism – earlier this year we witnessed the first fully commercial mission to the ISS with private spacecraft carrying private astronauts. Thus, becoming aware of the potential of the utilization of space stations, it comes as no surprise that the private sector is increasingly interested in developing their own stations – these would be much smaller in size than those currently in orbit but could serve similar functions.

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Such plans might have been considered too ambitious a few years ago. However, this has changed as the ISS is planned to be decommissioned in 2031. Since it is in the interest of the U.S. to maintain human presence in the Low Earth Orbit (LEO), the U.S. is turning to the private sector to build and operate several smaller space stations in LEO, aiming to save millions of U.S. dollars and allowing NASA and other federal agencies to focus on human exploration missions beyond Earth's orbit, without losing the presence in LEO.

What can the experience with operating a space station tell us about the future of commercial space stations? The main question is the following: do commercial stations have the prospect to create sustainable demand and eventually become profitable? What activities are seen as most promising for generating revenue for the operators of such commercial space stations?

2. Existing and Future Space Stations

Humans were thinking about establishing manned outposts in LEO and beyond long before the first rocket launched to space. The idea of a space station, defined as *"a large artificial satellite designed to be occupied for long periods and to serve as a base"* (Merriam-Webster, n.d.) started to appear in NASA documents as early as 1959. During the space race, the purpose of the space station was often political but the idea was to build a platform that would serve as a habitat for humans in space on longer-duration missions and a laboratory for scientific and industry-sponsored experiments in microgravity and for observing both the Earth and outer space.

After a relatively small number of space stations that were orbiting the Earth since 1971, there are currently two operational stations in orbit. Since the year 2000, the United States, Russia, Canada, Japan, and Europe jointly operate the International Space Station as a constantly crewed laboratory in LEO. The ISS as the largest human-built structure in space is the symbol of international cooperation in space activities. It has many objectives, including the promotion of partnerships between industries, research institutes, and educational entities, or the reinforcement of the aerospace industry.

For the U.S., the ISS has been an important tool for the commercialization of LEO, and this was noted already in the Commercial Space Act of 1998. It reads: *"Congress declares that a priority goal of constructing the International Space Station is the economic development of Earth orbital space"* (Commercial Space Act, 1998). Indeed, activities onboard the ISS have over the years become increasingly commercial. In 2005, the U.S. established the so-called ISS National Lab which is responsible for managing all non-NASA research onboard the station (since then, over 200 research projects were sponsored). This must be seen as a very important endeavor for raising awareness about the benefits of the space environment and for creating a demand for in-space services in the future. Today, several companies offer payload services and access to internal and external research and technology demonstration platforms. U.S., European and other companies and services operate on the ISS, such as Nanoracks, Airbus, Space Tango, or ICE Cubes Service. These commercial entities providing fast-track, simple, and affordable access to space for conducting activities of various character are significantly lowering the general threshold of engaging in space activities. End-to-end service provided by these providers allows for countries and private companies to leverage their financial resources – by not being required to develop means for independent access to space, customers interested in the utilization of the space environment can save a significant amount of resources and time. This can then increase the general awareness about the benefits of conducting activities in space and increase the number of entities interested in the utilization of the ISS and individual commercial platforms. But the presence of commercial service providers is important for other reasons – they support the creation of a market for commercial space stations and building on their experience with conducting business onboard the space station, they themselves can grow to become owners and operators of such stations in the future.

Since 2021, the ISS is joined in LEO by the Chinese Tiangong Space Station. Despite being a governmental station, China has been vocal about its ambition to open Tiangong to business and gradually turn its utilization into a viable business model. China Manned Space Agency (CMSA) has, for example, signed an agreement on international experiments being sent to Tiangong and attempts to attract space and non-space companies from all around the world. In this regard, business executives from U.S. companies that provide commercial services onboard the ISS have already been vocal about the fear of losing their business to the Chinese space station and openly call it their competitor (Jones, 2022). Due to the non-private character of the Chinese space station and the ability to not seek profits but rather focus on political capital, Tiangong can indeed pose a significant competition for future commercial space stations.

As noted earlier in this paper, the ISS is slowly coming to an end of its operational life and is planned to be decommissioned in the year 2031. Due to the activities happening onboard the ISS today and the number of prospective utilization areas that will both be analyzed later in this paper, it is obvious that states, particularly the U.S., are interested in the continuation of manned presence in LEO. In this connection, NASA organizes its efforts of transitioning from the ISS to a number of smaller commercial space stations under the so-called Commercial LEO Destination Program. Such a shift will allow NASA to save precious resources and save millions of U.S. dollars - all without losing manned spaceflight capabilities. Additionally, it will allow the U.S. to focus on human exploration missions beyond LEO, which have been the priority of the U.S. government since the administration of President Trump.

The Commercial LEO Destination program has two phases. The first is a design and development phase running until 2024 or 2025, which will be followed by a second phase aimed at certification and services. The program is foreseen to end by 2030 when the ISS is scheduled to end operations and the new commercial space stations will allow for an effective transition. In 2021, NASA announced the names of three companies that were awarded funding under the first phase of the program, with awarded funds totaling $415.6 million. These companies are:

· Blue Origin-led consortium with Sierra Nevada Space, Boeing, Redwire, and other companies was awarded $130 million to develop the Orbital Reef space station. The station is presented as a mixed-use space station in low Earth orbit for commerce, research, and tourism. According to available information, the project has already passed the design and system requirements review (Foust, 2022).

· Nanoracks was awarded $160 million for the development of a Starlab station. As in the case of the Orbital Reef, Nanoracks foresees a multi-purpose station. It will consist of an inflatable module able to host 4 astronauts at a time and a science lab module with various departments, including a biology lab, plant habitation lab, physical science, and materials research lab. Nanoracks is a company with extensive experience with working on the ISS, and the company does not only own science platforms but also a Bishop Airlock.

· Northrop Grumman Systems Corporation was awarded $125.6 million and aims for the development of a station based on technologies already developed or under development by the company – including Cygnus cargo spacecraft and the HALO module that will be a part of the NASA's lunar Gateway.

In addition to the three aforementioned companies, private company Axiom Space won a $140 million award from NASA in 2020 for the development of a commercial module that is foreseen to be attached to the ISS in 2024. The company plans to later use this module as a basis for a standalone station with additional habitation and scientific modules (Axiom Space, 2022).

Despite the lack of detailed information on the design phase and ongoing stage of the developments, the representatives of all four above-mentioned companies expressed their confidence in the initial operations of their space stations to be conducted by the end of this decade, meaning they could be at least partly operational before the decommissioning of the ISS. The real development is however hard to predict in advance.

3. Utilization of Commercial Space Stations

What exactly is the purpose of a manned outpost in Low Earth Orbit and what are the prospects for the utilization of commercial space stations? Until today, space stations are first and foremost utilized by space agencies. Space stations are an ideal analog for long-duration space missions allowing space agencies to better understand the changes in human physiology in space, which would not be possible on Earth or during short-term stays. Space stations are also the ideal platform allowing for the developing, testing, and maturing of space technologies that could be later utilized during orbital operations, interplanetary travel, or for enhancing life on Earth. Additionally, they are invaluable platforms for conducting research activities in space, where both governments and private companies can utilize the presence of the microgravity environment, vacuum, or radiation for basic or applied research in various fields.

Since almost all of the activities conducted on the ISS today could be performed onboard a commercial space station, we will analyze the utilization areas of space stations in closer detail. This will allow us to access the commercial viability of such stations that will orbit the Earth once the ISS is decommissioned.

3.1. Basic and Applied Research

The most important benefit of conducting research in outer space is the presence of an environment that is only very difficult to mimic on Earth – microgravity, vacuum, radiation, or perfect visibility. Utilization of this unique environment allows for novel approaches and the ability to understand processes that could be hardly mimicked on Earth - improving our knowledge and allowing us to later apply findings to various products and processes utilized both in space and on Earth.

The effects of microgravity can be utilized in a number of R&D areas and sectors including pharmaceutical, biotech, chemical industries, and medical research institutions. For example, microgravity is an ideal testbed environment that stimulates the effects of aging and debilitating chronic human diseases in humans and model organisms (function of immune cells in microgravity is suppressed, cell growth accelerated and stem cells, embryos, tumor cells, and organisms all behave differently). Thus, by modeling diseases (e.g., cancer), and observing their altered growth and progression, spaceflight provides opportunities for analysis of these rapid physical changes and for testing of therapeutics. Particularly the research in cancer (and non-cancer) related 3D Tissues/Organoids/Spheroids (TOS) that can be grown in microgravity is an emerging and promising field with enormous implications.

Utilization of a microgravity environment can also support the fight towards the elimination of global hunger and food-related problems humanity is facing, particularly by allowing for invaluable and novel agricultural R&D, and for an innovative and suitable approach toward food production that would not be possible (or would be significantly limited) in normal conditions on Earth. Research in the areas of agriculture and food production can support not only reaching the goal of eliminating hunger but also provide better and healthier nutrition (and therefore the overall health of the population), the transition from dependence on natural resources, waste prevention and can support the fight against climate change, water scarcity and soil degradation (FAO, 2009). The space environment can play an important role in helping us to optimize food production and make it more sustainable. For example, it can be an input or testbed for extreme environment food production, medically optimized food, and personalized high-tech nutrition; it can also be utilized for studying and testing food safety - by researching ingredients formulations and stability, preservatives, colorants, and other food components. Emerging areas that already take advantage of utilizing a microgravity environment include cellular agriculture, which is often considered to be the new era of human sourcing of protein. Israeli company Aleph Pharms successfully 3D-printed beef steak on the ISS made purely from cow muscle cells, further proving that cell-cultured meat can be produced without reliance on local land and water resources - anytime, anywhere, in any condition (AlephPharms, 2022). This marked an important step not only towards the ability to sustainably feed astronauts in space but towards increasing the sustainability of food production on Earth. Likely, the interest of companies in utilizing space environments for health and food-related research will increase and will be an integral part of the revenues of operators of commercial space stations.

3.2. Technology Demonstrations/Validations

Activities conducted beyond the Earth's atmosphere are inherently connected to our desire to explore new frontiers, but it is also a well-acknowledged reality that space activities radically change and improve our lives and bring tangible benefits to society. Neither of these would be possible without continuous improvements of technologies used in space, constantly adapting to novel challenges by advancing already established tools, instruments, and techniques and by creating new ones. Naturally, it is crucial to demonstrate and validate new technologies in a specific space environment before being confident in their full utilization or raising confidence in their further development. With the ever-increasing number of various activities conducted in space, there will be a demand for such technology demonstration and validation platforms, and space stations would be an invaluable platform for such activities allowing for a number of benefits over unmanned platforms.

When we think about entities conducting technology demonstrations and validations in space, naturally, the most active ones are space agencies that constantly aim for improving current technologies to be able to react better to challenges related to exploration, exploitation, and utilization of outer space. Thus, it can be expected that the main customers of technology demonstrators would be space agencies and other governmental agencies. Nevertheless, the participation of the private sector, while always present in some form, has grown significantly in recent years. With the overall increase in the number of commercial entities involved in space activities, there is a larger number of companies developing and producing space technologies and applications than ever before, and there will be an increased demand for technology demonstration/validation platforms.

Technologies that can be demonstrated or validated in space encompass a vast number of fields and concern all parts of the space systems environment. In terms of the construction of the spacecraft itself, the impact of the harsh space environment on materials must be taken into account, particularly the temperature and ultraviolet, thermal, and energized particle radiation. For this reason, platforms offering long-duration exposure to the space environment are an ideal tool for the demonstration or validation of novel materials that could improve the current state-of-the-art. Technology demonstrations and validations in space can be focused on other crucial aspects of spacecraft design, such as thermal control and thermal management systems, power and energy systems, or in-space propulsion. A significant portion of activities is also focused on areas such as robotics, telerobotics, computing, and autonomous systems that play a more important role in space activities than ever before.

If the mission is manned, requirements for incorporated systems and thus for tools, instruments, and applications are much higher, as every manned spacecraft must provide a stable, self-contained micro-environment and systems for revitalizing air, collecting and processing wastewater, or managing solid waste, just to name a few. Demonstrating and validating novel or upgraded technologies that could improve the performance and reliability of such systems is crucial before they can be considered reliable and utilized in crewed missions. In this regard, the space station occupied by humans for a long period presents a unique opportunity to increase the operational availability and long-sought decrease of system mass, consumables and power needs. It would be crucial for any state or private company attempting to go for a mission beyond the Earth's orbit to have a platform where various systems could be tested for a long time and with humans present.

3.3. Additional Utilization Opportunities

Even though the ISS has been orbiting the Earth for over 20 years, there are several fields where progress has so far been limited and the full potential of a space station has not yet been fully unlocked. However, in recent years, there has been tremendous progress in the maturation of a number of promising areas of space activities with enormous implications for advancing spaceflight but also for terrestrial applications. In this subchapter, we will take a closer look at in-space manufacturing and we will also take a closer look at space tourism which is coming to the forefront of attention.

First, with the advancements of 3D printing and additive manufacturing on Earth, significant developments have been made towards in-space manufacturing (encompassing on-demand fabrication, repair, and recycling), which is seen as a solution toward more sustainable, flexible missions supporting critical systems, habitats but also mission logistics and maintenance. However, in-space manufacturing can serve non-space purposes too. One example of in-space manufacturing that gains attention is the production of high-quality ZBLAN optical fibers in microgravity that are difficult to produce on Earth due to the formation of impurities in the fibers resulting from gravity-driven forces. Taking into account the utilization of these fibers in telecommunications, remote sensing, and laser development, the commercial potential and value of such products and thus in-space manufacturing are obvious. Examples like this mean that more companies involved in non-space businesses might become interested in the value space environment offers, and potentially connect some of their R&D activities with the utilization of space environment for future benefits (ISS National Lab, 2019). In-space manufacturing would likely be among the main utilization areas of the commercial space station where the crew will be able to take part in the manufacturing processes.

Another specific utilization area is space tourism. The prospect of sending humans to space for not scientific but touristic purposes is as old as the spaceflight itself. The International Space Station has been occupied by several non-professional astronauts that paid large amounts of money for their trip to Earth’s manned outpost. The first was American businessman Denis Tito who spent 8 days onboard the ISS in 2001 and paid some $20 million to a U.S.-based company called Space Adventures. Since then, few private astronauts followed and visited the ISS. Nevertheless, space tourism on the ISS is still in its infancy and likely never will become a routine. In recent years this has changed and this year we have seen the first fully commercial mission to the ISS, Axiom-1. Each of the private astronauts paid around $50 million for a ticket, which still seems too much to create a sustainable demand. Despite this, commercial actors foresee space tourism to be a large part of their revenues from operating space stations. What could pose a challenge for these operators is the gradual maturation of suborbital spaceflights which already attract paying customers. Such suborbital flights will be significantly cheaper than the stay on a space station and the companies offering these flights will be well-established by the time the first commercial space station opens to business. Additionally, we can expect more short-duration flight opportunities in manned spacecraft, similar to the recent Inspiration4 mission, posing additional competition to space station tourism.

3. Can Commercial Space Stations Become A Viable Business Model?

As noted above, space stations have the prospect to become an invaluable platform for both space-for-space and space-for-Earth applications and both public and private entities are interested in their prospective utilization. However, simply acknowledging that such interest exists is not enough to evaluate the viability of commercial space stations.

It is very difficult to estimate the cost of development, cost of operation, and the revenue from commercial space stations - experience from the past is not relevant anymore and the business model utilized by commercial space actors will be radically different from those of Mir, ISS, or Tiangong. What gives positive prospects to the future commercial space stations is the fact that we now have regular access to space and the costs of launches to LEO are lower than ever. There are private companies capable of flying cargo and humans to LEO, including the space station. We can expect that competition (e.g., between Boeing’s Starliner and SpaceX’s Crew Dragon) together with the maturation of space technologies including launchers will gradually drive the prices down, making the transit to and operations of the commercial space stations more viable.

Understandably, the key to the viability of any commercial space station would be the ability of companies to minimize their construction and operation costs. As noted, both can be significantly lower than in the past - the question is to what extent. According to an article published on the internet, the CEO of Axiom Space noted that the company *"could replicate the ISS's capabilities at an annual expense of $1.2 billion, about half the current operating cost"* (Fernholz, 2022). However, as noted earlier, these costs are very hard to determine in advance.

While we can predict with certainty that both development and operations of commercial space stations will be significantly lower than in the past, what is important is the revenue that such stations can generate. In a report from 2017, it was estimated that *"the total annualized revenues from activities conducted on a space station is $455 million and the high estimate is $1,187 million"* (Lal, 2018). This figure includes revenue from in-space manufacturing, microgravity research, technology demonstration, supporting satellite infrastructure, space tourism, visits of professional astronauts, and commercial activities such as advertising or filmmaking. To compare these revenues with the current revenues of private companies that offer services for research and technology demonstrations onboard the ISS, Nanoracks - which is the most active commercial entity operating onboard the ISS - notes that its revenue to date has been around $40 million (Manber, 2018).

These uncertainties would likely be a hurdle for attracting private investors to invest in the development and operation of commercial space stations. In this regard, the report from 2017 notes that *"projections of revenues and costs are so uncertain that* [venture capital] *would have no interest in financing a space station until projected revenues from these activities show signs of materializing"* (Lal, 2018). Even if Axiom and other companies are successful in their efforts to minimize expenses, taking into account the federal report quoted above, it seems it would still be difficult for companies to generate significant profit in the early years of business.

Connected to the uncertainty about revenues from operating a private space station is the issue of a still rather low demand for the utilization of the space environment, including the space station. The lack of demand can be caused by several factors. As Scimemi notes, this lack of demand is caused first and foremost by various barriers, including restrictions and difficult regulations and procedures, or uncertainty about the total price for transportation and operations. What is also problematic is the relatively low awareness of the non-space sector about the benefits of the utilization of space environment and space stations in particular (Scimemi, 2015). Thus, it is absolutely critical that NASA and other space agencies work on raising awareness about the benefits commercial space station would offer namely to space-to-Earth applications, and educating the general population and business executives on how the utilization of the space environment can help companies in achieving their business or R&D goals. These efforts must gain momentum as soon as possible before the commercial stations are in orbit. Despite any efforts, it shall be noted that it would be likely difficult to create a sustainable demand to an extent that more than one commercial space station is profitable in the early years of their operations.

In connection with raising awareness about the utilization of the space environment, NASA should focus on establishing a program similar to the ISS National Lab that would promote commercial activities on the ISS such as tourism or advertising before it is decommissioned. Since 2019, NASA allows private companies to launch crewed missions to the ISS focusing on for-profit activities, including marketing and filmmaking. Despite this important change in policy, NASA lacks a dedicated arm that would facilitate these activities. While certainly not a priority, it is important that NASA considers the establishment of such an arm if it is to maximize the awareness about the value of space stations for commercial entities and help create and stimulate further commercial demand in areas other than research and/or technology demonstrations.

We could say that the success of any commercial space station will depend on the ability of its operator to establish cooperation with states that have created a market for the utilization of the space station over the years, particularly those currently serving as the ISS implementation partners. None of the partners but the U.S. have a stable concept of post-ISS operations, opening the door for the commercial space station to capture the demand created in their markets. The biggest would likely be Europe and Japan.

ESA currently lacks a formal plan for operations in LEO after the ISS is decommissioned. The head of ESA's Washington office noted earlier this year that *"ESA will probably not be in a position to buy commercial services from U.S. providers for its research activities in LEO or to fly its astronauts"* because, as she noted, *"this will probably not be acceptable for our member states"* (Foust, 2022). The reason for this is the ESA's policy to support domestic space industry and contract services from the domestic providers. If European unmanned platforms where experiments could be conducted exist, these will likely be prioritized. One solution could be if NASA serves as an intermediary between ESA and operators of commercial space stations, yet this setup would likely be difficult from a long-term perspective.

Another ISS implementation partner, Japan, also thinks about the strategies for post-ISS years. The most recent strategy by JAXA presents three options on how Japan can sustain experiments in LEO. First would be the development of a small-scale experiment service, either as a manned or unmanned platform. The second option is built around the potential utilization of foreign platforms. The third option directly concerns the future U.S. commercial space stations, suggesting that JAXA and Japanese companies could procure various services from the U.S. commercial entities (JAXA, 2017).

Following up on the abovementioned, apart from the lack of sustainable demand, one major challenge for the commercial space station would be the existence of alternative platforms - and this will be amplified by the fact that the ISS' implementation partners and other spacefaring and emerging spacefaring nations will be focusing on the development of such indigenous platforms upon the decommissioning of the ISS. Separate, unmanned platforms either in a form of free-flying capsules or satellites will be created for research and technology demonstrations, but also for services like in-space manufacturing. These platforms will make it relatively difficult for space stations to become established as a viable and cost-effective business model for the aforementioned activities. In this regard, the main advantage of space stations on which they need to build their business model is the promise of a longer stay in space and the ability to have humans interact with the experiment/activity.

Governments will likely remain the most important customers of commercial space stations and the commercial space stations will depend on government contracts in the early years of their operations. However, with such a boost in demand that government agencies will produce, could these space stations remain viable once the focus of federal agencies shifts further from activities in LEO? Shall we expect that the U.S. government will support commercial space stations with funding even if they are unable to become profitable for a longer period? In the light of the political and symbolic value that lies in the utilization of a manned outpost in LEO and because China as the main competitor of the U.S. in space will remain the only state operating a space station, prolonged support of a commercial space station is likely. However, it is questionable whether it would be viable for NASA to support more commercial space stations at once, particularly if their character and utilization areas are similar because no additional marginal value would be gained from such support.

4. Conclusion

After the decommissioning of the ISS, the door will open to the era of commercial space stations. Despite uncertainties related to costs and revenues that are only very difficult to predict, space stations will remain to be an invaluable platform with a number of utilization opportunities, such as basic and applied research, technology demonstrations, tourism, or in-space manufacturing. In this regard, commercial space stations will be able to deliver all the benefits generated by the ISS today and simultaneously allow for significantly enhanced affordability. This enhanced affordability is connected to the maturation of products & processes, smaller size, more effective operations, and the capability to fly humans and cargo to LEO on a regular basis.

The actual success of these stations will depend on several factors. First of all, it will depend on how the ISS will be utilized in the last decade of its operational life and on how well NASA and other implementation partners will raise the awareness of both space and non-space sectors about the benefits of the space environment and about possible utilization of manned outposts in LEO. It will also depend on the interest of space agencies themselves in the utilization of manned platforms in LEO in the future. While we can expect that space agencies will be the main customer of any of the commercial station, the actual interest is hard to predict because the future of space activities conducted by states will likely be beyond LEO, and NASA and other space agencies plan on developing space stations in lunar orbit and beyond. The success of commercial stations will also depend on the number and capabilities of various unmanned platforms for research, technology demonstrations, or manufacturing that will be the direct competitor of space stations in a number of areas. Furthermore, the success of commercial stations will depend on the level of the maturation of processes and technologies. It can be expected that such maturation will lower not only the cost of development and construction of private stations but also the cost of their operations. The crucial determinant of the economic viability of commercial space stations will be the ability to minimize operation costs and thus the ability to provide more cost-effective services than competitors.

Due to the challenges related to the possible lack of demand for utilization of space stations by entities other than space agencies, it could be very challenging for companies to become profitable if there are several commercial space stations in orbit that serve the same function. Despite this, we can predict that in order for any private space station to become profitable, it should be a multi-purpose platform allowing for activities of various character – and various stations will thus indeed be providing similar services. In this regard, we also need to acknowledge the competition posed by the Chinese Tiangong station which will be well-established and open to international customers long before the first commercial stations become operational. Overall, we shall expect a significant first-mover advantage – the first commercial space station that will become open for business will have the best prospects for capturing the demand for utilization of space station generated by decades of operations of the International Space Station.

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"New Space – Space 4.0" Competition for Turkey

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1. Introduction

On July 17th, 1975, docking of Apollo and Soyuz spacecrafts in space, started a new era in the space race between the USSR and the USA. In the last 40 years, dozens of other countries have been involved in the use of space for navigation, communication and observation purposes. As we approach 2030, it seems that the fuse of a new space race, in which the low earth orbit is the focal point, has been ignited.

The race which is called as "New Space" by some researchers who closely follow the industry, has become the entrepreneurs' and global companies' industry which is supported by venture capital seeking a return, and tries to profit from innovative products or services developed in or for space and primarily targets commercial customers. (New Space Global, 2021).

The race which is also called "Space 4.0" by some other researchers (Wörner, 2016); as a result of years of development activities, it has created a new space infrastructure that provides access to space on an unprecedented scale, along with reusable launch vehicles that significantly reduce launch costs. With this infrastructure, it seems certain that the existing markets for satellite-based communication, navigation and observation services will increase and allow new businesses and industries to expand. For this reason, "Alternative Space", "Entrepreneur Space" and other names have been used to describe space development approaches in this new era (Hobby Space, 2021). All individuals, businesses and organizations who are working to open the space frontier to human habitation through economic development have also become new players in this new race.

"New Space" or "Space 4.0" or whatever we call it, in this new race that started in the world, new opportunities and possibilities for communication, navigation and ground observation

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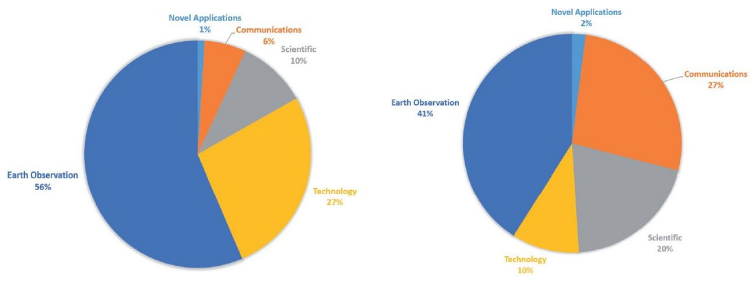
applications, are starting to come to the fore and increasing day by day which led by private companies and venture capital, supported by new technological opportunities.

2. Current Situation and Trends in the World

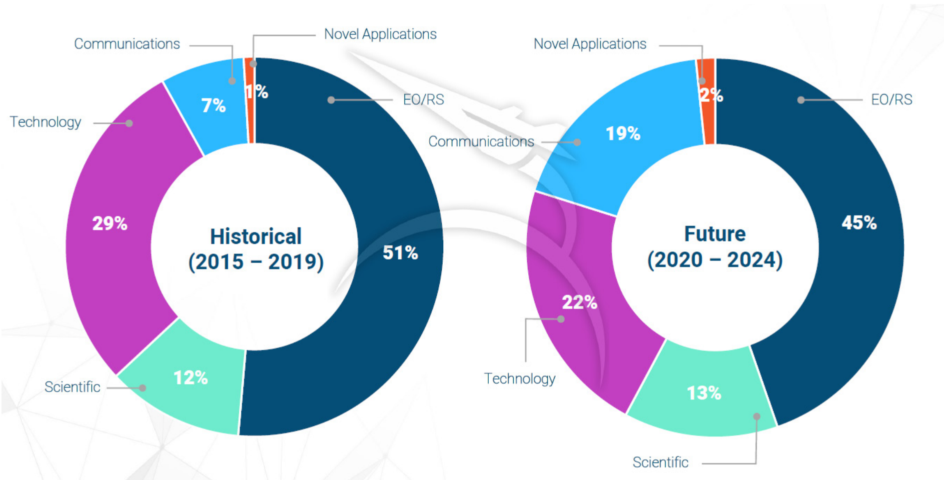
Historically, the first companies that tried to provide communication services via low earth orbit satellites could not grow enough or had to go bankrupt due to not being well launched, not providing high-speed access, attracting few users as a result, and being hindered by high costs. Iridium, which still offers satellite phone services, filed for bankruptcy protection in 1999 (Gertner, 2016). Globalstar, whose client platforms are oil-mining, utilities, forestry, fisheries, military, transportation and emergency applications, faced the same situation in 2002 (Rae-Dupree, 2004). Although it continued its existence with its second-generation satellites later on, it has never been able to capture the desired market share. Teledesic company also declared the cost of the project as 10 Billion USD, but as it could not find an investor, it officially suspended its satellite construction works in October 2002 and terminated its activities (Farrar, 2022). Although Gonets satellites, a Russia-based service, transmit messaging, M2M (machine-machine) communication and data from the GLONASS (Russian Position Tracking Satellite) satellites to the ground, its usage area has been limited to Russia (Zak, 2020).

As a result of all these developments, the operators that have been active in this field from the past to the present have actually come to the fore as unsuccessful attempts. However, the fact that low earth orbit satellites enable uninterrupted communication with lower delays in order to meet the increasing user needs and demands all over the globalizing world today brought up the issues of establishing communication networks on this infrastructure. It is thought that especially the IoT (Internet of Things) applications brought by 5G technology will both gain an important place as a market (Telkoder, 2021) and lead to a radical change in existing infrastructures (Khodashenas et al., 2019). At this point, the work of the world's leading technology companies, which have plans to establish infrastructure over low earth orbit satellites, comes to the agenda of the world more and more every day. In addition, many companies are working to bring 5G technology together with satellite communication infrastructure (Corici, et al., 2020). Especially when we look at the number of mini-satellites weighing 1- 50 Kg, it is observed that there has been a 30-fold increase in the last ten years (Del Pozzo & Williams, 2020). When we examine the satellites in this class according to their application areas, it is seen that there is a proportional increase in the share of satellites produced for communication purposes more than 4 times (See: Graph-1) compared to some studies, while in some studies there is a prediction of an increase close to 3 times (See: Graph-2).



2014 – 2018 2019 - 2023

Graph 1. Satellites according to application areas (1 - 50 Kg) (Camps, 2019)



Graph 2. Satellites according to application areas (1 - 50 Kg) (Del Pozzo and Williams, 2021)

In line with these developments, new businesses of different sizes enter the market every day in the field of New Space (See: Appendix). When companies established with venture capital are also considered, it is seen that this number exceeds 250 and approximately half of them are based in the USA (See: Figure-1). At the same time, when the work areas of these enterprises are examined, it is seen that the most prominent applications are those in the field of IoT (See: Graph-3). However, one of the most important components of New Space is the provision of services by providing access to space with low-cost cube satellites. The number of launches of these cube satellites, which came to the fore for the first time in 1999, has approached two thousand today (See: Figure-2).

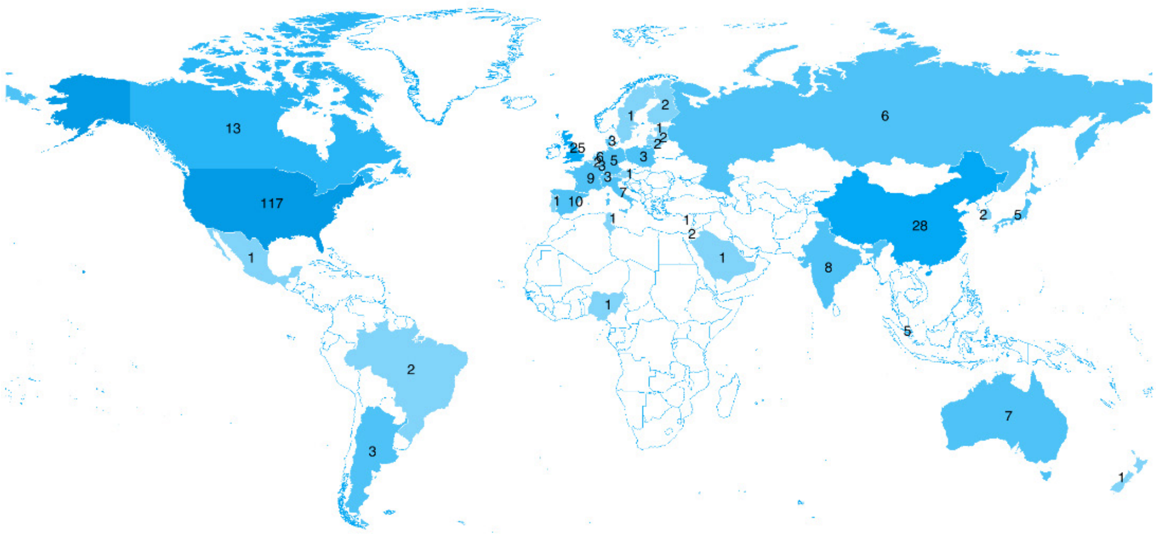


Figure 1: Number of businesses established in the New Space area (NewSpace Index, 2022)

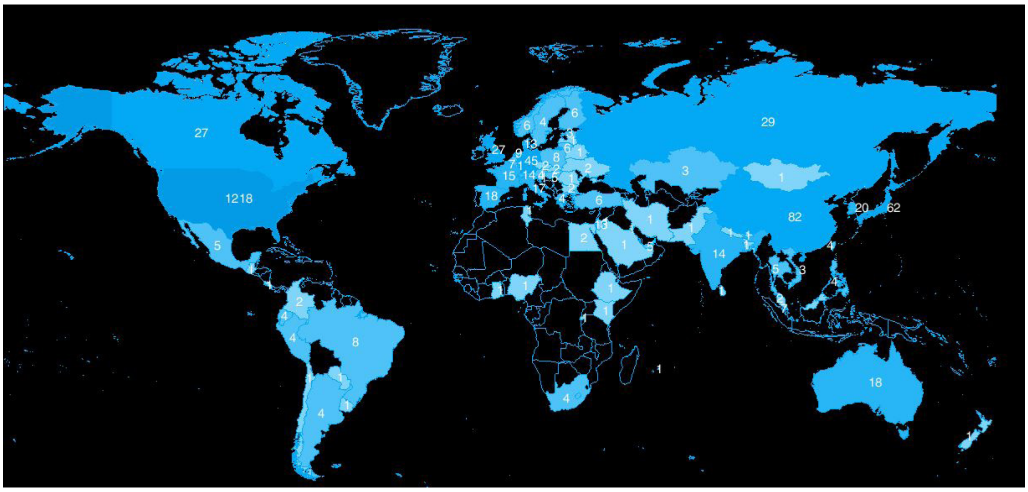
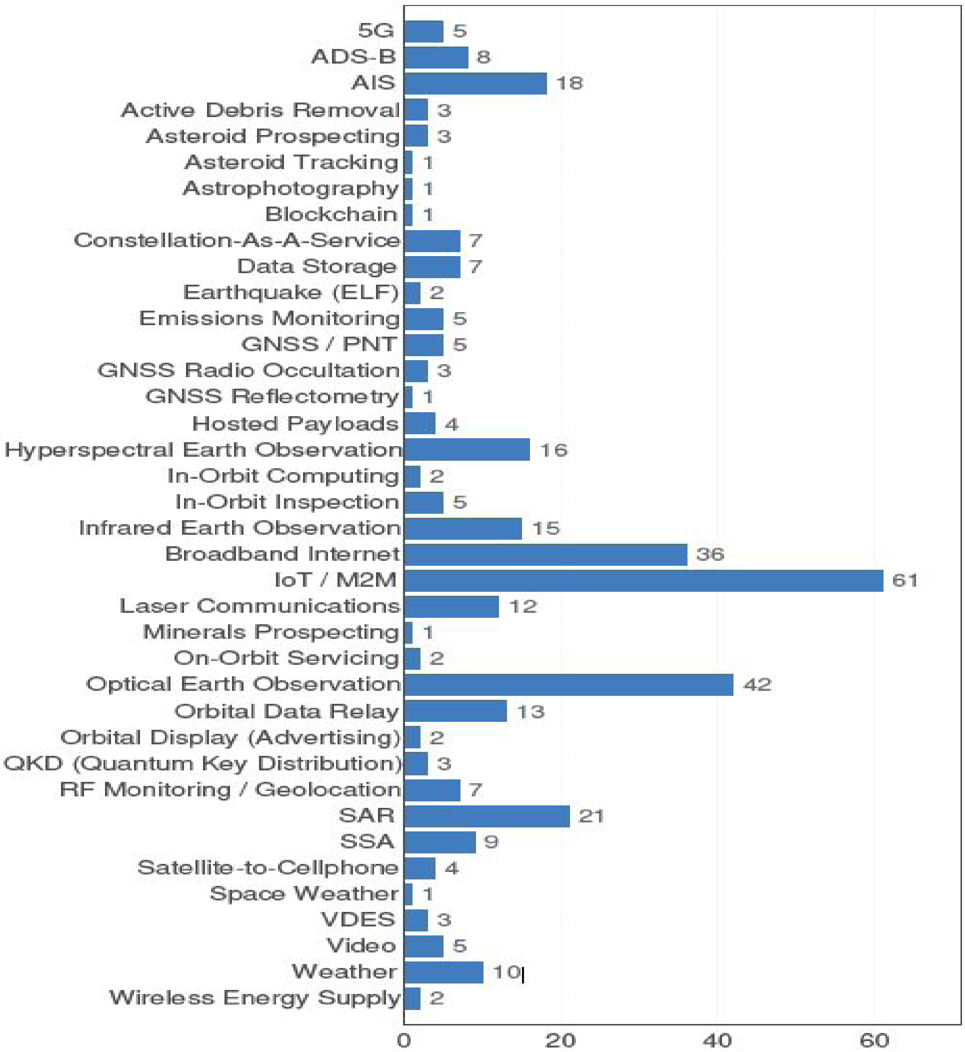
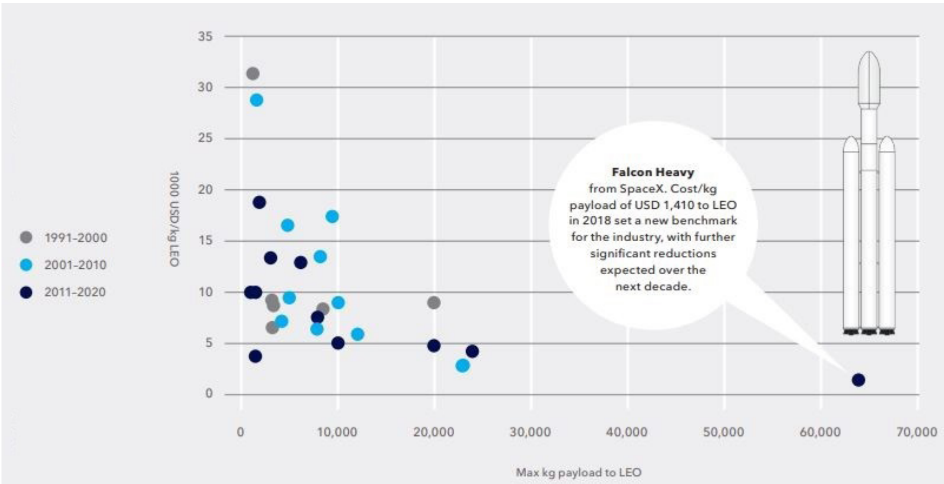


Figure 2. Number of cube satellites launched into space by country (Nanosats Database, 2022)



Graph 3. Mini-satellite fleets by application areas (Kulu, 2021)

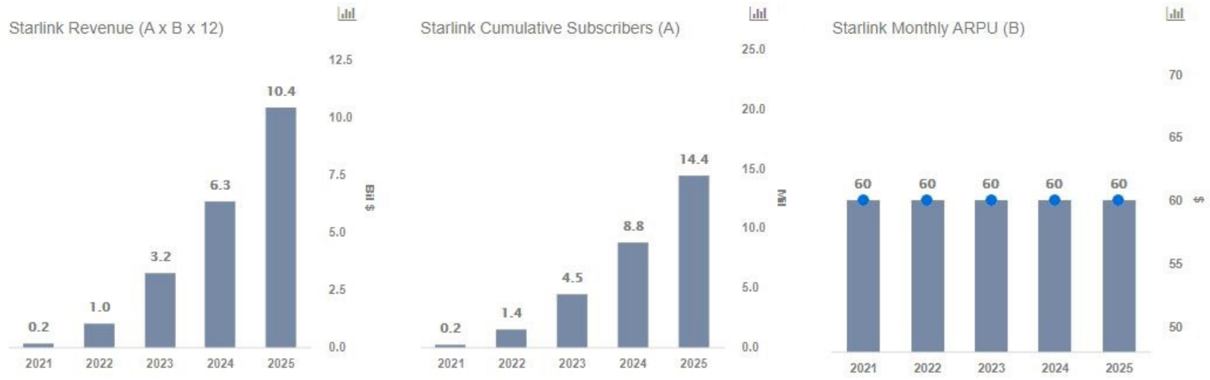
With the new capabilities the humans will have, by 2030 it is estimated that the number of satellites planned to be launched all over the world will exceed ten thousand, together with the decrease in unit costs (See: Graph-4) (Timeline of Spaceflight, 2021). This means that the number of active satellites in orbit today will increase fivefold. A significant portion of these new satellites are planned for 5G and IoT (Internet of Things) applications. A large number of studies are currently being carried out, especially for the delivery of 5G applications via satellites and the evolution of communication infrastructures in this direction (Khalili, Khodashenas, Fernandez, Guija, Liolis, Politis, Atkinson, Cahill, King, Kavanagh, Jou & Vidal, 2019). Thus, it is expected that small satellite fleets that provide real-time broadband communication on a global basis will reach a structure that complements geostationary satellites and have a global impact by 2030. (Det Norske Veritas GL AS, 2021). The trend towards small satellites has not only reduced the costs of constructing, launching and operating satellites, but has also made viable faster and more flexible deployed large fleets of satellites in space (Lag & Scarnato, 2021).



Graph 4. Satellite launch costs per kilogram (FAA, 2018)

After the technological and economic progress achieved, satellite operators led by companies such as SpaceX, OneWeb, Telesat and O3b have started to create satellite fleets of unprecedented size in recent years. With these fleets, which the satellite numbers are expressed in thousands, the world is knitted like a web and it became possible to provide high-speed access services to all parts of the world.

In particular, the fact that SpaceX has started to use the beta version as of November 2020 has made the world public believe more strongly in the feasibility of these projects. The idea for SpaceX's communications satellite network was announced in January 2015. With its own launch rocket Falcon 9, 60 Starlink satellites per launch are launched in biweekly periods. The entire system is planned to be completed with approximately 42,000 satellites. In this process, SpaceX uses some satellites to demonstrate and verify new technologies. SpaceX aimed to provide internet service to underserved regions, and it aims to earn over 10 billion USD annually by 2025 from the project, which will spend approximately 30 billion dollars (See Graph-5). In addition to its commercial services, some of the capacity of the Starlink system is planned to be used for military communication purposes in the future.



Graph 5. Number of subscribers and revenue forecast of Starlink Project for 2021 – 2025 (Trefis Collaborate on Forecasts, 2021)

Canada-based TELESAT stated in 2016 that it aims to launch a satellite fleet called TELESAT LEO, consisting of 120 satellites that will operate in low earth orbit. In 2020, they aimed for this satellite set to consist of 1600 satellites. It has announced that it has signed a contract with Thales Alenia Space in 2021 with a size of 3 billion USD, which includes 298 satellites and related ground services. The company plans to offer low-latency internet usage and 5G infrastructure service in rural and urban areas by 2023 (Space News, 2021).

O3b, which was purchased by Luxembourg-based SES satellite operator in 2016, is a company that currently provides voice and data communication to mobile devices as well as internet to mobile operators via middle earth orbit satellites. The name O3b (Other 3 billion) has been put to represent 3 billion people who have not yet received broadband internet service. It is the first operator to start providing broadband communication services in the New Space race, and made an agreement with the US Department of Defense in 2018 to provide low-latency, high-speed satellite communications (SES, 2018).

Since the UK left the European Galileo Navigation System in 2018 and also, European Union in 2020, it is considered important to be a partner in OneWeb in terms of continuing its satellite communication and navigation projects independently from European countries. However, it does not seem possible that it will be completely independent from Europe due to making a partnership with Airbus by founding the company of “OneWeb Satellites” to produce the OneWeb satellites.

In addition to these four companies, different companies such as Kepler, Kuiper and Hongyun are expected to start their services in this area in the future.

3. Current Situation and Trends in Turkey

From the perspective of Turkey, it has always been on Turkey’s agenda to take place in this high-tech and strategic field, which it stepped into the sector in the 90s. On the way that it set out with this goal, it first started to operate by purchasing service and then outsourcing its own satellite, and finally it has come to the point of producing its own observation satellites and communication satellites. In this nearly thirty-year period that has passed, Turkey has now come to a position to direct its own satellite projects and has developed various cooperation models through its institutions/organizations in this regard. Each project realized with both national and international cooperations has further increased Turkey's experience in this sector. At this point, "Turkey Space Agency (TUA)" was established in 2018 (Official Gazette, 2018) and "National Space Program (Turkish Space Agency, 2021) has been announced as of February 2021.

This is a subject that Turkey will frequently encounter in the future. Since both Turkey and the entire world, it is highly likely to experience new disruptions in the communication sector which is a new development as well as a threat and an opportunity.

4. Opportunities and Potentials

Due to the society's need for continuous information over large geographies, the need for information from high-precision satellites is increasing. This need can only be met by re-evaluating traditional solutions. It is foreseen that the satellite fleets, which provide service in low earth orbit and consist of many small satellites, will bring more capacity and reduce prices due to competition.

Communication infrastructures in which low earth orbit satellites are used generally consist of space segment, ground segment and user segment. In the space segment, there is a fleet of satellites that continuously scan the world. In the ground segment there are gateways and for the user segment there are terminals. Satellites that are constantly in motion and can see a certain area for a short time will begin to communicate with each other over time with inter-satellite communication subsystems called "inter-satellite link (ISL)". In addition, the internet infrastructure, which is accessed over the ground segment, is transmitted to user terminals via satellites.

A lower amount of energy is required to put low earth orbit satellites into the orbit. High bandwidth and low communication delay can be offered with these satellites. In addition, service is provided with smaller power and antenna sizes, and costs are significantly reduced.

However, despite the increasing of small satellites, larger and high-sensitivity satellites will be needed to also be used as a base/reference for small satellite data quality assurance. There also appears to be great potential in combining new data streams from small satellites with high-precision data from large satellites.

5. Risk and Threats

Although there seems to be a trend towards these new developments around the world, there are many hurdles to overcome for a satellite fleet of small satellites. First, the project must be fully funded, then regulatory approvals must be obtained and frequencies must be coordinated to ensure safe coexistence with other satellite systems. Then, within the framework of the project, many satellites need to be launched regularly, on time and economically. It will not be possible to start service until most of the satellites are launched and become operational. Complex and high-tech technical requirements such as the design of advanced antennas and modems, the development of user equipment and the short life of satellites pose a serious risk. Many startups and investors either failed before they started or had to deal with huge financial risks because they did not pay enough attention to these risks (Lag & Scarnato, 2021).

In addition to financial risks, some technical difficulties and problems are another risk area to be faced. Even after a fleet of satellites is up and running, "interoperability" issues will come to the fore as the number of small satellites orbiting the Earth increases. This is because radio frequencies need to be carefully managed not only to prevent interference between new low-orbit systems, but also to prevent previously in-orbit systems in other orbits operating in the same or adjacent frequency bands.

In addition to the financial difficulties and interoperability difficulties of satellites, a general concern is that many small satellites are unable to perform any collision avoidance or end-of-life destruction maneuvers due to the lack of propulsion systems, thus posing a risk to other satellites in the same orbit. In order to eliminate this risk, countermeasures such as collision detection and avoidance strategies should be developed. This will put a serious burden on system costs.

Although technological developments are very rapid, international regulatory studies are relatively behind. On a national scale, it is a fact that most countries are not yet ready for this new situation. This means uncertainty for both existing and new ventures. However, with the overcoming of these obstacles, it seems very possible that low earth orbit satellite fleets will create new technological, economic and social opportunities for the whole world.

6. Conclusion and Evaluation

For decades, public and private sector representatives in the satellite communications industry have been discussing the impact of Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO) satellites in communication. Existing discussions on cost, coverage, sustainability and various other issues continue in the light of the solutions presented and the constraints experienced. In line with technological advances and changing needs, these discussions change in content but continue.

Navigation applications, especially radio and television broadcasting, have a longer delay time due to their high altitude. In addition, despite their wide coverage, they are not sufficient on their own in terms of providing services to the whole world. For this reason, many critical communications are provided over wired systems or LEO constellations, which provide faster connectivity. The importance of LEO satellites has become more prominent in the last ten years in line with the changing needs / demands with the technological advances and especially the developments in the field of 5G / IoT. At this point, it is useful to examine the services provided over LEO satellites by dividing them into broadband and narrowband. Because, the technical capabilities and financial needs required in broadband communication services depend on the realization of large-scale projects. However, in narrowband communication, it stands out as a more effective and economical starting point in order to catch up with technology and gain competence with IoT applications. It seems possible to gain economic benefits by using technology in many social and public areas in this period when satellite fleets in mini-satellite classes are started to be established in the world in general. The earnings to be made at this stage, which can be a new turning point in the space adventure of mankind, can be used as a tool to deal with global problems such as climate change, demographic development, migration, resource shortage, conflicts and disasters, energy, digital divide and health. At the very beginning of this process, a critical period has begun for decision makers. Making the right decisions and policies in this critical period is to inspire and motivate future generations (Wörner, 2016).

In broadband services, it is highly imperative that necessary steps be taken so that Turkey is not caught unprepared and is not late. However, at this point, as can be seen in the examples in the world, national and/or international cooperation with public and private sector representatives is needed because the structures of the projects carried out and therefore their financial needs are quite large.

It seems extremely important to correct positioning of the issue by all relevant stakeholders in the country; creating awareness, developing solutions for this new situation and finally taking the steps promptly and correctly by developing a suitable business model for Turkey. In this context, it has a great importance to implement strategies and policies for the development of domestic and national products that can compete in the international arena.

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Appendix: Companies in the Small Satellite Market (2014 - 2024) (Curzi, Modenini & Tortora, 2020)

Company	No. Sats	Sats Size	Orbit	Year (Operative)
Globalstar Inc.	48	Medium	LEO	?
Iridium Inc. - Aieron	75	Medium	LEO	2019
OneWeb	648	Mini	LEO	?
O3b (SES mPower)	27	Medium	MEO	2021
Orbcomm	11	Mini	LEO	2015
Gonets SS (Roscosmos)	11	Mini	LEO	2014
SpaceX	4425	Mini	LEO	2024
Telesat	117		LEO	2021
BlackSky Global	60	Micro	LEO	2021
SPIRE Global	175	Nano	LEO	2020
Planet Labs	5		LEO	2008
Planet Labs	12	Nano	LEO	2015
Planet Labs	20	Nano	LEO	2016
Planet Labs	12	Nano	LEO	2016
Planet Labs	48	Nano	LEO	2017
Planet Labs (Terra Bella)	15	Micro	LEO	2017
Kepler Communications, Inc.	140	Nano	LEO	2022
Kineis	25	Micro	LEO	2022
ExactEarth	67	Nano	LEO	2018
Planet Labs	88	Nano	LEO	2017
Planet Labs	20	Nano	LEO	2019
Astro Digital	?	Micro	LEO	?
BRITE partners	5	Nano		2014
GHGSat, Inc.	3	Micro		2020
Satellogic	60	Micro	LEO	2020
Space View	16	Medium	LEO	2022
CASIC	156		LEO	2025
Leosat (Thales Alenia)	108	Large	LEO	*

Company	No. Sats	Sats Size	Orbit	Year (Operative)
Cloud Constellation Corp.	10		LEO	?
Transcelestial	?	Nano	LEO	?
Kleos Space	4		LEO	2019
HyperSat	6	Micro	LEO	*
Galaxy space	1000		LEO	?
ChinaRS	10	Micro	LEO	2021
Laser fleet	?		LEO	2022
XpressSAR	4			2022
Orbital oracle Technologies	100	Nano	LEO	2024
Methera Global	16		MEO	2022
Trident Space	48	Mini	LEO	2026
VEOWARE	?		LEO	2022
Umbra Lab	12		LEO	?
EarthNow	?		LEO	?
OQ Technology	?	Nano		?
Tekever	12	Micro	LEO	?
KLEO Connect	300		LEO	?
NorStar NorthStar	40	Medium		2021
Laser Light	12		MEO	2020
Koolock	?			?
ROSCOSMOS	10			2023

Company	No. Sats	Sats Size	Orbit	Year (Operative)
Hypercubes	?	Nano		?
ROSCOSMOS	288		LEO	2025
B612 Foundation	?	Micro		?
NASA	8	Micro	LEO	2017
CG Satellite	60		LEO	2020
Amazon	3236		LEO	?
Viasat	20		MEO	*
Iridium Inc.	66		LEO	2000
Boing	2956			*
Samsung	4600		LEO	*
Yaliny	135			*
Globalstart inc.	48		LEO	1999
OmniEarth	18		LEO	*
COMMStellation	72	Micro	LEO	*
Myriota	50	Nano	LEO	?
ADASpace	192		LEO	2021
Ubiquitilink	24			2021
ZeroG Lab	132		LEO	?
Stara Space	?	Nano	LEO	?
Hyperion	?	Nano	LEO	?
Horizon Technologies	10	Nano	LEO	?
SpaceFab.US	16	Nano		?
HEO Robotics	12	Nano	HEO	?
Artemis Space	?	Nano		?
Pixxel	?	Nano	?	?
US space Force	75	Large	MEO	1993
VKS	24	Large	MEO	1995
ESA	30	Medium	MEO	2020
CNSA	35	Large	MEO	2020

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Türkiye's Space Economy Preparation Roadmap

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1.Introduction

After the global crisis in 2008, the budget deficits of the treasury of many countries increased, and this situation, together with the COVID-19 pandemic, created greater pressure on public resources. Although there has been an improvement in the budget of the United States (USA) Space Agency NASA, which fell after 2008 for this reason, in recent years, it has not yet reached the high budget rates as before 1969. In addition to the budget, in order not to fall behind in the competition, due to the fact that each country can copy each other cheaper and faster with global technological developments, other forces and searches are in the agenda. With the facilitating and accelerating effect of the contribution of Industry 4.0 technologies and the increase in the appetite of other countries in this field, commercial space studies have gained more momentum due to these two mainstream developments. On the other hand, the Cold War period, which was re-entered with the last Russian-Ukrainian War, brought competition to the fore again in the presence of countries here, as well as the threats that may come from the above atmosphere, similar to the previous one. With the presidential decision signed by Trump in the last term of his presidency, the necessity of detailed investigation and disclosure of the records of the U.S. Navy on unidentified objects by the Pentagon has brought the interest in space more to the forefront, at the size of the magazine with the first commercial space flights with space tourism and the first civilian astronauts. In addition to the establishment of a space army by various countries, one of the reasons for the increase in the number of commercial space companies working in different fields in different countries is not only technical issues such as orbit, launch, capsule, rocket, but also attractive subjects such as space mining, Exoplanet and maybe water at many points in space, including the Solar System. It is seen that there are also potential opportunities for the existence of life.

The fact that Türkiye's F-35 aircraft project was blocked by the Pentagon due to S-400 missiles, F-16 aircraft demand remained in the approval process in the U.S. Senate, and the

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success of Turkish (Bayraktar) Drones in the Russia-Ukraine War are actually living examples of the vision of "The Future is in the Skies". Despite Russia's threat to use nuclear weapons, the tests of the U.S. Space Forces to destroy missiles at the atmosphere level seem like international relations and astropolitics topics, but are actually a part of the space industry from the defense industry dimension.

In this conceptual study, in the light of the reflection of Türkiye's commercial space activities in social sciences, the steps to be taken in subjects such as economy, finance, trade, banking, business, public and private sector and the topics that are beneficial to be done academically are discussed. It will be an important start for "Space Homeland" to implement the topics suggested in this study with a comprehensive road map in a project, in order to give an idea about the work of the relevant institutions and the regulation in line with the plans in coordination with the TUA.

2. Literature Review

2.1. General Data on Higher Education and Academia in Türkiye

The increase in commercial space activities has accelerated the growth of the industry in space businesses, which were monopolized by the states in the past. On the other hand, with the newly emerging commercial space, it is not easy to predict the speed and the size of the space economy in spacetime. In academia, on the other hand, studies on social sciences and especially on economics and finance are seen to be more limited in terms of space, where the technical, natural and positive sciences are more prominent. Since the subject of the study is the shaping of Türkiye's space economy activities with suggestions for the future, it would be more appropriate to start with a small analysis summary of the university departments related to space from the YÖK Atlas, YÖK Statistics site and the YÖK Executive Board decision before the literature review.

The data obtained from the YÖK Undergraduate Atlas for the period 2021-2022 of this study are as follows (YÖK ATLAS, YÖK, https://yokatlas.yok.gov.tr/, 2022):

a. There are five universities with departments of Astronomy and Space Sciences and they are under the Faculty of Science.

b. There are two universities with Space Sciences and Technologies departments and they are under the Faculty of Science.

c. There are nine universities with Aerospace Engineering departments, and they are under the Faculty of Aeronautics and Astronautics and the Faculty of Engineering.

d. There are three universities with Aerospace Engineering departments and they are under the Faculty of Aeronautics and Astronautics.

e. There is only one university with a Space and Satellite Engineering department and it is under the Faculty of Aeronautics and Astronautics.

In the light of these data, when compared with the YÖK statistics page, as of 2022, only 19 of 209 universities in Türkiye have a space-related department (YÖK İstatistik, https://istatistik.

yok.gov.tr/, 2022), it was observed that only one space-related faculty was not found in all of these 19 universities, and that the departments related to space were still handled differently despite the simplifications made.

One thing to consider when evaluating the number of these departments related to space studies is as follows: With the YÖK Executive Board meeting and decision held on 11.03.2020, it has been decided to use new department names as of 2020 YKS in order to simplify the name confusion in undergraduate programs (YÖK Meeting Notes, https://www.yok.gov.tr/, 2020, ET:2022). According to this;

a. Astronomy and Space Sciences, Astronomy, Astronomy and Astrophysics Departments as Astronomy and Space Sciences

b. Space Sciences and Technologies, Space Sciences and Its Technologies as Space Sciences and Technologies

c. Aviation and Space Engineering, Aircraft and Space Engineering, Aircraft and Satellite Engineering, Space and Satellite Engineering Departments as Aviation and Space Engineering

d. Space Engineering is used by remaining the same.

As it can be seen, there is no section on social sciences between these departments. Therefore, higher education in space or space related social sciences is taken into consideration in parallel with the world in natural sciences and / or engineering. In this way, multidisciplinary studies should be shifted to an interdisciplinary dimension and should be expected for space economy.

In Dergipark, in the web search made as well as this work date (before the symposium), three magazines include the word “space” and astronomy and astrophysics names. Twenty-three journals were returned as the scope of the journal, and it was seen that the same magazines are among this number in the searches made with the words “astronomy, astrophysics, astrobiology”. On the other hand, the number of these same journals, which returned with these three keywords, was seen as seven, two and two. When the magazines were searched with the “Space Sciences” keyword, approximately among 2,445 registered magazines there were eight turns. Again in the calls made with the words of astroeconomics and space economy, two articles have been observed in Dergipark, one of them belongs to the author of this study (Dirican, 2019). Six articles in space tourism and one article in space mining has been seen (Dergipark, https://dergipark.org.tr/tr/, 2022).

According to the type of keywords and search words, it is thought that missing results are very low even if the search engine has not returned. It will not be difficult to say that these numbers are very few on behalf of Türkiye and its Academy, which increases its activities with TÜBİTAK and “Türkiye Space Agency (TUA)”.

Eight conferences have been watched to date with a conference series planned to be held, with four symposiums and a workshop on the space related ecosystem and space economy in Türkiye. In this way, it is seen that academic meetings, which do not exceed 15, is an important finding and fact in terms of the newly developing space economy.

a. “Space Ecosystem and Security Workshop” took place in 2019. The main theme was “New Space Economy and Security Architecture”. The event was carried out by the “Tasam Türkiye Center for Strategic Research” (TASAM, https://tasam.org/, 2019, ET: 2022).

b. Symposiums were organized in 2021 and 2022 by Istanbul University’s Faculties of Economics and Law and Observatory Application and Research Center, including this study (Istanbul University, https://issels.istanbul.edu.tr/tr/_, 2022).

c. Organized by Erciyes Teknopark, the “International Aviation and Space Technologies Symposium” was held on March 2022 (Erciyes University, https://www.erciyes.edu.tr/, 2022).

d. The “Space Law and Space Sciences Symposium” organized by the “Law and Science Society of Uzaya” was held with the speeches of academicians (Uzaya Law and Science Society, https://www.uzayahukuk.com, 2021, ET: 2022).

e. “The National Aeronautical and Space 9th Conference is planned to be organized by İzmir University of Economics on 14-16 September 2022 (İzmir University of Economics, http://www.uhuk.org.tr/, ET: 2022).

2.2. Literature on Space Economy

When giving a summary of academic articles about space, it should not be forgotten the cyber space which has indirect relevance. As followed in the last Ukrainian Russian war, especially social media, competition in cyber space can have as much as the threat of nuclear or space missiles. The architect of the Starlink project, the founder of SpaceX project, Elon Musk’s (aim to) buy (of) Twitter can be given as another example for this dimension. Likewise, the information war among Russia and U.S., other cyber crimes and risks are a different field of expertise in the cyber world and are also a title that needs to be examined together with space politics and space forces (Girgin, 2020).

The activities of “the General Directorate of Aeronautics and Space” from “the Ministry of Transport and Infrastructure” until “the Turkish Space Agency TUA” is established, such as international cooperation, educational activities and satellite activities summarize the process in which Türkiye is involved in the space economy (Baygeldi, 2020).

Although the international agreements made in the United Nations prohibit space military activities in space, it binds only the governments. Therefore, considering the roles of security companies such as Centcom or Wagner in wars in the world, this offers different approaches for commercial space. Erdem and Örki (2019) examined military activities in external space in their studies where they address international relations, organizations, competition, access and law in terms of global cooperation and in terms of their threats.

In the studies of Yazıcı and Darıcı (2019), they examined the size of the investment types in the space related economy, its volume, the ranking of space army forces, their shares in GDP and found that countries that take into account the space economy will surpass others in economic growth through NASA and SpaceX samples.

Ganesh et al., (2000) in their studies, they compared the production costs in orbit or on a planet with extraterrestrial resources and the production costs on Earth with launch costs and they found out “Net Present Value” positive in these three alternatives.

Komerath, et al., (2006) stated in their studies that in the development of four-stage space economy, including energy, satellite repair, water supply of 15 possible different sectors / initiatives, net present value of investments in products and services such as providing garbage collection, oxygen in Moon will be positive.

In his study, Gürsel (2020) discussed the initiatives and financial dimensions of space tourism and the problems of space tourism and concluded that business success rather than an innovation in this field, i.e. financial profitability, would be important.

Civelek and Türkay (2019) examined cartoons of space tourism and summarized in the conclusion section that luxury hotels in space and space tourism will return to a standard in tourism in the future.

Sandler and Schulze (1981) examined production, costs and returns in the world and in space through INTELSAT. The first findings of space economy in 1981 are the low return of investment and income against the growth potential of the work. However, they stated that they did not do it to reject the space economy. The study can be considered as one of the first examples for the space economy and feasibility.

George (2019) concluded that the space economy will have a positive impact on employment, growth and tax revenues as a result of its numerical analysis.

Weinzierl’s (2018), deriving from commercial space licenses, revenues of commercial space companies, and commercial space companies’ activities concluded that the technological dimension in the space economy gains momentum, but in social sciences, economic development, industrial structuring and public financing will be the titles that will be studied on the academic side.

Dirican (2015) stated in his study that industry 4.0 technologies would accelerate and facilitate space studies, and stated that a new economic management doctrine should be developed in order to work in the social sciences in the field of space economy.

Apart from academic literature, there are professional works and reports prepared in the corporate life. Some of the corporate examples are as below:

According to the definition of PricewaterhouseCoopers on the Turkish website, which operates in the fields of consultancy, tax and audit on a global basis; the space industry is generally defined as a structure consisting of all commercial and public institutions that include products and services that will extend to the final user in the entire supply process, developing, producing, operating and using space-related systems and infrastructures. In this sense, space industry examined space mining and tourism, access to space and discovery, observation and satellite communication. Their examination report naturally examines the issue firstly from the tax dimension. The most popular news in the regulations and activities of commercial space has come from the USA. In 2015, the "U.S. Commercial Space Launch Competitiveness Act", which was adopted in the Senate of the United States in 2015, has opened the way for commercial space adventures. Blue Origin, Spacex, Boeing, Deep Space Industries, Planetary Resources are some of them. Other countries are not far from the charm of this race. The "Indian Space Research Organisation-ISRO" has promoted "Indian National Space Promotion and Authorisation Centre-IN–SPACe" to strengthen its relations with commercial space companies (Aracı & Bayamlıoğlu, https://www.pwc.com.tr/, 2021, ET: 2022).

Vidal (2021) in his report in general, prepared for "The French Institute of International Relations (IFRI)", examined Russia's space programs, the affects of the energy income dependent Russian economy falling revenues on the budget of Roscosmos. Apart from the "International Space Station" joint work, Mars astrobiology research, Russia works with China on the "Prevention of an Arms Race in Outer Space" (Paros), to bring the safety and the security to the external space from military actions. In 2014 that they have issued a draft agreement "Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects" (PPWT) for using military forces against threats and risks from space, and Russia allowed space-related activities for limited commercial companies such as Gazprom Space Systems, S7.

Pollpeter (2021) summarized China's commercial and public-based space studies in a report for "China Aerospace Studies Institute". Accordingly, China has about 7% of the satellites around the Earth. China, which aims to take the U.S. in 2045 in space studies, is in the second place in the world after the USA by far in the number of active and inactive satellites and rockets in orbit. However, unlike the USA, commercial space companies must be in the public or public partnership.

On the web page of the "The United Nations Office for Outer Space Affairs" conferences and studies on the Space Economy can be found. Finally, a daily conference on the commercial space market in Africa is one of them. The activities on Earth from security, nuclear, climate, celestial bodies, disaster management to the water, and a total of five international agreements about space and principles sequences are on their website where at least one satellite of the 65 countries is located in space (The United Nations Office for Outer Space Affairs, https://www.unoosa.org/, 2022).

According to the OECD's 2020 report, the ratios of state budgets against to GDP do not exceed 1% for space economy, including the United States. "The National Statistics Table" prepared by the "U.S. Bureau of Economic Analysis (Bea)" enables calculation of the national statistics such as turnover, added value, labor force through products for the space economy. Regarding to reference to the relevant academic studies, the U.S. and developed European economies are among in the first 30 countries including Türkiye. Likewise, the gains of these activities to other sectors since the beginning of the World space studies have been shown in table. The information that there are around 22,000 human-made celestial bodies around the world also took part in the report (OECD, https://www.oecd.org/, 2021, ET: 2022).

The "NASA Internal Control Unit" report, which measures the financial impact of COVID-19 on the projects carried out by NASA as of March 2021, calculated that expected postponement of projects had 3 billion dollars effect and shared the audit report on their project basis and situation (NASA, https://oig.nasa.gov, 2021, ET: 2022).

On the website of the "Turkish Space Agency TUA", in the "National Space Program", there are "Space Technologies Development Zone" and "Development of the Space Industry Ecosystem" regarding the space economy (TUA, https://www.tua.gov.tr, ET: 2022). In addition, attendance to "G20 Space Economy Leaders Meeting" in Italy in 2021 and news of cooperation agreements with various Turkish universities can also be found on TUA's website (TUA, https://www.tua.gov.tr, 2021, ET: 2022). TUA President Yıldırım stated in the first symposium where also this study was presented in the second one, space economy and law should not be ignored (Çetinkaya, https://www.aa.com.tr, 2021, ET: 2022).

3. Discussion and Suggestions on Türkiye's Roadmap

The above summary clearly demonstrates the necessity of evaluating many titles together in the light of literature reviewing and developments in the world in parallel to other countries in the space economy. Space safety, space law, astrophysics, astronomy, astrobiology, orbit and access, satellite technologies related to space are not the subject of this study in this section, instead the subject of economic, financial, trade, business, financial services are discussed as focused on. Naturally, there may be new topics or subtitles that are not taken into consideration, forgotten, will come to the fore with the developments in time or will arise. On the other hand, as it can be seen below, in detail, many titles should be studied in detail. There is a strong need for working groups, workshops and symposiums, congresses and organizations in the academic and institutional life, public and private sectors and regulators dimension. It is essential that these activities are placed on a time schedule and project plan under the coordination of a structure such as TUA or TÜBİTAK (and perhaps in the future T.R. Presidential Technology and Space Office). It is also natural that these discussions and suggestions will be required to be taken into account within the framework of global reconciliation and definitions of international organizations related to international agreements and best practices (such as BASEL criteria for the capital adequacy ratio in banking or international financial reporting system).

Considering the Kármán line as the starting point of space, it is obvious that different debates, issues and decisions may occur according to the boundaries of the relevant social sciences in the discussions and suggestions made in this study. International space law is important as well as national consensus.

Some of the following discussions and suggestions were also expressed in terms of financial, economic and business dimensions of space tourism in Dirican's paper presented at the 18th National Tourism Congress (Dirican, 2017). In the light of all this information;

a. Similar to the examples of the world, within "the Turkish Statistical Institute" (e.g. the U.S. example in the previous section), it is essential to create a metadata infrastructure of space economy and its components. First of all, it is a necessity for empirical, econometric, statistical research and studies that the academy needs.

b. In this direction, which activities, products and services can be related to the space economy on the basis of sectors, especially NACE/NICE codes, should be determined together with the "Customs Tariff Statistics Positions". For example, whether the space and aviation titles seen in the academy will be taken into account together or separately within this economic size is a matter of evaluation in itself. In brand, patent, utility model studies, goods and service information / class is another topic that should be studied in the same direction.

c. For countries, one of the most important topics to be addressed in the regulation of commercial space activities (e.g. the PWC review report for tax in the previous section) is the tax dimension. Here, it should be planned how the treasury tax revenues or expenditures will be included in the fiscal budgets as well as the tax incentives to be given for the space economy. Beyond the evaluation of the TUA's budget within public institutions, there are different issues from double taxation to whether to apply special tax items for the space economy within the framework of international cooperation.

d. On the other hand, although the atmosphere comes to the fore in the tax dimension today, there are different issues that should be considered for the future. In terms of financial services, detailed studies will be required to taxation of cross-border transactions (if space or Kármán line is accepted as a cross-border). Türkiye's space stations, its colonies, financial transactions made / stored in the satellites, records, securities and real estates (also at the foreign trade point) Free Zones, Customs Legislation, Capital Movements, "Decision 32 on the Protection of Turkish Currency", Financial Crimes or Money Laundering (MASAK), "The Law on the Protection of Personal Data KVKK", the exchange regime, 6483 and 6362 and 5411 laws will be questioned in terms of space economy.

e. To support entrepreneurship for the space economy, there is a need to harmonize structures such as unicorn, start-up, incubation centers, technocities, technology transfer offices, entrepreneurship offices, organized industrial zones, clustering activities, exporter unions, chambers of industry and commerce.

f. In addition to the development of a space and aviation index under the umbrella of Borsa Istanbul, a separate market requirement should be evaluated based on the capital market legislation in order to make the funds and IPOs available for these commercial space companies, which are generally likely to produce losses in the first years.
   Likewise, there will be a separate discussion whether there should be a difference in the information of Public Information Platforms and for the companies working in the field of national security.

g. In terms of Development Agencies, KOSGEB or TÜBİTAK supports, which areas related to space will be supported primarily, their budgets, calls, form conditions should be worked in coordination with TUA in line with the calendar and project plans in relation to other priority areas of space economy.

h. In the field of finance, such as the requirement of specialized courts, experts, mediators, etc. who will examine the legal status of commercial space companies at the point of space law need to be evaluated. The mechanisms that will operate the different situations of space law, such as the unique practices of maritime law, should be planned, including bar associations and universities as well as law faculties. Ensuring the compliance of space law with other existing laws is another important issue from the legislative dimension.

i. In addition to the departments related to space economy in universities, from the human resource dimension, the fields of expertise and necessary certificates for the space industry should be studied within the "Vocational Qualification Authority VQA".

j. From the human resource dimension, it is good to consider the reflections in the social security system in parallel with the developments. For example, the investment supports to be given to companies in the space economy is a comprehensive premium incentive.

k. The establishment of a "Space and Technology Office" in order to carry out strategic policies for the space economy in coordination with TUA among the offices created in the Presidential Government System is one of the topics to be evaluated. Although the "Digital Transformation Office" creates a set of intersection with its technological dimension, it may also be necessary to have such a structure due to different technical dimensions. The projections of the Ministry of Transport or Ministry of Industry and Commerce should also be considered together.

l. Planning of units and activities related to space economy within the body of "TÜBİTAK Space Technologies Research Institute" and "Turkish Space Agency TUA" as well as working with other institutions, especially with academia, in economy, finance, financial services, entrepreneurship, etc. need to be taken into account. Although its main task is technological and technical aspects rather than social sciences dimension, it should not be forgotten that ideas, concepts, brands and patents are at least as important as these in order to have a say in space.

m. As seen in the literature section, it is important to open new departments by YÖK in the field of social sciences, to promote and to boost space economy in the curriculum and academia, and to ensure that other main social sciences are included in the "Faculty of Aviation and Space Sciences" or related / new faculties.

n. Although the codes related to keywords in academic studies such as articles and papers are related to international structures such as JEL codes, national and international studies should be taken into account in order to create new code systematics in this field.

o. Related to keywords and codes, major branches such as astrobiology and astrophysics are generally accepted titles. The entry of titles such as astrocommerce, astroeconomics, astrosociology, astropolitics, astrophysics, astrobotics into academia should be considered as a top layer of space economy, considering that the above-atmospheric studies will increase in the future. Türkiye's academy and related bodies can lead these efforts globally.

p. Encouraging interdisciplinary space economy studies in academic journals in Dergipark is important in terms of literature accumulation. As a matter of fact, the number of references of Türkiye in this field is given in the previous section.

q. Another point is the personal experience of the author of this study on this subject above. His conceptual article (Dirican, 2019) on the elimination of threats from outer space with financial risk management was rejected by an ULAKBİM journal, before it was accepted from another journal, because it was said that it did not fall within the scope of the journal.

However, it is a journal that accepts studies in the field of business, economics and finance in the field of social sciences. Naturally, journals, editors and referees have the right to reject articles or studies. However, the fact that the subject is innovative or assertive confirms that interdisciplinary journals are essential at this point.

r. On the other hand, the title to be given to people interested in space economy is important. People who are interested in physics or biology in space are called astrophysicists or astrobiologist. Astroeconomist is unfortunate with financial astrology in the world and in Türkiye. The author of this study was forced to give him the title of Türkiye's first astroeconomist because there is no legally approved center to do so. He is also the owner of the domain names of this title in the global. Likewise, uzayekonomisi.com domain name belongs to the author of the study.

s. From the dimension of the defense industry, the planning on issues such as the space forces and space security of the public and private companies should be considered from the perspective of space law in order to respond to global competition. In particular, the reinforcement of the developments in recent years in the defense industry is essential in terms of the right to speak in space.

t. At the commercial space point, the aviation cluster in Eskişehir and Turkish Drone Industry will contribute to the GDP and to get more shares from the space economy in the world market with the contribution of the above related headings.

u. Many other topics such as the financing of space tourism, interest and net present value calculations, money transfers, securities and asset custody and clearing will take place as a topic in the space economy in the coming years that should be analyzed in details.

v. Transport and travel insurance, development and pricing of derivative products in space mining, licensed warehousing, customs, logistics and supplier financing, supply chain management, delivery and payment methods, waybill and bill of lading, etc. many futuristic titles will similarly be issues that need to be examined in the future.

w. Commercial space related accounting system should also be considered under the developments in that field like the paper of Tekbaş, I., Aktaş, A., Azaltun, M., & Kurnaz, E. (2021).

x. Likewise, in the global financial architecture established after 1944 in Bretton Woods, the names of financial and economic organizations such as "World Trade Organization, World Bank, World Food Organization, International Chamber of Commerce, World Health Organization, Bank for International Settlements, United Nations, World Federation of Exchanges, International Monetary Fund" should be obviously reconsidered and all structures will need to be re-evaluated as well as their related legal aspects. Türkiye can trigger and lead these efforts among these instutions and organizations.

y. The opening of a title for the space economy in the YÖK superior achievement awards and scholarship supports will provide an opportunity for the increase in academic studies.

z. Just as a proposed TRT Economic Channel which will support the Istanbul Finance Center, TRT Space and Technology Channel also will contribute to a similar purpose from space economy and digital transformation dimension.

aa. Finally, since the importance of commercial space will increase in the space economy, the activities of the private sector, especially business people and industrialists in Türkiye, are very important. The real economy and production economy remain in the background of the financial economy in Türkiye as in the world. The fact that the space economy is in the background will mean that Türkiye is behind the space economy. Public Private Partnership should be evaluated in this context in terms of bridges to be established in space. Samples such as Togg will be a gain in high investment amounts such as satellite and rocket technologies. In the space economy, whether the private sector will be the leading or subcontractor, based on the example of the automotive sector, it is an inevitable necessity in the point of "Space Homeland" to be considered as a whole in all the above titles.

4. Conclusions

In the light of these information, it is seen that Türkiye has given priority and focus on technical, natural sciences in the National Space Program in parallel with the global studies. Academic studies on space economy and commercial space are seen as limited. Space mining, space tourism, threats created by asteroids, black hole photographs, topics such as Pentagon's UFO research are mostly the magazine in the media in front of the social sciences studies or value created for the space economy.

While studying the headlines of social sciences for the space economy, business, economics, finance, and financial services, in fact, in many areas of social sciences, it may be more accurate to examine the issue as above or below atmosphere, i.e. Kármán Belt. Today, most of the titles related to outer space remain more futuristic at the level of science fiction due to its intentional or unknownness rather than science. On the other hand, development in the field of space technologies, colonizing and growing commercial initiatives in outer space will put the titles mentioned in this study more to the forefront. However, even today there are astrophysics theories and information that should be discussed regarding space economy. For example, in the concept of time that can be bent according to the mass (i.e. space-time), the interest rate calculations, and if settlement place is different, the exchange rate of the gold to be priced according to specific weight differences and time in space mining are some of the questions. For this reason, it is thought and it is proposed that it is appropriate to use the "space economy" for below atmosphere related (commercial) space industries and "astroeconomics" for outer space economic and business studies.

It is not easy to reach the data and to make econometric, empirical studies due to the lack of economic measurements and due to the fact that companies within the scope of commercial space are not yet open to the public. Likewise, the other reflection of this in the social sciences is that space economy is generally seen as out of scope in journals and congresses due to the conceptual dimension and its futuristic perspectives in social sciences.

In particular, the issue can be examined in two ways based on the discussions above. Planning and implementation of the needs and studies in social sciences on the subjects carried out in parallel with the space studies is the first and necessary step that should be taken. Secondly, countries and companies that lead in any subject inventive, have the first patents and brands generally have a first say in that field. However, the theory of comparative advantage theory is a title that can be considered for the space economy as well. In other words, the intellectual contribution to have a say in space (economy) is as important as concrete contributions. When Einstein presented the theory of relativity, humanity had not yet come into space. In order to create a new economic management doctrine under the name of the Istanbul School in a way that includes space economy as well, sometimes even a manifesto may be sufficient like other examples in history (Dirican, 2020).

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From Competition to Confrontation: US Space Strategy

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1. Introduction

Space has not been immune to the global geopolitical power politics since early 1950s, but it has never been so congested, contested and a real war fighting domain as it is today. It is not a domain where only great powers could afford anymore. Mid-level powers, even companies now claim their share in the space. Outer space, upper orbits are yet to be areas of confrontation, but lower orbit has already turned into a battle field. Confrontations in space are inevitable in a digitized world where from basic daily needs to war plans, pretty much everything is being relied onto a heavily loaded digital realm. However, norms and customary laws are not being set as fast as the escalation currently building up in space. There is almost no room for cooperation as geopolitical power race between China and the United States (US) has already spread to space. China and the US almost weekly conduct space launches with classified payloads. Militarization of the space has long been an international concern and intervening the lower orbit from the Earth via advanced intercontinental ballistic missiles (ICBM) is now a raging trend. Moreover, unlike other domains such as air, land and sea, space has significant constraints in terms of building defenses for the assets floating in it. In other words, there is a disparity between counter space offensive and defensive capabilities.

The U.S. and the Soviet Union, during the Cold War, viewed space as a sanctuary free of conflict and a non-warfighting domain. However, many states and international entities has now declared space a war fighting domain. The US has been concerned regarding the increasing threat in the space since mid 2000s but American security bureaucracy had remained restrained about confrontation in space until China launched a projectile up to geostationary orbit that is 36,000 kms above the Earth and Russia and China's launch of maneuverable satellites in 2013. Space war has since then been an inevitable fate in the future. So the US space policy accordingly evolved from a competition led strategy to a potential confrontation driven one.

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Under the light of this context, this study looks into the US space policy and tries to navigate answers for questions such as how the US approach to space has evolved over time? What are the main tenets of the updated US space strategy? How does the US security bureaucracy perceive the threats and security in space? Before divulging the US space policy and strategy, I will touch upon concepts related to the security, power projection, risk and threat in space and the literature surrounding these concepts. By doing that, this research will not only hypostasize the future of US space policy but it will also sketch out a conceptual framework for space as a military theater.

This research is divided into three main parts. In the first part, theoretical discussions and their limitations is being elaborated on. Without diving too much deep into the theory, this part portrays analogies drawn between space power and some of the theories in international politics. Cautiously approaching these analogies, this study points out the limits of these theories to explain the space.

In the second part, legal frameworks that are governing the use of space and celestial bodies. It should be emphasized that most of the agreements are crafted in late 1960s and 1970s led by US and USSR. Since then, no other sweeping multi-lateral agreement has been signed except for US-led Artemis Accords which opened to signatories in 2020 and stipulates use Moon as a permanent base.

In the third part, this research details the US space policy and strategy from 1950's to today. It handles the US space strategy in two conceptual eras. Chronologically the US space policy up until late 1990s was based on a competitive but strategic restraint. However, from early 2000s to today, this study purports, the US has moved from a competitive approach to a more confrontational one in space. This research unveils the developments that triggered this evolution by divulging into US national security documents related to space.

Hypothetically, this research claims that for the US, space is not a domain for competition anymore but a theater of confrontation and war fighting domain. In this context, on one hand the US is investing in space capabilities and heavily militarize its space assets, on the other, it is investing in capabilities to counter counter-space measures or deter counter-space adventures.

2. Theoretical Constraints in Militarized Space and Space Wars

There are some efforts to theorize the exertion of power in space but it can be very well said that all these attempts have certain constraints, because all have a predicament of lack of historical experience or precedent and almost all applications of these theories draw conclusion on space as an extension of terrestrial domains (air, land and sea), which is not really the case. The broadest definition of space power is laid out by Sheldon and Gray as "the ability in peace, crisis, and war to exert prompt and sustained influence in or from space" (Sheldon and Gray, 2011:2). Handling space just as an area where thousands of satellites orbiting the earth and talking about exerting influence in that limited area can be comparable to or considered as an extension of air, sea or land. However, space is not limited to these orbits and physical circumstances per se creates complications in space power projections.

Some theorists make an analogy between evolution of space warfare and classical land warfare. Making references to Sun Tzu, Clausewitz, Thucydides, they try to prescribe tactical exertion of power in space. However, unlike land warfare where physical conditions such as terrain, geographical barriers, climactic circumstances and more importantly human condition dictate the execution of power, in space infinity, lack of physical barriers dictate exertion of power or use of force. For instance, it is "the most difficult environment for verifying attacks", for subsequently "validating which country or entity was responsible" and for "determining the impact of space attacks on the final outcomes of terrestrial battles and wars" (Syzmanski, 2019:78). Therefore, this very basic complication provides an enemy the opportunity to conduct surprise attacks in space. For a terrestrial attack, militaries build up a posture, and make maneuvers to shape an operation which might give the adversary to take position or be aware of an incoming offensive. Based on experience militaries over time learn out of wars and battles. But in a space scenario, militaries have very little information about a surprise attack and the information available might also be an amalgam of misinformation, disinformation or conspiracy.

Some others try to correlate space race to the rivalry and animosity in the Cold War. These theorists put forward that Cold War as a unique case in history created its norms. Power relations internationally were set based on certain tenets during that period. In this case space race between China and the US, they put forward, will ultimately dominate the space and a peculiar norm of space power will come out (Compert & Saunders, 2011; Finch & Steene, 2011; France & Sellers, 2011). It is true that power competition in space was an infant of the Cold War but there are a few aspects to object here. First, the Cold War was still based on a terrestrial setting with traditional war fighting domains. Balance between the two powers was based on geopolitical boundaries and conventional or strategic arms with specific implications. This is not the condition in space. There are limitless tactical means for offensives and a limited capability for defense. In other words, power is diffused in space. Exertion of power, dominating the domain is not as definitive as other domains. Furthermore, balance of power was a precedented case in smaller scales.

In addition to this, as the international system evolves from a unipolar to a complex multipolarity, space is not going to be immune to that. Potency is space has already complicated and in a multipolar age of confrontations creating a balance will be extremely difficult. Of course, it cannot be said Cold War has some lessons to learn from but it is not a solely substantial for space power.

Some other theorists compare space power to nuclear power theories as both are unprecedented which is plausible (Morgan, 2010; Compert & Saunders, 2011; Syzmanski, 2019). However, nuclear arms have incredible implications to the existence of humankind and life. Thus, no power acquires nuclear power to use it. Conversely nuclear doctrines are based on no-use strategy. In other words, they are conceived as means of deterrence and preservation of stability. So, if a power resort to nuclear arms its means that the deterrence has failed. In space, "contrary to popular belief, space is not a target-rich environment where just about every target is strategic and costs millions of dollars (Syzmanski, 2019:78). And human life is not at stake. It might feed the space power theory but it cannot be sole point of reference.

International Relations theories are not also sufficient to describe how the power politics in space will be and to prescribe how it should be. “The traditional focus of international relations (IR) theory has been peace and war, cooperation and competition, among the political units into which the world is divided” (Pfaltzgraff, 2011:37). Therefore, all weaknesses of those theories apply to space power discussions as well. Furthermore, they consider space as an extension of other terrestrial domains. Liberal or realist theories might have a say in today’s circumstances where states use space only as an instrument to exert influence on the Earth. Most of the other theories are currently off-topic for space politics. Moreover, Current situation in space was not totally out of imagination back in 1960s. Academia, militaries, media, pop-culture outlets have been depicting a congested, contested space and power races in space. However, as perceived highly fictional and scented with conspiracies the idea of dwelling on celestial bodies brings in another layer of complication for these theories.

In this context, theoretically there is a significant gap to describe the space power politics or politics in a militarized space. However, this gap has the potential to pave the way for the emergence of a new branch in social sciences. International Relations per se is a good instance for that. It benefited from political theory and thought but it created its own theory and literature in the second half of the 20th Century. It should be noted that each theoretical approach might defend its position and might have a say to a certain extent but this does not mean that they can explain the space politics and be a sole point of reference in that regard.

3. Legal Framework for Exploration and Use of Space

Almost all of the comprehensive legal frameworks that govern the use and exploration of space were crafted in 1960s and 1970s. The space competition between the US and USSR started in early 1950s peaked in late 1960s. However, the strategic restraint of Cold War was also kept by the American and Soviet governments in space as well. Between 1960s and 1970s several agreements were introduced in an attempt to prevent both powers from arming space. The United Nations (U.N.) General Assembly adopted the Outer Space Treaty in 1967 that that is considered foundational for international space law. The Outer Space Treaty, or the “Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies,” was a trilateral agreement between US, USSR and UK. It was brought to the Legal Subcommittee of the UN General Assembly in 1966 and in 1967 it was brought to the UN General Assembly by the USSR, the UK, and the US. The treaty went into force in October 1967, and 110 countries have become parties to it.

Just three years before that treaty there was another treaty related to the space. Treaty Banning Nuclear Weapons Tests in the Atmosphere, in Outer Space and Under Water, also known as Partial Test Ban Treaty was signed by the US and USSR in 1963 and went into force on October, 10, 1963 (Bureau of Arms Control, Verification and Compliance, 1963). The main concern of this treaty was prohibiting a potential nuclear test in the atmosphere and it came at the wake of Cuba Crisis in 1962. Six months after its ratification by the US, 110 countries joined the treaty.

Another key treaty governing the use of space is The Agreement on the Rescue of Astronauts and the Return of Objects Launched in Outer Space signed in 1968 by the US, the UK and the USSR (UN Outer Space Affairs, 1968). This agreement is contextually important because it sets the norms for the competition. It came at the height of the tense competition between the US and USSR both powers agreed that they will help rescuing one another astronauts and return the space one another platforms if they retained it in a rescue operation.

In addition to these agreements, four other conventions regulating the space were also signed. Those include Agreement Relating to the International Telecommunications Satellite Organization or IntelSat (1971) which opens the door for every state and regulate the use of space for telecommunication satellites (United Nations, 1971); Liability Convention (1972), which internationally regulates liabilities of parties for damages to space objects (United Nations, 1972); Launch Registration Convention (1974) that entails all states to register the objects the launch into space (United Nations, 1974) and Moon Agreement (1979) which regulates use of the Moon and other celestial bodies by states and bans military usage of these bodies (United Nations, 1979).

Almost all of these agreements were signed in a sense of prudence despite harsh competition going on between the US and USSR. That is a key difference between Cold War era space race and current competition over space. Today, not only multi-polar power politics but also some rogue actors claim their share in space without seeking any sense of prudence. This operational environment pushed the US to evolve its space policy.

4. Evolution of the US Space Policy

This research divides the US space policy and strategy chronologically into two phases. The first one is competition phase, which covers the period between 1954 when the first space launch was carried out by the US to late 1990s when impacts of Cold War began to fade away and new actors started to emerge. The second is confrontation phase, which predominantly focuses on last two decades and portrays what the US government does about increasingly contested and congested space. The main purpose of doing this is not only detail how the US policy evolved but also to illustrate how the space has turned into battle field overtime.

4.1. Competition Phase

In 1950s when Cold War was about to gain an intensified traction, the main interest of the US government in space was a symbolic leadership in a divided globe. So, the US administrations were interested more in space launches. So, the government invested “heavily in research and development (R&D). Government research laboratories and agencies conducted a substantial amount of in-house research” (Abbey & Lane, 2005:15). Beyond its purpose, this effort created a significant workforce with technical and management ability. The US gained also gained a capability in creating missiles, space rocket launchers in that era. But sending capable satellites and human to space was not part of a real discussion until 1961 when President Kennedy asked the congress to commit the goal of a human launched to the Moon and safely returned home after Soviet Union had launched Yuri Gagarin with its orbital flight Vostok-1 (Kennedy, 1961).

In 1950-60s, the key goal of space competition between the Americans and Soviets was to open the space for human exploration. Definitely there might have been some military aspects to this goal but it had more of a political value rather than pure militaristic aspirations.

Therefore, despite an increasing military fraction between the US and Soviet Union we cannot say lunching human being to space or to the Moon had a specific military purpose.

When it comes to 1970s, political détente led to a prudence and cooperation in space. As mentioned above most of the agreements regulating the use of space as of today were signed in late 1960 and 1970s. There were fewer actors in space and they enjoyed the vast space without the need for a specific confrontation. Less powerful actors also started to be interested in space launches under the regulations ratified during that period. This cold peace environment, in other words, opened the space to new comers.

In 80s US President Ronald Reagan was much more interested in space than his predecessors because there was heightening tensions with Soviets in early 80s and Reagan revisited the means of competition at the peak season of the Cold War as part of his narrative of US global leadership. It can be called "Reagan Effect" because that ambitious approach to the space wined down back in late 80s. However, Reagan deserves a few credits here thanks to his contribution to the incorporation of the space strategy into national security strategy. It was during Reagan era when the administration produced a unified document that outlines the US aims and power projections in space. So the first ever US National Space Policy came on July 4 1982. In 1981 Reagan, issued a National Security Decision Directive (NSDD-8, November 13, 1981) that reiterated the central role of the Space Transportation System in U.S. space activities. Based on that directive, the White House prepared a comprehensive document outlining the US policy in space (Reagan, 1982).

The basic goals of that policy documents ware:

> (a) strengthen the security of the United States; (b) maintain United States space leadership; (c) obtain economic and scientific benefits through the exploitation of space; (d) expand United States private-sector investment and involvement in civil space and space-related activities; (e) promote international cooperative activities that are in the national interest; (f) cooperate with other nations in maintaining the freedom of space for all activities that enhance the security and welfare of mankind (Reagan, 1982).

These six goals were expressed in almost every subsequent National Space Policy document that were produced every four years.

Another key development under Reagan administration was the establishment of Space Force as a unit under Air Force. It was Navy rather than the US Air Force which inclined/interested and even obsessed with the space navigations. The US Air Force came into the game in 1982 by the establishment of Air Force Space Command a command under the Air Force Service Branch. This move paved the first stone into the foundation of militarized space. However, it was not until second half of 2000s that we heard about militarized space. President Reagan was vocal critic of the mutually assured destruction doctrine for use of nuclear weapons. This doctrine purports that use of nuclear force against another nuclear power would cause a nuclear response during which both powers would face devastating destruction. Reagan used to call this a suicide pact and he called for a missile defense system against a nuclear strike, which is an intercontinental ballistic missile interceptor. The initiative was called Strategic Defense Initiative and nicknamed as Star Wars Program. It did not have specific link to the space policy or activities but this effort led to the first ever US counter space experiment in 1985 (Keller, 1985).

To conclude, the competition phase of US space policy traced a parabolic movement with gradual escalation in 1950-60s and a prudent competition in 1970 which followed by a renewed competition in 1980s. The US government obsession with space in 1950s created a workforce that is capable in developing technology and managing space technology. The space race in 1960s opened the space for human exploration and the prudence in 1970s opened the space to the actors other than the Cold War foes, the US and the Soviet Union. It should also be noted that although winded down in late 80s the escalatory effort of Reagan in 80s paved the way for the use of space for military purposes.

4.2. Confrontation Phase

In the post-Cold War era the US enjoyed geopolitical hegemony and there was not a significant challenge against US power in space. However, the space was getting more and more crowded. In 1990s, particularly China increased its space presence in a pacing movement. In early 2000s as the role of space in civil and military infrastructure gained strategic momentum, concerns regarding confrontation loomed in Washington. Closely following China's rising as a space power and Russia's resurgent space policy, the U.S. space and intelligence community engaged in debates regarding the military impacts of weaponizing outer space and the use of weapons against space assets (Pawlikowski, Loverro, & Cristler, 2012).

The current concept and rationale for a study on space confrontations originated in George W. Bush administration's final Quadrennial Defense Review of 2006. Simultaneously, the Defense Department asked National Defense University "craft a space-power theory similar to that of other domains", to develop a framework for pursuit of national security, economic, informational, and scientific objectives of the US (Lutes & Hays, 2011:113). The document comes while invasions of Iraq and Afghanistan were going on and Global War on Terror was raging on. However, the document makes several references to intelligence and use of space in that respect. With sketches of war in Afghanistan, Iraq and previously 1991 Gulf War, it stresses the use of space for integrating air, naval and ground operations (US Department of Defense, 2006). Bush administration's perception of space was contextualized with Chinese investments in space and stipulates that the US government should get ready to face potential asymmetric Chinese counterspace confrontations.

Many American defense analysts draw similarities between Chinese space warfare doctrine and German strategic doctrine in the twentieth century (Grossman & Meyers, 2019; Pawlikowski, Loverro, & Cristler, 2012). The Chinese have the same strategic outlook, as they believe the United States would prevail in any protracted conflict due to superior technology. Thus, "the stage is set for space blitzkrieg at the beginning of any great power conflict between China and the United States" (Syzmanski, 2019:79). Therefore, for the security bureaucracy China in many ways is the greatest challenge to the US sanctuary of space. Chinese do not only pose a threat by counterspace measures but also consistently make space more contested and congested. As the US government, commercial sector and military is heavily dependent on space assets a Space Pearl Harbor is not a distant imagination.

Apart from threat posed by China, many smaller states and even companies have access to space. Many US adversaries now have access to ballistic missiles, counter space technology. Based on the changes in operational environment beginning from late 2000s the US government adopted a discourse that space is a warfighting domain. 2010 National Space Policy document points out the danger looming in the space. Thus, the document asks all departments in coordination with Department of State to help "demonstrate US leadership in space fora and activities, reassure allies of the US commitments to collective self-defense" (White House, 2010).

One year later, in 2011 Barack Obama administration published the first ever National Security Space Strategy. This document is significantly clear eyed that the space is "contested in all orbits" and American space assets and the infrastructure that they support are increasingly facing a wide array of "man-made threat that may deny, degrade, deceive, disrupt and destroy assets" (US Department of Defense, 2011:1). The document also reiterates the find of 2010 National Space Policy finding that irresponsible acts against space systems could have implications beyond the space domain by pointing out that the US commercial sector, military and intelligence community continue to rely of space assets. It assumes the current and future strategic environment is driven the fact that space is extremely congested, contested, and competitive. The document emphasizes the importance of space by saying:

> Space is vital to U.S. national security and our ability to understand emerging threats, project power globally, conduct operations, support diplomatic efforts, and enable global economic viability (US Department of Defense, 2011:1).

In 2011 the Department of Defense tracks approximately 22,000 man-made objects in orbit, of which 1,100 are active satellites. This number has tripled according to the Pentagon. At the face of increasing challenges space strategy document suggests improving the US space capabilities; creating alliances; preparing for deterrence, defeating attacks and operating in degraded environment.

It should be noted that the Obama administration still interested in keeping strategic restraint. So, it adopted a multilayered deterrence. In other words, it assumed the US should build up national power in a way to diplomatically, economically and militarily "dissuade and deter the development, testing and employment of counterspace systems," (US Department of Defense, 2011:10). However, the entire National Security Space Strategy is built upon the idea of a potential confrontation and deterrence (Hitchens & Johnson-Freese, 2016).

The idea of strategic restraint did not sustain too long. The consensus on multilayered approach fundamentally changed after China launched a projectile that reached nearly the geostationary orbit, 36,000 kilometers of altitude that was enjoyed by the US only for a long time. At the same interval, China and Russia announced they have been testing maneuverable satellites in low orbit, which was also a capability that only the US enjoyed. These developments led to a "quite panic" within the national security circles (Hitchens & Johnson-Freese, 2016).

The panic caused by Chinese and Russian tests led to the preparation of a new strategy document called Strategic Portfolio Review 2014. National Security Council, produced the publication and it anticipated the reconsideration and reprioritization of defense against counterspace capabilities. The document considers counterspace capabilities as kinetic physical such as missile strikes; non-kinetic physical such as lasers, high powered microwave weapons, nuclear weapons detonated in space; electronic such as jamming, spoofing, electronic attacks on transmitting systems; and cyber capabilities such as cyber-attacks on data itself. Apart from defensive measures, the review also stipulates the need for weapons to be prepared for offensive operations (Hitchens & Johnson-Freese, 2016).

After Donald Trump took office, much of the concerns were on his desk and being critic of Obama's diplomacy oriented foreign policy, Trump's space strategy was built on his first National Security Strategy of 2017 which emphasizes peace through strength. Think tanks closer to Republican party called for a leap in US space posture. They would go further to suggest creating an offensive posture would give the administration to impose legal norms and regulations upon others (Hendrix & Routh, 2017).

Trump administration, shortly after its National Security Strategy, came up with National Defense Space Strategy document in 2018. The strategy was built on four pillars. First it suggested building more resilient space architectures against counterspace measures for defensive purposes. Second, its strongly calls for developing deterrence and warfighting options for offensive purposes. Third, it calls for improvement of capabilities for situational awareness and intelligence. Fourth, the document suggests foresting domestic for a and international community to create regulatory frameworks and policies to better leverage US commercial space industry (US Department of Defense, 2020). The strategy also lays out four lines of effort namely:

> (1) build a comprehensive military advantage in space; (2) integrate space into national, joint, and combined operations; (3) shape the strategic environment; and (4) cooperate with allies, partners, industry, and other U.S. Government departments and agencies (US Department of Defense, 2020:5).

The next so called leap that Trump administration took was establishment of Space Command and later on separation of Space Force as a service branch. Space operations were under Air Force Space Command and mainly it was responsible for operation and management of US surveillance sattelites. Operationally it was also integrated into missile defense and strategic operations. However, establishment of the Space Command as a unified combattant command pertained to launch military spaces assets and develop offensive and defensive options for US government.

Shortly after the foundayion of Space Command, in 2019 Trump signed the establishment of Space Force as a service branch into law as part of the National Defense Authorization Act. Now the US military has a new branch with a separate budget and operational autonomy. The implication of this move is yet to come out but US will have a fighting force for a new warfighting domain when the contentions and confrontations peaked in Space. Joe Biden administration with a specific emphasis on prudence in space still follows the footsteps of the Trump administration with respect to space policy. Particularly after China's hypersonic test, the US is expected to increase its confrontational posture in coming years.

5. Conclusion

The US had enjoyed the space for almost half a century until, it started to see confrontations and increasing congestion in the all orbits by early 2000. Tracing down the US space strategy for over 7 decades this study nagivated the evolution of the US space policy. It found out that with China as a rising space power and Russia with its resurgent space capability, the U.S. space and intelligence community is engaged in debates regarding the military impacts of weaponizing outer space and the use of weapons against space assets.

Space race between Soviets and the US never evolved into a confrontation. The geopolitical tensions short of war many times during the Cold War did not transpire in space. The highly competitive struggle between the two great powers not only contributed to the development of space technologies but also brought about regulations and treaties that govern the space up to date. During the Cold War, in 1980s Ronald Reagan reasserted a competitive space policy and reorganized the US space policy but publishing the first ever US National Space Policy. He also paved the way for military use of space including ballistic missile defense systems. However, Reagan’s endeavors did not evolve into a confrontation.

After a decade of enjoyment of unipolar world politics, the US bumped into an increasing space investment by resurgent Russia and raising China as well as other smaller states. Beginning in the first half of the 2000s the US felt the congesting and contesting space environment and security bureaucracy engaged in a discussion on inevitable confrontation in space. Despite these discussions the US policy regarding space predominantly rested on a strategic restraint. However, environment has changed significantly and Washington is getting ready for confrontations in space. War preparations become more public with each unveiled space weapon. In 2007, China proved its ability to destroy a satellite in low earth orbit using a ground-launched missile. The United States conducted a similar demonstration in 2008. In 2013 China launched a projectile into geostationary orbit and tested its first maneuverable satellite. Russia also positioned a spacecraft within 10 km of commercial satellites, raising suspicions. Russia and China more recently conducted anti-satellite missiles and hit some of their out dated satellites. In other words, rise of China as a space power and Russia’s resurgent space capability has in many ways triggered a panic within the US security bureaucracy and US defense strategy was updated in a way to invest more in offensive capabilities and ensure US superiority.

All in all, the mounting concern is not only about a potential war in space but also about implications of a degraded space capability on conventional operations in terrestrial domains. While space has not yet been overtly weaponized and no wars have been fought in space, strategists are concerned that the U.S. military’s current asymmetric reliance on vulnerable space-based assets to project global power may lead adversaries in a conventional ground war to attack assets in space. These strategists believe the potential military gains that could be realized by depriving the U.S. of the use of space systems is too great to be ignored and that any rational opponent would attack.

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The New Dimension of Accounting in the 21st Century: Space Accounting*

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1. Introduction

Beginning with Ancient Mayan astronomy, the curiosity of humans in outer space has continuously increased throughout history. It is a fact that the interest in and desire for space is as old as the history of humankind. Although humankind's desire to live on other planets was initially regarded as impossible, the world has reached the level of exploring space travel and the unknown through technology by the second half of the 20th century. Advances in technology will make spaceflight a regular part of our daily trips around the planet in the next 50 years. (Reed, 2017).

Economic and technological conditions that change over time require accounting practices to change and adapt to new processes. In this context, accounting science can recognize the developments expected to be experienced in space. For example, the claim that American astronaut Anne Mcclain accessed the bank accounts of her husband, who was about to get divorced from the international space station in 2019, went down in history as the first financial crime committed in space (https://tr.euronews.com/2019/08/24/uzayda-islenen-ilk-suc-iddiasi-astronot-bosanma-davasi-acan-esinin-banka-hesabina-girdi). While even going to space was perceived as a difficult task in the past, the science of law had a difficult time in the face of this event. It was faced with the questions of by which rules and methods the American astronaut should be tried. Undoubtedly, since the incident is related to a financial event, it will affect accounting science. Starting from this point, the need will arise for accounting to examine,

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evaluate, and report space activities within its field of interest, just like aerospace engineering and space law. As the size of the space economy grows, it will be necessary to seek and find answers to many questions that may arise within the science of accounting, which will be indirectly affected by this (Reed, 2017).

Due to the structural characteristics of the economic activities in the space industry, today's accounting practices and systems may need to be revised to solve such issues. An international accounting authority, including new measurement methods and measurement units, may be required for the healthy and reliable accounting and reporting of activities in space by their true nature. In other words, developing a common accounting language will be necessary to enable similar events to be understood and interpreted similarly.

2. Space Industry

Outer space, commonly shortened to space, is the expanse beyond Earth and its atmosphere and between celestial bodies (https://en.wikipedia.org/wiki/Outer_space). Radio broadcasts from space, discovered by an engineer named Karl Guthe Jansky by chance in 1932, led to the birth of radio telescopes in the following years, and thus, to listen to the depths of space and to find the sources and causes of those radio broadcasts (https://tr.wikipedia.org/wiki/Uzay).

Having started with a coincidence, space studies indicated superiority or prestige during the Cold War. Thanks to technological developments, space studies became vital, offering the opportunity and potential to contribute to security, economy, environment, and development.

On the other hand, the space industry includes regulating economic activities in developing and producing products and services such as ground stations, launch vehicles, and satellites within the scope of space studies. Today, the global space industry has become a fast-growing field of the high-tech market. Furthermore, many professions, such as engineering, architecture, and law enforcement, have reached a point to be fulfilled in terms of space.

While solely government organizations had invested in the space industry in the past, the number of private companies and states investing in the space industry, the budget transferred to the industry, and their activities have been increasing daily since the beginning of the 21st century. The Treaty, which was opened for signature in the USA, the United Kingdom, and the Soviet Union on January 27, 1967, to steer the space industry, entered into force on October 10, 1967. The Outer Space Treaty, officially known as the Treaty on the Principles Governing the Activities of States in the Exploration and Use of Space, Including the Moon and Other Celestial Bodies, forms the basis of international space law. This agreement includes the rules that the investing actors must follow to continue the space activities effectively without interruption, the satellites, the rockets that take them, the removal of the satellites whose function is completed out of the space ecosystem, space garbage, etc. The Outer Space Treaty, formally the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, is a multilateral treaty forming international space law. The pact includes the rules to be followed by the investing actors to continue space activities effectively without interruption, and the satellites, the rockets that carry them, and the removal of the satellites that fulfilled their mission out of the space ecosystem. (https://tr.wikipedia.org/wiki/D%C4%B1%C5%9F_Uzay_Anla%C5%9Fmas%C4%B1)

This agreement states that the use of space, including the Moon and other celestial bodies, will be carried out for the benefit and interest of all countries, regardless of their economic or scientific development level. In other words, it is accepted that space will be the province of all humanity. It is also stated in the same agreement that space, including the Moon and other celestial bodies, is not subject to national possession by claim of sovereignty, use, or occupation, or by any other means. (https://www.financierworldwide.com/can-spaca-activities-betaxed#.Y1UAzHZBxPY)

The paradigm's new players are universities with only space capability and newly established companies. Especially in the USA, some companies founded by visionary people successfully undertake large satellite projects by bringing together engineers and operators with no previous space experience but with high technological skills and using venture capital. Big space companies are only trying to catch up with this trend by following them up.

International cooperation has been a significant encouragement for such rapid development. The support of the United Nations and some states, such as Japan, in both satellite design and production phases and free launch has been necessary for those who took the first step into space. While there was no central institution to organize space studies in Turkey until recently, the establishment of the Turkish Space Agency in December 2018 has been considered to fill the existing void in this sense (https://tasam.org/tr-TR/Icerik/52506/uzay_ekosistemi_ve_guvenligi_calistayi_-_1_sonuc_raporu).

Looking under the hood of some developments in the space industry, Starlink satellites are produced in high quantities, six per day. SpaceX can genuinely create an economy. Elon Musk SpaceX is estimated to have annual revenues of $30 million by 2025 (May 2022: 55). Private companies compete to provide a competitively priced launch service to their customers and governments. The big breakthrough occurred when SpaceX launched its dual-stage Falcon 1 rocket on September 28, 2008 (May, 2022, p. 55).

A comprehensive report by Citigroup analysts announced that the space industry could reach $1 trillion in annual revenue by 2040, owing to a 95% reduction in launch costs. Citigroup states that rocket launch costs have fallen rapidly since the 80s. From 1970 to 2010, the average launch cost remained stable at around $16,000 per kilogram for heavy loads and $30,000 per kilogram for light loads. On the other hand, lower launch costs emerged with SpaceX's launch of the Falcon 9 in 2010. The Falcon 9 rocket has reduced the launch costs to about $ 2,500, which is 30 times lower than the costs of NASA's Space Shuttle and 11 times lower than the previous historical average. It is estimated that by 2040 it will decrease to about 30 dollars per kilogram. Thus, many more people can travel to space in the coming years. (Sheetz, 2022)

Table 1. Companies operating in the space sector

Space Transportation	SpaceX (http://www.spacex.com/), Orbital (http://www.orbital.com/) Virgin Galactic (http://www.virgingalactic.com/), Planetary Resources (http://www.planetaryresources.com/), Blue Origin (http://www.blueorigin.com/), Stratolaunch Systems (http://stratolaunch.com/), Sierra Nevada Corporation (http://www.sncorp.com/index.php).
Space Tourism	Mircorp (http://mircorp.org/corporate.html), Space Adventure (http://www.rocketshiptours.com/), RocketShip Tours (http://www.rocketshiptours.com/), Virgin Galactic(http://www.virgingalactic.com/).
Production of Vehicles Used for Space Transportation	Orbital Sciences Corp. (http://www.orbitalatk.com/), Scaled Composites (http://www.scaled.com/projects/), TSC (http://www.thespaceshipcompany.com/).
Satellite Production	ThalesAleniaSpace (https://www.thalesgroup.com/en/worldwide/space?LangType=2057), Boeing (http://www.boeing.com/), Israel Aircraft Industries (http://www.iai.co.il/2013/22031- en/homepage.aspx).
Satellite Service	Türksat Satellite Communications Cable TV & Operations AS (http://www.turksat.com.tr), GlobalCom SA (http://www.globalcom.cl), Danish Space Expo (http://www.spaceexpo.dk).
Production of Satellite Launch Vehicles	Arianespace (http://www.arianespace.com/), International Launch Services (http://www.ilslaunch.com/), SUPARCO (http://suparco.gov.pk/webroot/index.asp).
Production of Research and Exploration Robot	Brown Engineering Company (https://tbe.com/), Lavochkin (http://www.laspace.ru/)

(Bozkurt & Ercan, 2016, p. 4)

3. Space Economy and Space Accounting

The accounting transformation into the space dimension should include accounting practices, financial reporting, business processes, and auditing issues. The problems associated with space accounting include those that can be solved with the help of new concepts, principles, and multidisciplinary approaches. This shows that accountants should be ready to do business through a multidisciplinary approach. To put it more clearly, the accounting will need to consider those developments and develop a holistic understanding that covers much more than a change in accounting standards.

In this regard, some of the questions that need to be answered within the science of accounting are as follows:

- How will the space economy affect accounting science and the accounting profession?
- What is the place and significance of accounting in sustainable space activities?
- Will it be possible with the current accounting system to solve the problems that may arise in the accounting and reporting economic activities in space?
- How will the accounting records of the economic activities occurring in space be kept?
- How and in which accounts income and assets will be traced?
- Which methods and principles will need to be used in costing processes?
- How will taxation processes be conducted?
- Will specific measurements, value units, or even a brand-new monetary unit in space currency exist?
- Is it necessary to establish unions or organizations, such as chambers of commerce or industry, for matters such as commissioning, authorization, classification, limitation, permission, auditing, and surveillance at various stages of space activities, about the regular industry procedure?
- Who will be responsible for decision-making and drawing up regulations regarding the structure of this organization?

The above questions can be reproduced to provide a reasonable basis for thought and discussion about space accounting.

Space accounting can be defined as "*a sub-specialty branch of accounting science that enables the creation of accounting standards and information systems for monitoring and reporting all economic activities that occur during the discovery, research, understanding, management, and exploitation of space, and to enable the institutions to make conscious decisions on space activities and ensure sustainability*" (Tekbaş et al., 2022, p.19). The term "space" here refers to the activities conducted in space, rather than the space-related activities conducted on Earth.

Undoubtedly, space accounting will continue to take shape with the development of economic activity in space. It aims to produce information explaining the interaction between space activities and the economy. It can be an essential catalyst for space exploration and the space industry's growth. Space accounting is a multi-disciplinary concept in which accounting, space sciences, law, and economics are involved, and it will undoubtedly enable integrated reporting that considers the financial and non-financial data of the enterprises and explains the situation within the sustainability framework.

4. Key Issues Regarding Space Accounting

Accounting involves a set of assumptions, frameworks, and methodologies used to produce realistic and relevant financial reporting. As a constantly developing field of science, it should seek new ways of doing business, technological developments, and unique solutions to new information demands to adapt to today's world. As progress continues, especially in space exploration, asteroid mining, space tourism, and space production, issues that might need fixing for accounting will emerge. In this regard, there is a requirement for studies that scientifically examine the effects of economic activities in space on accounting.

Will accounting need to alter much when it deals with outer-space activities? Certainly not, but it must consider how financial reporting should be done, which accounting measurements and valuation methods should be used, and which currency should be used when preparing financial statements. It is necessary, though, especially after discoveries in space, to investigate and examine the kind of costing models, financial reporting standards, and skills required for accountants if space production is to commence. This is important for space activities to be sustainable.

In terms of being a remarkable accounting approach, it would be appropriate to examine the space ecosystem in two dimensions suborbital and superorbital. Today, it is possible to monitor suborbital activities with an accounting system based on the current legislation. Because orbital space activities are primarily based on predictions and certain activities might occur decades later, the current accounting and financial reporting standards may not meet the need.

The reflection of space activities in accounting will include more than financial reports. Many courses such as management accounting, cost accounting, auditing, environmental accounting, sustainability reporting, and integrated reporting that emphasize the need for financial and non-financial information to be included in the academic curriculum, which accounting and finance department professors teach, will have to include explanations on space activities.

Figure 1. Critical issues in the science of accounting may arise with space discoveries (Tekbaş et al., 2022, p.18)

Some answers will be sought on specific topics or questions emphasizing space accounting.

4.1. International Financial Reporting and Auditing Standards

At the center of the current discussions lies the opinion that, probably, the accounting, auditing, and reporting standards in practice today will not be sufficient for accurate and requirement-oriented reporting of new economic activities such as space exploration, space tourism, space mining, and space production.

If we consider these new economic activities and space industry concepts, we can imagine there will be a demand for the activation of vehicles that will transport passengers to space; there will need to be construction, activation, and a cost determination of living areas to be established on any planet or star, hotels to be accommodated, and satellite stations to be fueled in space.

International Accounting Standards must provide a system of rules and principles that determine the format and content of financial statements. These standards should cover accounting for stocks in space, depreciation, research and development costs, income taxes, investments, and tangible and intangible assets. A practical, understandable, and applicable set of space accounting standards will provide significant added value to businesses operating in space.

In this regard, space accounting is a field of expertise that will ensure that the activities in space are reflected in the financial statements consistently and accurately, that the financial statements can be understood in the same way by all parties, and that similar events are interpreted similarly. Space activities will introduce the need to add to and modify existing international accounting standards and even the need to develop new standards, such as in agriculture, construction, or insurance accounting.

4.2. Space Commodity Exchanges and Their Operation

A new space paradigm called “New Space” has taken hold in space technologies and the use of space in the new century. Space is no longer a field used only by big nation-states or related giant companies. The widespread and easy availability of technological developments, especially the downsizing of electronics, paved the way for many non-state new players in satellite design, production, launch, and operation (https://tasam.org/tr-TR/Icerik/52506/uzay_ekosistemi_ve_guvenligi_calistayi_-_1_sonuc _raporu).

For instance, the “Lunar Hilton” is a project heard long ago within the scope of lunar tourism. In addition to accommodation in this hotel, scenic tours to the historical Apollo landing sites and new sports activities that can be done in one-sixth of the world’s gravity will attract the attention of space tourists (May, 2022, p. 105).

Fiber optic cables are another product produced in space instead of factories worldwide. They have more excellent conductivity than old-fashioned copper cables. The performance of the fibers can be enhanced by using fluorides of heavy metals (ZBLAN zirconium, barium, lanthanum, aluminum, sodium)). However, most of the yield of this substance, which can be produced in tiny crystals, is lost due to the conditions on Earth. However, it is possible to have higher quality in space with metals in a weightless environment of the planet (May, 2022, p. 98). Moreover, Axiom Space is one company that wants to carry its production activities to space. The company is working on the viability of production in the area, including optical fibers, superalloys, and medical implants (May, 2022, p. 99).

Due to the high-priced investment, the commercial activities of the private sector in space are limited. However, it is assumed that the private sector’s interest in this field will increase daily, depending on the technological developments and the incentives given by the public. In particular, the increase in startup companies reflects the potential envisaged in this transition. All these developments in space trade take the accounting function to a much more critical position in terms of the sustainability of private sector businesses established for profit.

Considering all those developments in space trade and space industry, managing Earth from space appears as an idea. At this point, it may be beneficial to establish space commodity exchanges with regulations on the correct calculation of pros and cons related to space activities, incentives for investments, and protection of investors.

Thus, companies will be supported in providing long-term funds for developing the space trade market. This, in turn, will contribute to forming space financial markets and spreading space-oriented financial instruments, thus enlarging space activities.

4.3. Cost and Valuation Methods of Space Activities

Today, while space vehicles’ design and production processes are shrinking to one-tenth, one hundredth, or even one thousandth in terms of time and cost, the number of satellites in operation is expressed in less than tens but in thousands. While design and production periods decrease from years to months, satellite sizes and masses decrease from tons to kilograms or even below, and costs decrease from hundreds of millions of dollars to millions of dollars and much down (https://tasam.org/tr-TR/Icerik/52506/uzay_ekosistemi_ve_guvenligi_calistayi_-_1_sonuc_raporu).

Some matters, such as how the cost of the produced goods will differ during the production in space or how the wear level of fixed assets in space will be measured, become prominent. Substances used as superconductors in high-tech products such as yttrium and niobium, for instance, are present in lunar rocks, albeit in small quantities. It may be possible to detect and extract these mines on the moon and bring them to Earth more cost-effectively. Moon Express, one of the companies participating in the Lunar X-Prize, has already devised such an idea (May, 2022, p. 107).

In 2022, based in Houston, Orion Span plans to build the first luxury hotel in space (Neagu, 2018, p. 23). It is necessary to establish a set of rules that determine with what values the financial events and transactions considered to take place in space, such as the depreciation method to be applied for the assets of the hotel to be built, the valuation and costing methods of stocks, will be recorded, how they will be classified, and which reports will be presented.

The accurate and realistic reporting of space activities will depend on the accuracy and effectiveness of the methods to be determined and selected regarding cost and valuation. This topic falls within the field of study of space accounting expertise.

4.4. Legal Infrastructure of Space Operations and Taxation Problem

In addition to its civilian economic benefits, space is also of military importance. Advances in reconnaissance, intelligence, navigation, and communication provide military forces with superior advantages that cannot be obtained from the ground. This feature of space, along with other civil-purpose applications, has revealed the need for international regulation and led to the field of space law.

Since the first satellite, Sputnik, launched in 1957, space law development studies have been conducted in various environments, including the UN. The General Assembly established the UN Committee on the Peaceful Uses of Space (COPUOS) in 1959 (https://www.unoosa.org/oosa/en/ourwork/copuos/index.html). Under the committee's leadership, the OST Outer Space, forming the basis of international space studies, and a series of other regulatory agreements following it were put forward, and declarations were published in accordance. Although all these have the signature and approval of many states, a consensus has yet to be reached, and some issues of significance still need to be discussed.

The basis of other space treaties, especially the Outer Space Treaty, is using space for peaceful purposes. Free access to and benefiting from space has been accepted as the inalienable right of every state. In military matters, it was forbidden to place weapons of mass destruction (nuclear, biological, chemical, radiological) in space, but no prohibition or provision has been made regarding other weapons (https://tasam.org/tr-TR/Icerik/52506/uzay_ekosistemi_ve_guvenligi_calistayi_-_1_sonuc_raporu).

The functionality of accounting will only be possible in the light of legal regulations, for the accrual of the income and expenses of the enterprise will depend on them. In other words, all legal regulations related to the space economy will appear first, allowing normative regulations in accounting. Suppose an enterprise operating in space by international law, for instance, encounters a situation that gives rise to compensation. In that case, the responsibility will belong to the country of residence of the enterprise. As the recourse of the resulting compensation to the company will vary depending on the legislation of the relevant country, in such a case, the provision of doubtful receivables will be set aside, and its reflection in the financial statements will depend on the legislation in the relevant country.

Space accounting will function as a tool to seek answers to the questions such as how the tax legislation will be prepared, how the expenses of tax will be calculated, how the tax base will be created for the calculation of earnings, income, cost, and tax value, by whom the tax will be released, who will be responsible if some specific applications such as DVTA-Double Taxation Agreement will be available.

The problems of taxing the commercial operation of space have been introduced previously. Many lawsuits are filed in the UK Tax Courts due to tax disputes arising, especially regarding satellite activities in space. For example, in the case of Vodacom Nigeria and FIRS (CA/l/556/2018), the Nigerian Court of Appeals decided on the Value Added Tax incurred on applying satellite technology. A satellite operated by a Dutch company provided bandwidth capacity for use in Nigeria. The Dutch company transmitted the bandwidth to the satellite in geostationary orbit, transmitting the power to a Nigerian company's ground station in Nigeria. The court ruled that the supply was one of the services provided in Nigeria and was subject to VAT. (Schwarz, 2019)

4.5. Technology Infrastructure, Contracts, Human Resources, Training and Talent Sets, Space Labor Law

Satellites operate in almost every aspect of space exploitation. Earth observation, communication, technology development, and scientific applications are of great dominance in space studies. Applications not thought of before in observation and communication or believed to be carried out only by big states, companies, or universities in financial and technological terms are being developed rapidly. These include taking pictures of any region at least five times daily, providing video from space, and direct internet access via satellite sets in low earth orbit. For instance, by determining the location with a distance error of only 15-20 cm, the project of autonomous vehicles is in progress.

The most prominent example, which started the shrinking trend brought about by the new space period, was the cube satellite (CubeSat). This type of satellite, whose basic dimensions are well-defined but can grow up to 27 times in scale, has provided rapid design, production, and launch opportunities by introducing many subsystems and components as nearly ready-to-rack products. Cube satellites (pico: 0.1-1 kg, nano: 1-10 kg or microsatellite: 10-100 kg) or non-cube satellite micro-satellites, used by many countries and private enterprises in space whether they are wealthy or space-capable, has paved the way for the introduction of technologies and applications. With the rapid growth in the field, the number of satellites launched in record numbers in 2017 and 2018 is expected to increase further in the future, breaking new grounds (https://tasam.org/tr-TR/Icerik/52506/uzay_ekosistemi_ve_guvenligi_calistayi_-_1_sonuc_raporu).

As accounting is a system that records and reports actual and existing financial transactions and events, one might ask how accountants can form an opinion on an event that has yet to happen. However, it will be necessary to understand and interpret space activities based on expected scenarios and adapt them by regulated accounting processes. For this purpose, we need working groups to create the necessary simulations, projections, and models to bring the complex economic activities in space closer to reality. These working groups should include personnel with the appropriate knowledge, experience, and competence to discuss and investigate topics such as space tourism, space life, space production, asteroid mining, and space discoveries; the department of Space Accounting could be established in universities to train these experts.

In parallel with technological infrastructure developments, it will be necessary to plan regarding matters such as contracts to be made within the framework of space activities, human resources, training and skill sets, and space business law and space business ethics for both people and institutions within the scope of space activities, which eventually turn into an industry.

Space accounting experts will be expected to know the terms, concepts, measurements, weights, and calculations used in space activities in this field and be competent to manage each process. In this context, internationally recognized professional competency-certified programs in space accounting should be organized for space accounting professionals. When determining the certificate education program, science branches or disciplines such as physics, biology, mathematics, engineering, and internet and information technologies should also be utilized to provide the necessary skills for space research.

4.6. Sustainability and Integrated Reporting in Space Activities

The use of space is now considered together with other current issues on Earth. Climate change, environmental pollution, sustainability of agriculture and natural resources, energy, and social development are now observable effects and are predictable with data from space technologies. While observation from space provides essential information on these issues, it also contributes to sustainable development with its communication and navigation services (https://tasam.org/tr-TR/Icerik/52506/uzay_ekosistemi_ve_guvenligi_calistayi_-_1_sonuc_raporu).

Space mining may alter the issue of the scarcity of resources on Earth at any time. Thus, while space activities contribute to the world's sustainability by offering an alternative to the scarce resources on Earth, sustainability needs to take the necessary measures to ensure that these activities can continue without interruption. Helium-3, which is another valuable element that is likely to be mined on the moon and cannot be obtained on Earth, has the potential to save humanity from seeking energy for the next 1000 years (May, 2022, p. 107).

How will the provisions regarding the liabilities that the business will face due to the creation of space waste be calculated? How will the shares of the parties involved (business, state) in the obligation to insure (insurance costs) assets sent into space be calculated? Which legal regulations will the necessary explanations in the activity reports or integrated reports to determine the risks related to space activities and to minimize these risks be based on? Space Accounting will be the key to finding answers to such questions.

5. The Difference Between Space Accounting and Conventional Accounting

Since space is an area without borders, it can be stated that the economic activities in space will be in a wide range. Space is abstract and infinite. In other words, space is everything beyond Earth. On the other hand, today's accounting standards have focused on preparing and reporting financial statements, depending on the developments in the world's economic field. (Mikail & Aslan 2017). In other words, the accounting principles, standards, and practices we use today have emerged from the necessity of meeting the information needs of third parties regarding the commercial activities carried out within the borders of the world. For this reason, the need for high-quality, global financial reporting standards may arise when we go beyond the world's borders.

Regarding space accounting, new elements can be added to the worldwide financial statement elements. In addition, new cost methods may be needed due to production in a gravity-free environment. In the future, new measurement methods that we do not know and cannot even predict may emerge to meet the economic activities in space. For this reason, space accounting will involve the following and reporting of all economic activities that occur in space, different from the measurement and reporting in conventional accounting. While traditional accounting focuses on commercial activities on the borders of Earth, space accounting goes beyond the world's accounting systems. It requires a broad and futuristic view of space industry issues. The development of space accounting depends entirely on the increase in economic activities in space, new assets, and new financing tools and effects in space law. At this point, it will be understood more clearly that the arrangements within the framework of space accounting are different from today's conventional accounting, depending on the short, medium, and long-term developments in the space ecosystem.

6. Conclusion

There has never been a time in the history of the world when businesses have shown such interest in space activities. We have celebrated relatively minor victories, such as the first moon landing 50 years ago. Today, companies sell tickets for low-orbit commercial flights and dream of colonizing Mars. Although a large part of today's space economy includes satellite and R&D activities, sectors such as space tourism, space mining, and logistics are gaining importance daily. Today, the global space industry emerges as a rapidly growing and shaping area of the high-technology market. It is considered that the global space economy, with a value of 388 billion dollars in 2021, will increase significantly soon, thanks to space mining and space tourism. According to the estimation of economists interested in the space market, the size of the space economy may increase to 2.5 to 3 trillion dollars in the next three years. Of course, accounting will inevitably be at the intersection of all these economic developments and monetary changes. (https://www.businesswire.com/news/home/20220414005509/en/Global-Space-Economy-Market-Analysis-Report-2022-with-Comparisons-of-SpaceX-Astra-Blue-Origin-Relativity-Rocket-Labs-and-Virgin-Orbit---ResearchAndMarkets.com)

Will accounting need to alter much when it deals with outer-space activities? Certainly not, but we will encounter fundamental issues such as how financial reporting should be done, which accounting measurements and valuation methods should be used, and which currency should be used when preparing financial statements. It is necessary, though, especially after discoveries in space, to investigate and examine the kind of costing models, financial reporting standards, and skills required for accountants if space production is to commence. This is important for space activities to be sustainable.

Due to the structural characteristics of the economic activities in the space industry, today's accounting practices and systems may need to be revised to solve such issues. After all, all legislation and scientific foundations are based on events and needs in today's world. An international accounting authority, including new measurement methods and measurement units, may be required for the healthy and reliable accounting and reporting of activities in space by their true nature. In other words, developing a common accounting language will be necessary to enable similar events to be understood and interpreted similarly.

There will be a need for an expert authority that ensures integrity and uniformity by considering the properties specific to space when providing solutions to critical problems – such as the technological infrastructure, contracts, human resources, currency to be used, valuation methods, international agreements, costing models, auditing, skill sets, taxation, sustainability, and integrated reporting which are assumed to constitute the scope of space.

The International Space Accounting Standards Board can be recommended as the authority that will ensure the activities of the working groups to be formed to closely monitor the economic activities in space and the selection and authorization of the persons to be assigned. In this way, it will be possible for accounting science to follow and analyze more closely the economic developments in space, such as engineering, astronomy, and physical sciences so that the relevant accounting science will be fully established by the time the related field of business starts to operate.

In conclusion, developments in space are changing both the accounting application processes and the skill sets that will be required. Strategies for sustainable space activities will be based on information developed on the mutual interactions between economy and accounting. The primary purpose of space accounting is to present space exploration and economic data together and comparably, aiming at sustainability.

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Economic Shocks and International Space Projects: The Russian Invasion of Ukraine

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1. Introduction

A vast body of research exists around the space industry which has been growing significantly in almost every region of the world. The space industry is prone to major shifts in the world system where it could be considerably influenced by wars, pandemics and fluctuations in economies. For instance, the latest Russian invasion on Ukraine has had considerable impacts on economies all around the world. It is clearly seen that international projects and cooperation have been affected by this invasion that remains ongoing with a strong defense and response exemplified by Ukraine and the international community.

This paper discusses and analyzes whether international space projects are fragile when political shocks like the example of Russia and Ukraine are experienced. In recent years, other economic shocks have emerged including the Covid-19 pandemic and supply chain problems; however this paper will not take these into account in detail. Russia began its invasion on February 24, 2022 and as this paper is written, the war continues. Every other minute, new developments appear and those developments cause different reactions from all over the world. What demands more urgent attention than long-term prognosis is the shock wave that the war has triggered across the world economy, starting with the combatants, the wider region of Eastern and Central Europe, and global food and energy markets (Tooze, 2022). Additionally, many countries have applied heavy sanctions on Russia for economic reasons, whereby the most effective sanction was removing Russia from the SWIFT system which was implemented by the United States in order to limit Russia from the global financial system.

In this paper, the global economic outlook for 2022 will be discussed and in turn the global space economy and the actors in space will be talked about. Furthermore, the international

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space project and agreements will be analyzed with the economic shocks and evaluated to an extent using the limited data available. Finally, this paper will explore whether Russia's invasion on Ukraine has exerted any influence on the space industry internationally and search for an answer about whether the space industry is entering a new phase or is it still possible for it to have a stance as if the war had never occurred.

2. Global Economic Outlook in 2022

In recent years, the world economy has suffered from many different causes. In 2020, many changes materialized with the Covid-19 pandemic. The supply chain was disrupted significantly, and many countries' governments had to release aid packages to save their industries and labor force. Those aid bills caused high inflation all around the world while shortages were taking place in the chip industry and agriculture.

America's fiscal stimulus packages that were revealed during the Covid-19 pandemic helped to increase significantly imports, providing markets for the main producers all around the world with raising prices while there was an active competition for an impact in the world economy between the West and China. The latest shock has come from a regional conflict between Russia and Ukraine which led to war between two countries. From the beginning of the conflict, Russia chose to be invasive and not in favor of an agreement. The expectations regarding the war were that it would end in a couple of days after starting with Russia taking over however it was seen that Ukraine and its people have shown great resistance which inevitably resulted in the Russian military withdrawing from major cities in Ukraine such as Kiev. This invasion has played a direct role in impacting the global economy and the withdrawal of Western companies and institutions from Russia has worsen the shock. According to the IMF's statement on March 5, 2022:

"The war in Ukraine is causing massive damage to Ukraine's physical infrastructure and has sent a wave of refugees to neighboring countries. If the conflict escalates, the economic damage would be all the more devastating. Price shocks will have an impact worldwide, especially on poor households for whom food and fuel are a higher proportion of expenses."

International sanctions on Russia's banking system and the exclusion of a number of banks from SWIFT have significantly disrupted Russia's ability to pay for imports, receive payments for exports, and engage in cross-border money transactions (IMF, 2022a). Due to this, many countries in the region including countries in the European Union will also have to find solutions with dramatic uncertainty with regards to both energy prices and supplies. Though, it is too early to foresee[1] the full effect of the sanctions mentioned above.

3. Global Space Economy and the Actors in Space

In 2020, the turnover of the space economy was approximately 446.9 billion USD worth globally, a significant increase from 428 billion USD in the previous year. The most important

1 Only the IMF's projections are included in the article due to its limitations, which prevent it from describing the characteristics or impacts of both country-based and international economic shocks in detail. However, this article is expected to be a good source for further studies in the near future especially if there will not be a quick solution to put an end to the war. For more insight it would worth to read; "Transcript of April 2022 MD Kristalina Georgieva Press Briefing on GPA" April 20, 2022 via IMF website (IMF, 2022b).

sector in the global space economy in 2020 was the space products and services that produced commercially, accounting for almost 50 percent of the total income (Salas, 2021).

Figure 1 portrays how the growth in the space industry took place in years and how consistent it was. According to Salas (2021), governments spending across the world on space programs were more despite the Covid-19 pandemic. The overall expenditure on the space programs conducting by the goverments worldwide has been increasing over the last years. There exists a few organizations that help shape coordination for space related issues; the Consultative Committee for Space Data Systems, the United Nations Committee on the Peaceful Uses of Outer Space and the United Nations Office for Outer Space Affairs which are the main ones. They try helping to the international community for space policies and law to understand each other and act together.

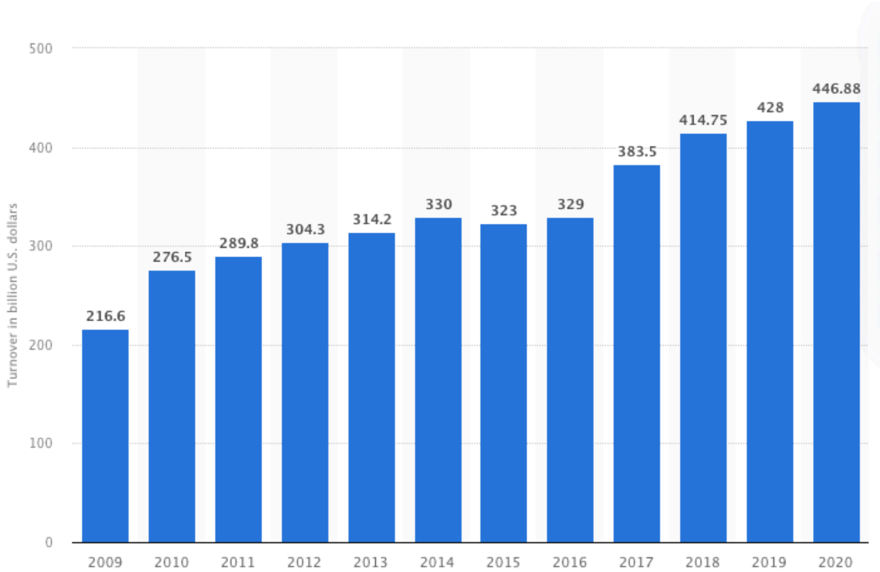

Figure 1. Global turnover of the space economy (in billion USD) (Salas, 2021)

Alongside NASA, Roscosmos and the Chinese Space Agency, there also exists other space agencies that have been established including the European Space Agency, the Latin American and Caribbean Space Agency (with seven member states), Asia-Pacific Space Cooperation Organization (Bangladesh, China, Iran, Mongolia, Pakistan, Peru, Thailand, Indonesia and Türkiye are among them), the African Space Agency (with 55 member states), and the Arab Space Coordination Group.

In 2021, global government expenditures for space programs continued to grow and reach a record of more than 92 billion USD, with an increase of 10.7 percent despite the Covid-19 pandemic. Figure 2 displays that the United States Government has spent approximately 54.6 billion USD on its space programs in 2021, making it the country with the highest space expenditure in the world. The government expenditure on space programs followed by China which is almost 10.3 billion USD, and Russia was the fourth country after France (Salas, 2022). These numbers show that countries continue to invest in space expenditures from their budgets. That is also a good example of showing that governments are still biggest buyer in the industry compare to the private side.

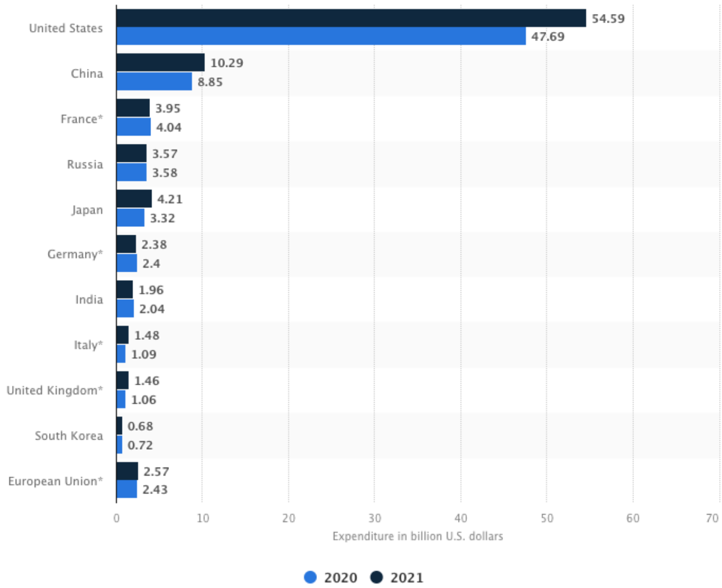

Figure 2. Government expenditure on space programs between 2020 and 2021 (in billion USD) by major country (Salas, 2022)

As this growth continues for the countries, private companies are having a wider share in the space industry each year. Figure 3 shows that the launches have been carrying out more payloads in 2022 with private companies such as SpaceX, Northtrop Grumman Space Systems or Arianespace compared to Russia and China. SpaceX launched about 115,900 kg of spacecraft upmass in the first quarter followed by Roscosmos with about 19,000 kg. According to the data shown on Figure 3, SpaceX has carried out payloads six times more in comparison to Roscosmos in 2022 which reveals the strength of this private company supported by the United States in the space industry.

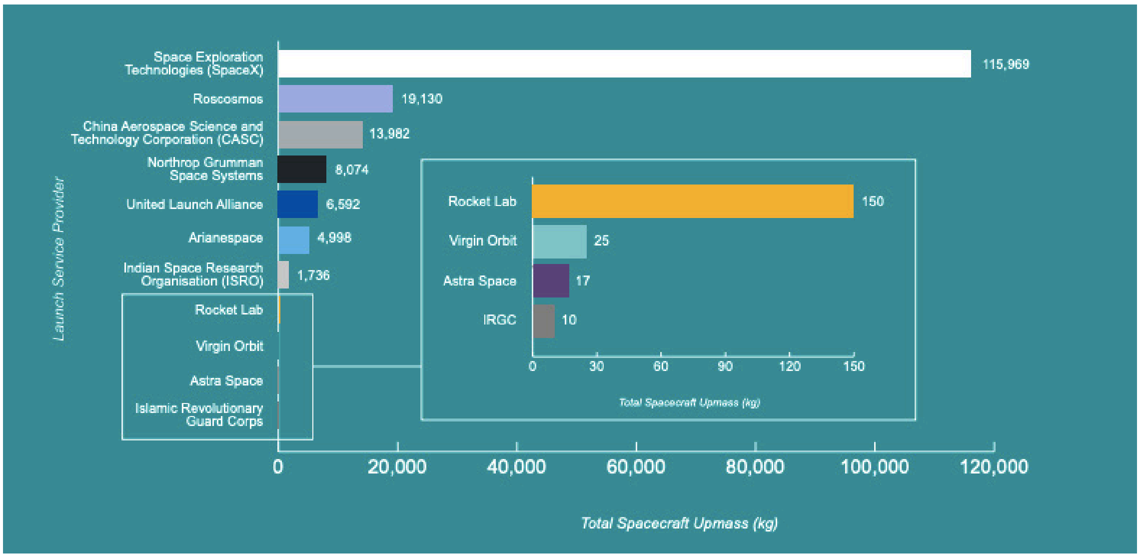

Figure 3. Spacecraft upmass (includes estimates of spacecraft mass when not publicly disclosed) carried by launch provider in 2022 (Bryce, 2022).

Due to the innovations and developments in space technologies every day, expectations have also been rising for the future. According to the Institute for Defense Analyses' report (2020), the future of the space industry is promising. One of the main reasons that government agencies now buy more services and technologies from the private companies[2] is so they can allocate their budgets for other missions and projects. In terms of predictions for the future of the space economy, there are several different approaches. The global wealth management company UBS, Morgan Stanley, U.S. Chamber of Commerce, Bank of America and Goldman Sachs are the main institutions that are attempting to find the best way possible to predict the future of the space industry (Crane, et al., 2020). Rather than choosing one of them, it was decided to share all in one graphic so that it could help in making comparisons altogether, as seen on Figure 4.

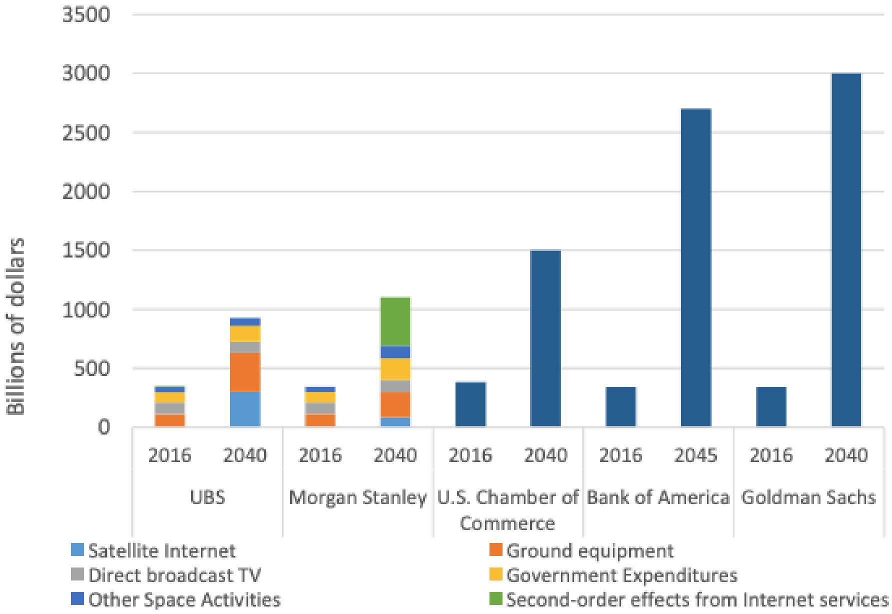

Figure 4. Comparisons by Category of 2016 Estimates and 2040 Projections of the Size of the Space Economy (Crane, et al., 2020).

The three largest projections of the future size of the space economy in 2040–2045 are by Goldman Sachs, Bank of America, and the U.S. Chamber of Commerce: “multitrillion dollars,” $2.7 trillion, and $1.5 trillion, respectively. The two smallest projections of the future size of the space economy are from Morgan Stanley and UBS, at $1.1 trillion and $926 billion respectively (Crane, et al., 2020). It is impossible to foresee the future, but all the institutions are displaying optimistic expectations for the space economy. It is evident that many countries show an interest towards space related projects and act to get services from the commercial entities. The key commercial players of the global space economy market for 2022 are: Space Exploration Technologies Corp. (SpaceX), Virgin Galactic Holdings, Blue Origin, Relativity Space, National Aeronautics and Space Administration, Northrop Grumman Corporation, Boeing Company, Rocket Lab, Astra Space, Firefly Aerospace. Even though some of those companies are focusing in space tourism their part in the industry is relatively smaller than other components of the industry.

5. International Space Projects

Despite the conflicts on the ground, outer space has been an opportunity for collaboration for the countries. Because of the possible consequences from risky situations, all sides acted

2 Having services from private companies does not mean they are cheaper. It is true that cost decreases but companies do not reveal the price that they charge from the agencies at the end of the day.

carefully to avoid causing crises and even continued to cooperate on couple of projects in space. The cooperation can be very wide-ranging, ranging from the simple sharing of data and results to totally integrated efforts such as the International Space Station (ISS) which is one of the great example for both scientific and exploration-associated program (Dupas, 2009). There are different space project areas including scientific research, Earth science applications, education initiatives, observations to benefit the environment, international space weather initiative, and the Lunar Science Institute (Younes, 2011). NASA is one of the greatest institutions in the world that actualizes the most international space projects. NASA has also partnerships with ESA, JAXA, ASI and CSA since the 1980s. After the Soviet Union had collapsed, another partnership was established between Roscosmos in 1993.

The number of international agreements has been fluctuating in recent years and NASA has not released the exact number for each year. For instance, in 2011 the number of total international agreements was 464 with 125 countries. This number went up to 731 with 122 countries in 2015 as it can be seen on Figure 5. There are no releases on the data for 2012, 2013, 2014, 2017 and 2018. So, this limits to see how the change occurred in years. According to the NASA report in 2015, international agreements at NASA include over 4,000 agreements (with the agreements that are still continuing) with over 120 nations and international organizations. By 2015, over 700 active international agreements between 8 partners (France, Germany, ESA, Japan, UK, Italy, Canada, and Russia) account for 50% of the agreements which also shows the strength of the international cooperation for the projects.

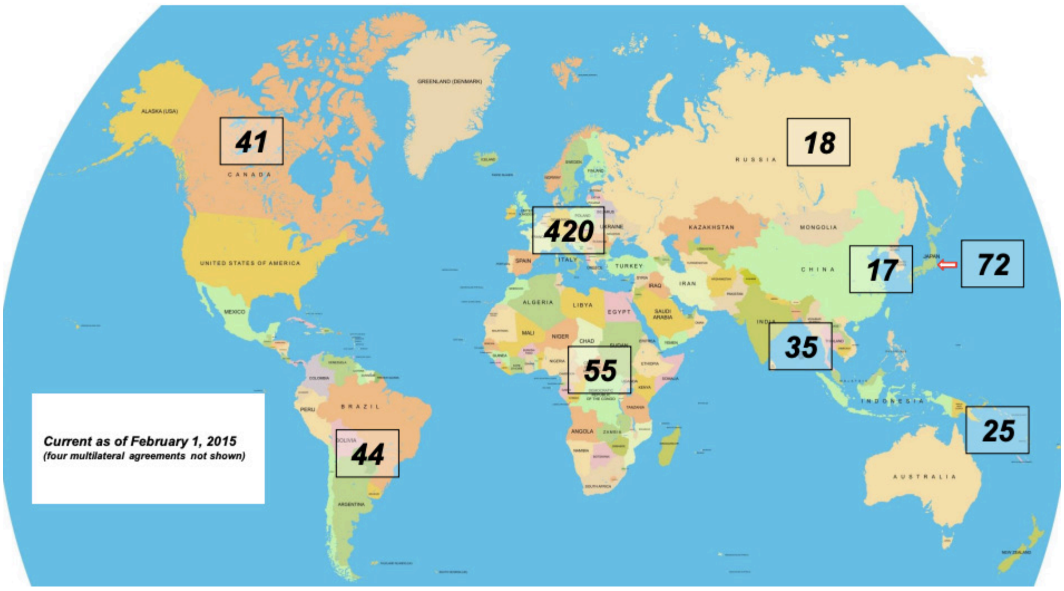

Figure 5. Total International Agreements (NASA, 2015).

In 2016 NASA had over 750 active agreements with more than 120 nations around the world for collaboration that provides to almost all aspects of NASA's activities. As of June 30, 2019, this number decreases to 709. As of June 30, 2020 active total international agreements continue to decrease to 679. In 2021, as of March 31 the total agreements decrease even further to 602 and finally as of March 31, 2022 some recovery can be seen as 637 projects remain active for the international agreements.

According to NASA, the ISS has been a representative of hope for peace in the space industry for international collaboration since then. An international partnership of space agencies provides and operates the important elements of the ISS. The principals are the space agencies of the United States, Russia, Europe, Japan, and Canada and just because of that the ISS has been the most politically complex space exploration program ever undertaken (NASA, 2020). The U.S. and Russia started to work together in 1998 to build the International Space Station as a largest cooperation example of the international politics, which is now supported by 15 countries. NASA relied on Russian rockets to get its astronauts to and from the ISS for 10 years until May 2, 2021. SpaceX has brought the old tradition back to the US soil with the latest innovation of Dragon rockets, and helped American astronauts to get to ISS but this development has not weakened the cooperation on the ISS with Russians until February 24, 2022.

6. Economic Shocks after the Invasion

In economics, economic shock has been defined as a significant change to fundamental macroeconomic variables that has a substantial effect on outcomes and measures of economic performance, such as unemployment, consumption, and inflation. Shocks are often unpredictable and are the result of events thought to be beyond the scope of normal economic transactions. After the invasion has started, the economic shocks have started to impact on the global economy. Russia has first made threats to invade Ukraine many times previously to the actual invasion. They have prepared hundreds of thousands of troops near the Ukraine border starting January, 2022. Following President Putin's orders, the Russian military initiated the invasion (it has been called "Special Military Operation" by Russian Government), hitting many Ukrainian cities simultaneously. In two days, the US, EU, UK, Canada, France, Germany, Italy, Australia and Japan jointly committed to applying sanctions[3] and they removed some Russian banks from SWIFT, targeting the Russian Central Bank economically.

Responding to massive sanctions led by the U.S. and the European Union on February 26 Russia's space agency, Roscosmos, pulled its workforce from Europe's launch site in French Guiana, where Russian-built Soyuz rockets were being prepared for upcoming missions. Now those missions are in limbo. Roscosmos went on to prompt the cancellation of a Soyuz launch from its own Baikonur Cosmodrome in Kazakhstan when it demanded that the London-based company OneWeb guarantee that the rocket's payload of 36 global communications satellites would not be used for military purposes and that the U.K. withdraws its investment in the company. OneWeb and the U.K. did not agree to those conditions (David, 2022).

Similar sanctions imposed by the United States because of Russia's invasion of Crimea in 2014, but projects continued despite the threads from Russia about barring the United States from the ISS because Soyuz rockets were the only option for the NASA to get their astronauts to the ISS. Even though cooperation continues on the ISS, it has not been a reason for Russia to renounce its invasion of Ukraine in 2022, so far. Ukraine's small but highly specialized space industry has been hit harder than Russia by the conflict over Crimea after 2014, but this time expectations show that recovery will last longer not just for Ukraine or Europe but for the entire

3 For a visual timeline on the invasion, please check; Sanctions against Russia and other major events starting November 2021 released by Peterson Institute of International Economics (2022): https://www.piie.com/blogs/realtime-economic-issues-watch/russias-war-ukraine-sanctions-timeline

world. Moreover the European Space Agency has also canceled its partnership with Russia following the imposition of Western sanctions.[4]

After ESA, DLR's executive board went further and terminated all collaboration activities with Russian institutions on current and planned projects, citing Russia's military aggression as the cause. Russia responded by rescinding its support for ongoing German-Russian experiments on the International Space Station (ISS) (David, 2022). However, these economic and political sanctions were not enough to stop Russia. Moreover, Roscosmos has implied it could eliminate ISS reboosts and decouple its modules from the space station, in theory allowing the rest of the ISS to crash and burn as its orbit decays. By expediting its pullout from the ISS, Russia could then turn to an emerging partnership with China (David, 2022).

After the West imposed economic sanctions[5] on Russia for annexing Crimea in 2014, an element of economic nationalism has made an appearance in Moscow pushing for "import substitution" in all the other sectors. In other words, Russian manufacturers should only make parts for Russian rockets, not Ukrainian producers. Ukraine should certainly not be building rockets for Russia especially considering the completion of Russia's new Angara rocket (Bodner, 2015). As it can be seen in Figure 6, the space station is a great example of international cooperation and both the United States and Russia are involved heavily not just technologically on the station but also with the command centers on the ground. Even though, politically, the two countries are running in opposite directions, they have to continue collaborations. For instance, NASA astronaut Mark Vande Hei returned to Earth in a Russian space capsule on March 30, 2022 while Russian troops were continuing their invasion. The Soyuz with three more Russian astronauts touched down successfully in Kazakhstan while the tension was extremely high between Russia and the rest of the world.

4 For more information about how cooperation evolved in the years until 2021, this book would be useful: European-Russian Space Cooperation: From de Gaulle to ExoMars (Springer, 2021). This book explains how the relationship evolved; what factors - scientific, political and industrial – improved most between Russia and the EU. Although the primary focus is on the technical aspects and outcomes of cooperation, the relationship is set within the wider diplomatic contexts that were also included in the book.

5 This article is worth reading, it has a historical discussion on the sanctions and how they have an impact from the Cold War era especially about Russia. Popescu, N. (2015). *Sanctions and Russia: Lessons from the Cold War.* EUISS. Also this; Aleksashenko, S. (2016). *Have Sanctions Hurt the Russian Economy?* Atlantic Council.

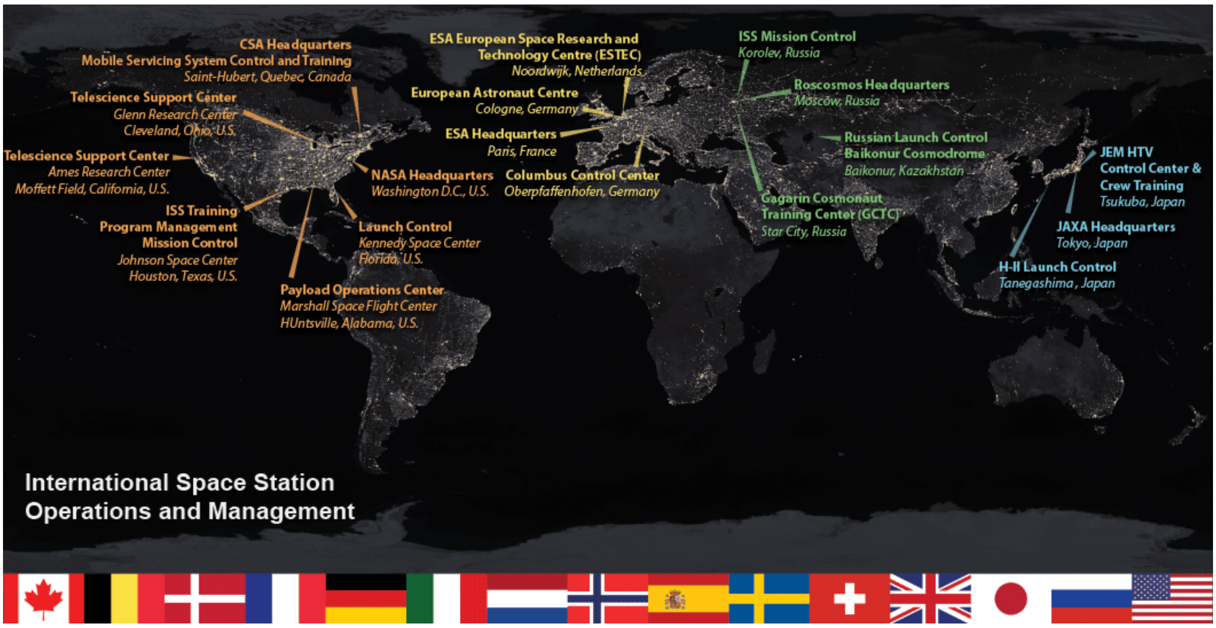

Figure 6. Facilities around the world support the operation and management of the ISS (NASA, 2020).

Even though the situation has already imposed risks for future collaborations in the space industry and has caused many cancellations around the world for projects to the Moon, Mars and beyond, there are also some new agreements between countries. Such as, the United States and India have both declared (White House, 2021) that they will develop their cooperation in the space projects, UAE will send an astronaut to the ISS with Axiom Space Company in one year and many other new agreements are expected to happen between countries and also companies anytime soon.

7. Results and Discussion

The conflict has not yet ended. Ukraine has been fighting against Russian military for over two months and Russia has been suffering with failures militarily and economically due to the international political pressure and economic sanctions. This is one of the main limitations of this study because it is unknown how the situation on the ground will develop and what else will be triggered in the future. One delay in the space projects might be followed by another one; administrations might be replaced, projects' budgets might be limited or even get cancelled. There are also situations where planets are sometimes not in the right direction for launches or even weather conditions do allow them. Space projects in this perspective are very fragile and extremely complex. In this perspective, this invasion will change the fundamentals and attitudes toward international space projects. As Professor John Logsdon said in an interview with David (2022) 'basically, I think it's the end of an illusion that working with your former opponent in space will spill over to better relations on Earth. … The Russian [civil space] program is not in robust condition anyway. They really don't have much going on. And in the possible Russian-Chinese partnership, it's China that is going to be the leader, not Russia'.

With that being said, China will continue to increase their space capabilities similarly in 2019, China and Russia have already reached a deal to collaborate on a mission to send people to the south pole of the Moon by 2026. Therefore, Russia will support and assist China to take the leadership for the future of the space industry instead of the United States. This would mean new blocks might be shaped in the future to be able to establish long-term projects that require high budgets but this would be a topic for future studies. The space industry has been shifting for so many years, and it will continue to do so. However, the most essential part of the industry has been affected most during the political crisis, economic shocks and regional conflicts which is the labor force. According to Callahan (2014), in the 1980s, NASA's planetary science budget was cut to the bone and the entire enterprise was nearly abandoned. The volume of talent and capability abandoned to attrition during this time is difficult to measure. This resulted in a "lost decade" of planetary exploration for U.S. space exploration.

Now, despite these kinds of budget cuts or limitations that have impacted the space projects and labor force in the industry, it is now easier to replace positions between companies and institutions since there is high demand of labor from the commercial space sector all around the world. Still, losing an organizational culture and the experience of project groups are not easily replaceable. From this study we also observe that even though some of the projects are easy to lose, some of them are not as can be seen via the ISS example not just because of the cumulative experience of cooperation but also high costs and technological collaboration. Any major partner change in the ISS could take at least years for every other partner that currently work in the station. According to Thompson (2022), Asif Siddiqi says he does not see a future for U.S. and Russian collaboration in space beyond the ISS's decommissioning, currently planned for 2031.

However, NASA states its position for the ISS in a stable manner, assuring the international community that they will continue to work with all of their international partners as NASA spokesperson Joshua Finch (Gohd, 2022) has emailed space.com a statement:

> "NASA continues working with all our international partners, including the State Space Corporation Roscosmos, for the ongoing safe operations of the International Space Station. The new export control measures will continue to allow U.S.-Russia civil space cooperation. No changes are planned to the agency's support for ongoing in orbit and ground station operations."

NASA's public response to the latest incidents also proves this is not an easy geopolitical or economical decision to act on, it is more complex just like the space environment itself.

8. Conclusion

This research aimed to explore the economic shocks in relation to the international space projects considering the Russia-Ukraine conflict. The findings show that generally not all the international space projects are influenced directly by economic shocks or regional conflicts. Despite countries having disagreements or falling apart in opinions, they remain intact and the projects usually continue without cancellation. However, in the case of the latest Russia-Ukraine conflict, a contrast in this pattern is seen as it has directly affected the space projects internationally. Nonetheless, not all projects are easily cancelled thus, some continue to prevail. Analyzes show that this is due to technological and financial limitations.

As the war continues, it is obvious that it will be challenging to restore long-term international cooperation with Russia. Conceivably, the most striking feature of the present situation is that contrary to the peace attempts offered by countries after the cold war, the current war is paving way for more impenetrable boundaries which could mean less peace talks between countries, hence could have dramatic impacts on the global space industry.

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In-Space Manufacturing: An Acquisition Policy Perspective

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1. Introduction

In-space manufacturing is the process of manufacturing goods uniquely leveraging the space environment, in particular space vacuum, low temperatures, or microgravity. This is not a novel concept, as many public and private actors have worked over several decades to make in-space manufacturing successful. It reached a pinnacle in the '80s during the space shuttle era, and the focused activities of the NASA commercial centers remain to date where we have most of the success stories of potential products in microgravity (Cozmuta, 2016). However, in-space manufacturing did not take off at that time because companies were not able to close the business case. That was because the price per pound transported to and from Earth's orbit was extremely high and because the shuttle did not fly as often as initially advertised. Furthermore, there was no commercially friendly infrastructure to support quarterly revenue building as bedrock for sustainable businesses. Four decades later, we are experiencing a shift in financing and technologies that the space industry calls New Space.

Three main shaping forces determine the success of companies pursuing in-space manufacturing: technology, economics, and policies. Technological advancements require research and development funds, fueled by government spending in the case of basic and even some early applied research, and private investment in the case of the last stages of applied research and product development. Technology, economics, and policies are closely intertwined. Space policies determine the spending priorities of the federal government, which in turn generate the basis for product development, insofar as such products can satisfy existing market demand.

Many specialized entities are conducting analyses on the space market and its contributions, but and there are some conflicting definitions of space manufacturing and in-space manufacturing.

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In a recent study, the Department of Commerce included in the category of space manufacturing many space-related products, notably "manufacturing of satellites; ground equipment; and search, detection, navigation, and guidance systems (GPS/PNT equipment) (Highfill et al., 2020)." Today space providers such as Airbus and Boeing equate space manufacturing with manufacturing for space; in other words, manufacturing structures on Earth, assembling them on Earth, and then launching these structures and operating them in space. So what should be considered in-space manufacturing and what should not?

A distinction needs to be made within the umbrella of space manufacturing. Some focus on in-situ resource utilization or manufacturing products in space for applications in space. However, the more immediate economic need is for intellectual property and products that companies can commercialize on Earth. As much as we would like to dream of humanity becoming a truly interplanetary species, the reality, for now, is that all of us are part of the economy here on Earth. Extensive research and development are still necessary to determine whether such products are economically viable. If space manufacturing were an established market today, the commodity traded on this market would be products manufactured in space for Earth and space use.

The International Space Station (ISS) remains the place where in-space manufacturing has been tested so far. The station currently dubs as a platform for kickstarting the space economy (NASA, 2019). The ISS has been continuously inhabited for the past two decades. According to the ISS Program Science Forum (2019), 2775 investigations have been conducted on the ISS, out of which 2098 were completed. One thousand five hundred thirty-four unique investigators from 68 countries conducted these experiments. The lifespan of the ISS has been extended several times, but the national laboratory will eventually come to an end as the bulk of its technologies are surpassed by new systems. Since 2016, NASA has been working extensively with Axiom Space to make the transition to commercial space stations. The latest indications from Congress suggest a 2030 extension; however, funding has to be secured for the continued operation of the ISS. It seems that companies now have less than a decade to prove their success with R&D onboard the national lab. A question remains of how can this success best be measured.

2. Technology

There are currently only a handful of companies that could bring products back from the ISS, SpaceX being the most prominent contender. Without a reliable and cost-effective infrastructure to close the production value chain, alternative materials produced in LEO (Low-Earth Orbit) will never be able to compete in terrestrial markets. Therefore, ensuring access to and from space is an essential element in the enabling of in-space manufacturing and the commercialization of LEO.

The technology of additive manufacturing, or 3D printing, developed on Earth needs to be carefully calibrated to a microgravity environment, as well as miniaturized and shielded. Some potential applications for additive manufacturing include orbital refineries, parts and components, and even the construction of large-scale structures in space. Several companies around the world are also working on developing new ways to reduce orbital debris, recycling it into useful components. Furthermore, asteroid and lunar mining could provide the prime materials for additional manufacturing capabilities, making the technology attractive for sustainable missions beyond Low Earth Orbit.

NASA has focused on developing additive manufacturing technologies primarily for long-term exploration missions (NASA, 2020), offering grants to private companies such as the Interlog Corporation, Techshot, and Tethers Unlimited. The workforce behind 'old space' was predominantly characterized by engineering backgrounds and naturally placed its focus on the development of technology, leading to a culture of technological push that still prevails today in the space industry. Oftentimes, problems have been expected to have technological solutions, rather than socioeconomic ones.

Although successful in proof of concept projects, there is still a long way to go in establishing a consistent demand for products manufactured in microgravity. Is the technological capacity alone sufficient to prove to customers on Earth that products manufactured in LEO are worth the premium? That is where the economic factors come into play.

3. Economics

The space economy is defined by the Organization for Economic Cooperation and Development (OECD, 2020) as the full range of activities and the use of resources that create value and benefits for human beings in the course of exploring, researching, understanding, managing, and utilizing space. The U.S. Space economy's gross output has experienced a period of slow growth between 2012 and 2018, as reported by the Department of Commerce's Bureau of Economic Analysis (Highfill et al., 2020). The share of gross output attributable to manufacturing has decreased from 32.6 per cent ($53 billion) in 2012 to 27.1 per cent in 2018.

> "Manufacturing was the second largest sector in terms of gross output, accounting for $48.1 billion of gross output in 2018. The share of gross output attributable to manufacturing decreased from 32.6 per cent ($53 billion) in 2012 to 27.1 per cent in 2018, mostly reflecting a decline in the computer and electronic products industry. This industry includes many space-related products, notably manufacturing of satellites; ground equipment; and search, detection, navigation, and guidance systems (GPS/PNT equipment)" (Highfill et al., 2020).

The increase in recent private investments in space can lower the initial barriers to entry in the business of in-space manufacturing. At the same time, demand for space infrastructure is growing and several commercial companies have already started building toward it. Space manufacturing is happening now and it is part of the second wave of new space companies emerging over the horizon together with in-orbit servicing and refuelling.

Where there is still a remaining gap is the microgravity product development that would support the in-space manufacturing industry to finally take off. While the cost of access to LEO has been slowly decreasing thanks to the Commercial Orbital Transportation Services (COTS) program, the cost of bringing people and equipment down to Earth remains at high-enough levels to pose serious challenges to business models trying to capitalize on in-space manufactured products. On June 23rd, 2022, Redwire Corporation announced its first sale of in-space manufactured crystals to a terrestrial customer, namely the Center for Electron Microscopy and Analysis (CEMAS) of the Ohio State University, at a price of $2M per kg (Redwire, 2022).

The market value of the space economy tends to be often associated with unreasonably large numbers. Recent investments in companies that focus on space manufacturing suggest that this sector promises future growth for this untapped market. Companies like Varda Space are raising impressive investment capital to tap into the growing field of in-space manufacturing of products to be sold on Earth. Ultimately, the difficulty relies on proving that the added value of in-space manufactured products can justify its large costs. This uncertainty could be ameliorated by a demand signal from the US government, recognizing the value of in-space manufactured products and offering a tangible initial price point.

4. U.S. Space Policies

Strategic federal-level policies have had demonstrably decade-lasting impacts on the advancements of space endeavors, in part due to the historically large scale of programs such as Apollo and the Space Shuttle (Hertzfeld et al., 2022). Although facing increasing international competition in space systems, the United States remains for the most part a trailblazer at the forefront of new space. Much like in the decades of the Apollo program, executive leadership from the White House continues to set the direction in which space technologies develop. The Biden Administration chose to continue entrusting space leadership to the U.S. National Space Council, which includes secretaries of relevant federal departments and agencies for more streamlined coordination of efforts in space. Historically, large and comprehensive national space policy documents have been produced decades apart, thus it is very likely that the current administration will follow the guidelines set forth by the most recent comprehensive National Space Policy (NSP) (White House, 2020) of the United States, a product of the previous administration.

The 2020 NSP directs the federal government to encourage the continued commercialization of operations in and beyond low Earth orbit. Furthermore, the document offers specific guidelines for NASA about the continued use of the ISS. Nevertheless, the US seeks to maintain a continuous presence in Earth orbit by transitioning from ISS to commercial platforms and services. Companies like Axiom and Nanoracks are working towards this end. The question remains whether these new commercial platforms can be economically viable without in-space manufacturing.

In April 2022, the White House announced a new strategic policy document specifically addressing the servicing, assembly, and manufacturing of spacecraft directly in space, with the intent of addressing the following challenges associated with these activities:

1. improving coordination and collaboration both within the USG, as well as among the USG, academia, industry, and international partners;

2. sending a clear and consistent demand signal to private industry in order to stimulate investment, mitigate risk, and address investor confidence; and

3. establishing and adopting ISAM standards to help promote growth.

The In-Space Servicing, Assembly, and Manufacturing National Strategy (National Science & Technology Council, 2022) outlined six goals as the United States continues to develop

ISAM activities: advancing ISAM R&D, prioritizing the expansion of scalable infrastructure, accelerating the emerging ISAM commercial industry, promoting international collaboration and cooperation to achieve ISAM goals, prioritizing environmental sustainability, and inspiring a diverse future workforce as a potential outcome of ISAM innovation.

"ISAM capabilities can create the foundation for sustainable operations and serve as a strategic enabler to spur U.S. scientific and technological innovation, ensure the freedom to operate, and preserve the use of space for future generations" (National Science & Technology Council, 2022).

Although it appears that most interest from the government is behind capabilities such as life extension services (inspection, refuelling, and repair), and docking to legacy satellites, the in-space manufacturing component remains essential to the success and sustainability of ISAM operations. A new policy addressing demand signalling for in-space manufactured products would contribute to the acceleration and emergence of the ISAM commercial industry, one of the major goals supported by the In-Space Servicing, Assembly, and Manufacturing National Strategy.

5. In-Space Manufactured Commercial Product (ISMCP)

The commercial off the shelf (COTS) approach has been attractive to NASA and other government agencies as a means of accessing already developed technologies available on terrestrial markets. In the case of space applications, such technologies would be acquired from the marketplace and then adapted and qualified for space projects (White, 2017). However, this approach can have its limitations, as it assumes that technological innovations can only happen terrestrially.

In recent decades, new material formulations have been discovered which take advantage of the unique environment of space, mainly the sustained microgravity and clean environment aspects. Microgravity R&D has the potential to create new technological innovations which could not only support space applications but also permeate terrestrial markets. In-space manufacturing is a currently untapped and underdeveloped source of technological innovations. As new activities become available in LEO and beyond thanks to the increased access to space and return capabilities, a new model of innovation, opposite to COTS could emerge. Under this model, the government will become able to acquire in-space manufactured products and intellectual property and then adapt these for terrestrial applications.

However, for such a shift to be possible, the US government needs to adopt a new policy aimed at supporting in-space manufacturing by becoming the first customer for in-space manufactured products. This would not be an entirely novel concept but an adaptation of the existing Commercial Orbital Transportation Services policy (NASA, 2014) to the next wave of new space development-the commercialization of LEO. That policy supported the market for space launch services, firstly with investment in R&D, then with acquisition of launch services. The success story of SpaceX in the launch market illustrates the power of demand signalling from the government: once the government became the anchor customer, the price of the launch could be set and communicated to the market, enabling other interested companies to purchase launch services from SpaceX.

The government needs to continue to invest and needs to replicate the success of the COTS model for in-space manufacturing. The government needs to be a reliable customer and buy space manufactured products. However, it seems that government agencies are not yet convinced of the value of space manufactured products. To convince itself, the government needs to support the creation of the demand not just through the development of the hardware but also through deploying capital to fund microgravity translational research. The executive branch needs to take the stance and communicate to the industry a message such as: to maintain the U.S. competitive advantage in multiple markets and strategic areas, we need to be the first to fund, buy and use the superior products manufactured in space.

This strategy would support not just the growth of the LEO economy but also the development of infrastructure in the cis-lunar space and a more successful and broader impact on the Artemis program. Ultimately this will lead to moving the industrial base supporting the space program from the surface of the Earth and the bottom of the gravity well (which is expensive and counterproductive to effectively reaching multiple destinations in the solar system) to Earth's orbit and the cis-lunar space. In-space manufactured products for Earth and those for space exploration will likely be different. Whereas those produced for markets on Earth are highly specialized and innovative, those produced for use in space will resemble more traditional infrastructure elements (e.g. solar panels, circuit boards, radiation shields). The key to having the two lines of products develop in harmony will be finding those few systems that overlap.

In addition, moving manufacturing and industrial processes into space would also be advantageous from a sustainability perspective. One of the top factors contributing to global pollution, amounting to ~20%, originates directly from industry (IPCC, 2014). Blue Origin CEO Jeff Bezos envisions the commercialization of space through a transition of heavy industries such as manufacturing in Earth's orbit (Beilstein et al., 2021). However, in-space manufacturing can contribute not only to sustainability but also to national defence. The Space Force created a new assistant secretary for space acquisition and integration, offering an organisational framework for the acquisition of in-space manufactured products, insofar as they can provide a competitive advantage. The newly created branch of the U.S. military can thus also reinforce the superiority of U.S. national economic power by supporting the development of the LEO economy through in-space manufacturing. At the same time, the Space Force could benefit directly from increasingly autonomous systems for space operations, as current regulations keep space launch as a somewhat lengthy process.

6. Conclusions

In the next decade, we will experience a move away from the ISS and towards privately operated space stations in LEO. In-space manufacturing has the potential to justify investments in these stations and provide a steady revenue stream. However, in-space manufacturing is often misunderstood, resulting in unrealistic economic forecasts that will hurt the long-term trust of investors. The long-term success of in-space manufacturing depends on three types of factors: technology, economics, and policy. As long as the stars align and all three factors are optimized, the probable outcome will be a vibrant environment for cutting-edge research and technology development that to be possible, a change in approach is needed now to support the commercialization of LEO, through in-space manufacturing.

The government needs to step up and support this effort that needs well thought out and structured policies to rely upon. The government needs to send out a stronger signal as well as a pragmatic plan to execute a successful transition to help commercial companies create value from space manufacturing to both US and global industries as well as to space exploration efforts. This is strategically important for US leadership in space and also pragmatically contributes to the long-term sustainable development of space activities. The In-Space Manufactured Commercial Product (ISMCP) policy would ensure that the LEO economy can continue to develop at the current, or even faster pace by reducing uncertainty and thus enabling the in-space manufacturing sector to grow organically.

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The Ownership Question on the Resources Derived From Space Mining

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1. Introduction

Space mining is the process of extracting space resources from asteroids and celestial bodies (Infogence Global Research, 2022). So far, platinum, iron, nickel and some valuable metals have been discovered on the near - earth asteroids, and water, regolith oxygen, helium 3, etc. have been found on the Moon. The exploration of these elements is very promising, as the metals discovered on asteroids are used in the automotive, jewelry, medical and electronics industries. They could also be used to 3D print spacecraft components on the Moon without being brought from Earth. This would facilitate and reduce the cost of building space mining infrastructure on celestial bodies. In addition, water on the Moon could be used for in situ propellant production on the Moon, to be used for interplanetary travel (Anderson, Christensen & LaManna, 2019).

Scientific exploration of lunar resources has been conducted by the United States, the Soviet Union, and China since the 1960s. As for asteroid resource exploration, the first resource collection and return project was the Hayabusa project conducted by Japan. The mission was launched in 2003 and the probe returned in 2010. The next sample collection mission is also planned by the Japanese Space Agency (JAXA) and is named Hayabusa 2. Hayabusa2 was launched in 2014 and dropped its sample in 2020. And finally, the OsirixRex mission of NASA, which was launched in 2016, and the return of the collected samples are expected in 2023 (Missions to Asteroids).

As a result of space resource exploration and findings, space mining is arising as a new commercial activity of the decade. The market value of space mining was $710 million in 2017 and could grow to as much as $ 3.87 billion (Statista Research Department, 2022). Initially,

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space mining is still focusing on scientific exploration of space resources. For example, Lunar Outpost, Masten Space Systems, ispace Europe and ispace Japan were selected by NASA to collect space resources and transfer their ownership to NASA in 2024. The outcome and lessons learned will play an important role for the Artemis program (Schierholz & Finch, 2021).

The space mining sector will eventually grow even further, and activities will evolve from collecting samples for government agencies to profitable commercial activities. In order to support and encourage the growth of the market, the creation of a legal framework that grants certain rights to the players in the sector is essential. In this case, the question of ownership of extracted resources is particularly fundamental and must be answered by the legal system. Because the answer to this question would attract private actors, investors, etc. to the sector (Infogence Global Research, 2022).

In this paper, I will first discuss the property rights to extracted resources in light of the Outer Space Treaty and the Moon Agreement. Then, the national legislation of the United States of America (USA), Luxemburg, United Arab Emirates (UAE) and Japan will be refered. Finally, non-governmental initiatives, the Hague the International Space Resources Governance Group (The Hague Group), the Moon Village Association (MVA), and Outer Space Institue that have announced proposals for an international legal system and how they address this issue will be examined.

2. Sovereignty v. Property Rights on Celestial Bodies

In general, Article II of the Outer Space Treaty (OST) prohibits the appropriation of outer space and celestial bodies by claiming sovereignty by any means (the principle of non-appropriation). Accordingly, outer space and celestial bodies are *res communis* area of humankind, no state owns them. This approach is repeated in the Moon Agreement, Article 11. In addition to prohibiting sovereignty over celestial bodies, the MA also prohibits claims of ownership over the land on the Moon (or other celestial bodies) on which state or non-state institutions have been established, as well as on other celestial bodies.

The non-appropriation principle of the OST mentioned above refers only to states and prohibits sovereign claims to immovable property (Outer Space Treaty, article II). The MA refers to both states and private actors when it comes to prohibiting sovereignty and property rights over the immovable property of the Moon and the other celestial bodies (The Moon Agreement, article 11). However, because the OST has been ratified globally, its sole reference to states has led some private actors to assert property rights over the Moon and other celestial bodies. For example, some private companies have been selling pieces of land on the Moon or other celestial bodies for a certain amount, and issue certificates for the purchase (Mann, 2012).

These purchases and claims of ownership of the celestial bodies have no legal effect. In fact, the title to the immovable object should be acquired by registration in a national registry. The establishment of a national registry for immovable property is a sovereign act of states; therefore states can carry out this practice in their territory. Therefore, no sovereignty over outer space and celestial bodies also means that there are no property rights claims over outer space and celestial bodies (Erdem, 2014).

Another legal basis for its conclusion is declared by IISL (International Institute of Space Law, 2015). According to the declaration;

> *"... according to international law and pursuant to Article VI, the activities of non-governmental entities (private parties) are national activities. The prohibition of national appropriation by Article II thus includes appropriation by non-governmental entities (i.e. private entities, whether individuals or corporations), since that would be a national activity. The prohibition of national appropriation also precludes the application of any national legislation on a territorial basis to validate a 'private claim. Hence, it is not sufficient for sellers of lunar deeds to point to national law or the silence of national authorities to justify their ostensible claims. The sellers of such deeds are unable to acquire legal title to their claims. Accordingly, the deeds they sell have no legal value or significance, and convey no recognized rights whatsoever."*

As opposed to prohibition of immovable property rights on celestial bodies, movable property rights could be claimed over the collected samples, since the legal basis for immovable property ownership differs from the legal basis of ownership claims on the movable property. As for movable property, possession of the movable material, in this case the samples returned from the Moon and asteroids, is sufficient to claim property rights in it (Hertzfeld & Von der Dunk, 2005).

Consequently, the principle of non-appropriation of the OST and the MA only prohibits the sovereignty and ownership claims to the land of the Moon or any other celestial body, which are immovable assets. Claiming ownership of movable material on the Moon or other celestial bodies does not fall within the scope of the non-appropriation principle.

3. The Question Ownership on Resources in Outer Space

There are three aspects to the question of ownership on space resources. First, the legality of claiming ownership on the mined space resources; second, the establishment of an international legal regime and an authority that grants rights over the resources and governs them; and third, the sharing of benefits derived from the ownership of space resources.

3.1. Claiming Ownership on the Mined Space Resources

The question of ownership on space resources arose after the U.S. passed the IV chapter of the Space Competitiveness Act in November 2015, the first piece of national legislation to include provisions on space mining. Initially, the debate centered more on the legality of space mining, and there were two camps. One camp argued that space mining may be breach of the OST, because it was not specifically provided by the OST (Kerrest, 2004). On the other side, it was argued that the freedom of exploration, use, utilization of outer space and celestial bodies provided by the OST implicitly permit mining activities above celestial bodies. Ultimately, the majority of the international community recognizes the legality of mining activities in space under the OST and defends that any mining activities should be conducted in accordance with the provisions of the OST (International Institute of Space Law, 2017).

In fact, the MA gives us a clear answer, and in light of the treaty, there would be no need to discuss this issue. However, the fact that it has been ratified by only eighteen countries has implications for its implementation worldwide. Therefore, this clear answer does not provide direction for most space stakeholders. However, there are some scholars who argue that Article 11 of the MA could be incorporated into the OST via systemic interpretation, and their arguments may be worth noting (de Man, 2016).

The OST and the MA implicitly or explicitly permits space mining and natural resource exploitation. Since the natural resources of the Moon and other celestial bodies are movable goods, whoever mines them can become the owner.

The international community also recognizes that the mined resources and the products derived from them may be acquired by the operator in accordance with national legislation, bilateral and/or multilateral agreements (The Hague Group, 2019).

Lastly, domestic legislations adopted by the USA, Luxemburg, United Arab Emirates (UAE) and Japan are leading the way in regulating space mining and answering the ownership question. In the U.S., the Commercial Space Launch Competitiveness Act of 2015 allows U.S. citizens to own, possess, use, and sell space resources obtained through their commercial activities in accordance with international obligations of the United States arising from the OST.

The Space Resources Act of 2017 adopted by Luxemburg states in Article 1 that *“space resources are capable of being owned”* As the third legislation UAE, the Federal Law of the United Arab Emirates on the Regulation of Space Sector of 2019 allows the exploration, exploitation, and use of space resources, including acquisition, purchase, sale, trade, and transportation with a permit issued by the UAE Space Authority. Lastly, Japan through the Promotion of Business Activities Related to Exploration and Development of Space Resources Act of 2021, allows claiming ownership on space resources by the person who has obtained permission to exploit in accordance with the approved activity plan.

3.2. The Establishment of an International Legal Regime and an Authority

Regulation of space activities has been driven by individual states since 2015, increasing from one to four. As sovereign states, they are free to legislate in accordance with their international obligations. As for space activities, space mining in this case, international space law places responsibility on states to authorize and monitor domestic governmental and non-governmental space actors, which could be done through national legislation. (Outer Space Treaty article VI) However, an activity that must be carried out for the benefit of humanity requires the special attention of the international community to establish the international legal framework for it.

After the adoption of the first national laws on space mining, the international community has begun to advocate for international regulation of space mining and management of space resources. Thus, three the non-governmental initiatives have prepared and announced their proposals, including the principles that an international regime should adopt. Moreover, UNCOPUOS established a working group after Austria, Belgium, the Czech Republic, Finland, Germany, Greece, Slovakia and Spain submitted a proposal to this effect, and considering proposals of international community (Working Paper on the Establishment of a Working

Group on Space Resources, 2021).

The first legal regulation to establish an international resource management system was Article 11 of MA. The last paragraph of the article states that the international regime should include *"the orderly and safe development of the natural resources of the Moon; the rational management of these resources; the expansion of opportunities for the utilization of these resources; an equitable sharing by all Contracting Parties..."*. Today, non-governmental initiatives are advocating in even greater depth and detail for an international regime and management mechanism. According to the International Space Resources Management Group in The Hague, space resources should be governed by an international framework, and this framework should *"create an enabling environment for space resources-related activities that takes into account all interests and benefits all countries and humanity"* (Building Blocks for the Development of an International Framework, 2019).

In terms of institutional arrangements, the Hague Group proposes to *"establish and maintain a publicly accessible international registry to record an operator's priority rights to explore for and/or extract space resources, establish and maintain, in addition to the international registry, an international database to make it available to the public, and designate or establish a body or bodies responsible for this purpose...."* (Building Blocks for the Development of an International Framework, 2019).

The Moon Village Association also supports the idea of *"developing a management system to facilitate the establishment and expansion of lunar activities through the cooperation of government and private entities."* In addition, it proposes to establish a publicly accessible international land use registry and database containing scientific information from lunar activities and best practices related to lunar activities (Moon Village Principles, 2020).

The Vancouver Principles focus primarily on the creation of an international legal system, defending *"the unilateral adoption of national legislation as an inadequate response to the need to ensure that space mining, wherever and whenever it occurs, is conducted in a safe and sustainable manner"* (Vancouver Recommendation on Space Mining, 2020).

3.3. The Sharing of Benefits Derived from Commercial Activities on the Owned Space Resources

Benefit sharing of the use of space resources is first mentioned in Article 11 of MA, which defines lunar resources as a "common heritage of mankind". According to this article, *"benefits from the exploitation of Moon resources should be shared on equitable basis with the special consideration of the interests and needs of the developing countries, as well as the efforts of those countries which have contributed either directly or indirectly to the exploration of the Moon"*.

Unfortunately, the common heritage of humankind and the benefit-sharing system in the MA were not endorsed by the major space actors, and this provision remained ineffective for years. Today, however, sharing of benefits arising from space mining is being reintroduced by the international community. The Hague Group, for example, promotes the idea of benefit sharing, which takes into account that *"the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and humankind"* And benefits to be shared are defined as *"the development of space science and technology and of its applications;*

the development of relevant and appropriate capabilities in interested states; cooperation and contribution in education and training: access to and exchange of information; incentivization of joint ventures; the exchange of expertise and technology among states on mutually accepted basis; the establishment of an international fund". However, they excluded the compulsory monetary benefit sharing.

The Moon Village Association proposes consideration of the interests of other stakeholders and benefits to all countries and humanity, and benefit sharing through all feasible means, such as encouraging participation in lunar activities.

In the case of the Vancouver Principles, the benefit sharing mechanism mainly focuses on monetary benefit sharing, which is to be mandatory and performed through the establishment of an international fund.

4. Conclusions

The very first legal question on space mining is the ownership of space resources, and current international space law grants this right to private actors who involve space mining business. Domestic legislation on space resources and space mining also confirms the ownership rights of private parties performing commercial space resource/ space mining activities. However, the international community, i.e. non-governmental initiatives, proposes a specific international legal system for space mining and a space resource management mechanism, to grant space resources rights for the actors of the sector, and protect their rights. At the same time, they propose benefit-sharing mechanisms so that space mining could be carried out for the benefit of humanity. In this case, the ownership on the space resources is not restricted, but the exercise of property rights over the resources imposes some positive obligations on those engaged in space mining activities to be used for the benefit of mankind.

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Liability of Private Entities Arising From Space Operations*

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1. Introduction

The interest of private entities in the space field is increasing day by day. As the process of commercialization of space activities continues rapidly, the space treaties drafted during the Cold War era, do not legislate effectively for private activities (Hobe, 2020). Article VI of the Outer Space Treaty subjected the realization of private activities to the authorization and continuous supervision of States. The same article emphasized that States bear international responsibility for their national activities including activities carried out by private entities. Also, the liability regime of International Space Law has no limit and is considered to be victim-oriented, compared to other liability regimes.

It is argued in academia that the responsibility and liability regimes established by space treaties, hinders the development of private activities, and becomes outdated with the rise of private entities. The issue sought to be answered within the scope of this study, is whether or not these regimes are up-to-date and whether or not they are compatible with today's realities. In this context, we will first underline that private entities do not bear responsibility at the international level (2). Following which, we will deal with how the responsibility undertaken by States, is reflected to private entities in their national space legislations (3).

In this study, the issue of responsibility and liability only arising from space operations will be discussed. The definition of a space operation is the launch of a space object into outer space, its control in outer space or its return to Earth. Also, the concept of a private entity should be understood as the person who carries out the operation, namely the private operator. In

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short, an operator is a person who conducts a space operation independently and under his own responsibility. The operator does not need to have ownership of the space object, it is sufficient to exercise effective control over the object.

2. A State-Centric Approach Developed in Space Treaties: The Non-Existence of Obligation of Private Entities at the International Level

In Space Law, States bear responsibility arising from internationally wrongful acts (2.1.) and are also liable for damages caused by space objects (2.2.).

2.1. Responsibility of States for Internationally Wrongful Acts

The existence of an internationally wrongful act of a State is necessary for State responsibility. The breach of an international obligation by a State and the attribution of the unlawful conduct to that State, are two elements of an international wrongful act. The difference in the responsibility regime in Space Law arises regarding attribution of conduct to a State. In International Law, the conduct of any state organ is considered an act of that State. Therefore, as a rule, States do not bear responsibility for the conducts of private entities (Achilleas, 2020). In Space Law, the actions of private entities are considered as an act of State. As previously stated, according to Article VI of the Outer Space Treaty, States bear responsibility for their national activities, including the activities carried out by private entities. Therefore, a wrongful act arising from a national space activity entails the State responsibility (Dos Santos, 2020; Hobe, 2020).

Concurrently with responsibility for wrongful acts, States are also liable for damages resulting from dangerous activities that are not prohibited by International Law.

2.2. International Liability of States for Damages Caused by Space Objects

A specific liability regime has been written into in Space Law as space activities are ultra-hazardous ones (Dos Santos, 2020; Achilleas, 2020). In general terms, this regime has a very high level of victim protection compared to other regimes. According to Article VII of the Outer Space Treaty, States are liable for damage caused by space objects. This article clarified only which States would be liable, whereas other issues (definition of damage, nature of liability etc.) were detailed by the Liability Convention. According to the second article of the Convention, the launching State shall absolutely be liable for damage caused by space objects on the surface of the earth or to aircraft in flight. Article VI of the Convention provides for the exoneration from absolute liability if a launching State proves that the damage has originated from gross negligence, or a conduct made with intent to cause damage by a claimant State (Smith & Kerrest, 2013). The liability of the launching State for damages caused in outer space is fault liability. In summary, States are liable for the damage caused in outer space to the extent that they are in fault.

Finally, it would be appropriate to deal with the relationship between responsibility and liability.

2.3. The Relationship Between Responsibility and Liability

Whilst damage is not one of elements of an international wrongful act, it would need to occur, in order for liability to arise as a result of lawful activities. While the fault is not one of elements for an internationally wrongful act, it is determinative in the emergence of liability for damages caused in outer space. Responsibility and liability regimes exist independently, and it is at the discretion of the Claimant State which regime to apply (Smith & Kerrest, 2013). When we look at the practice that has developed following the coming into force of the Outer Space Treaty, it can be claimed that Articles VI and VII of this treaty have gained the status of customary international law. Therefore, Article VII of the Outer Space Treaty, as a general liability rule, will be applied especially in the case of States not party to the Liability Convention (Kerrest & Smith, 2009). Similarly, the same article can be applied in matters outside the scope of application of the Liability Convention.

States have tempered the heavy responsibility (and liability) they bear due to private activities at the international level, by sharing it with private entities in their national space legislations.

3. National Space Legislation as an Essential Source of Commercial Space Law: The Limited Liability of Private Entities at the Domestic Level

With the commercialization process in the space field since the 1980s, there have been some changes in the sources of Space Law. National space legislation, as an essential source of Commercial Space Law, is one of the consequences of these changes. In these legislations, States usually address operator's liability to third parties (3.1.). This liability is generally limited to encourage the development of private activities (3.2.).

3.1. Operator's Liability in General

The State that has compensated the damage caused by an operator at the international level, has generally a right of recourse against the operator (3.1.). Taking out an insurance is generally demanded by States to ensure the compensation to the victim (3.2).

3.1.1. Establishment of a Right of Recourse against Operator

The liability of an operator can generally arise in two ways. The victim of damage can seek reparation in national courts, or the State (or the State representing the victim) can make a similar claim against the State to which the operator is affiliated (Kerrest & Smith, 2009). In the second case, a State that paid compensation at the international level, may present a claim against the private entity. Indeed, doing so permits States to transfer the risk of damage to the operator. In fact, applying the recourse mechanism in national space legislations is clearly of great importance in terms of providing legal certainty. The value of the sum insured by an operator generally constitutes the limits of indemnification of the damages, in terms of amount.

3.1.2. Obligation of Operator to Obtain Insurance

The most important consequence of an operator's liability at the domestic level is the obligation to insure against damages to be caused to third parties. However, taking out insurance is not an obligation arising from space treaties. With the commercialization of space activities, this practice has arisen and made a great contribution to the development of these activities (Marboe et al., 2015). In practice, the taking out insurance, has generally become one of the conditions for authorization in practice. In some cases where the public interest requires, or the risk is low, the mitigation or elimination of this obligation may be provided. This is as a result of the legal policies elaborated by States in the field of space (Çakır, 2021). Another reflection of these policies is the limitation of an operator's liability.

3.2. Operator's Limited Liability of Damages Caused to Third Parties

Two main factors limiting the liability of operator deal with amount (3.2.1.) and fault (3.2.2.).

3.2.1. Limitation of Liability of Operator in term of Amount

Considering that the risk for damage arising from space activities is very high, it can be said that private entities do not have the capacity to financially bear this risk. States are liable without ceiling at the international level, but they deflect this liability to private entities by limiting it at the national level. This limitation in particular, makes it possible to obtain insurance and contributes to the development of space activities. It is at the discretion of the States to determine the maximum limit of the operator's liability. This ceiling can be a fixed amount, or it can be flexible, taking into account the risk factor implicated in the operation. Although the specified cap constitutes the limits of the recourse against an operator, this limit may also be excluded in some cases (for example, in case of breach of authorization conditions).

3.2.2. Fault as a Limiting Factor

As stated above, the liability of States for damages caused in outer space is fault liability. States reflect this liability to the extent that operators are at fault in the occurrence of damage and thus limit the liability of operator. It is also necessary to remember that if the fault is attributed to the victim, this is one of the reasons that exonerates an operator from absolute liability. The issue of how to prove the fault is not addressed in space treaties. In academia, it is asserted that the general principles of law can be applied (Marboe, 2012). Furthermore, the non-binding recommendations and guidelines adapted by the UN General Assembly (especially those related to the mitigation of space debris) are of great importance in proving the fault of space actors (Marboe, 2012).

4. Conclusion

The space responsibility and liability regimes have not prevented the development of private activities. On the contrary, they have positively affected the development of these activities. With the protection provided by States, the development of private entities, generally far from reaching maturity, has accelerated. Therefore, it would be appropriate to continue applying the current regime until these entities reach a certain maturity. Although the current liability regime has strict features, it has also forced States, in the authorization process, to ensure the reliability of an operator, in order to minimize the risk of damage (Marboe et al., 2015). This is of great value especially in order to ensure the sustainability of space activities.

As a result, the current regime regulating the liability of private entities is still up to date, although the context of space has radically changed. In keeping this up to date, the complementary and reinforcing role played by national space legislations is indisputable. These sources constitute an important reflection of the legal policies elaborated by States in the field of space. In this context, Turkey should develop competitive policies and then take the necessary steps to enact national space legislation (Çakır, 2020).

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The Legal and Policy Dimensions of Cyber-Conflict in Outer Space*

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1. Introduction: Cyber Security Is Becoming Outer Space Security

On February 24, 2022, the ViaSat network suffered a widespread outage as "AcidRain" malware invaded the company's infrastructure of modems and routers designed to inter-connect ViaSat's fleet of four satellites and thousands of customers using ViaSat for Internet connectivity (Pearson, 2022). On the same day as the Russian invasion of Ukraine, thousands of modems were rendered permanently inoperative. The malware was labelled by the perpetrator "ukrop" possibly identifying a linkage to the "Ukraine Operation." While details are being investigated and ViaSat is declining to reveal more about the cyber-attack due to security concerns, the incident illustrates the cyber vulnerability of satellites and their networks to Internet-related attacks (Kan, 2022).

The emerging legal and policy topology of outer space governance is compelling policymakers and legal scholars to re-map the long-standing analog outer space regime as it adapts to a digital world system increasingly penetrated by eruptions of cyber-conflicT (Erwin, 2022). At the dawn of the space age, satellites interfaced with terrestrial analog telecommunications networks which operated as giant mechanical switching machines relaying long-distance messages distributed by copper cables under the oceans and across the landscape. Satellites made possible instantaneous high-bandwidth programming across and between continents, subject only to the few entities capable of disrupting radio frequency links between highly secure ground

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stations connected via satellites orbiting more than 35.000 km above the earth's equator in the geostationary orbit. The foundations of the outer space governance regime reflected these early technological realities in two policy areas of outer space management: (1) outer space as a "place" as defined by the five outer space treaties; and, (2) outer space as "electromagnetic spectrum" - an extension of terrestrial telecommunications infrastructures already regulated by the International Telecommunication Union (ITU) (UNOOSA, 2022).

1.1. Mapping the Legal Topography

The five foundational outer space treaties promulgated in the UN Committee on Peaceful Uses of Outer Space (UNCOPUOS) established the legal basis for exploring and using outer space as a "place" while the ITU's constitutive agreements and Radio Regulations were likewise "hard law" legal treaties for regulating the use of radio frequency spectrum in outer space as a communication medium (ITU, 2022). During the first decades of the Space Age, exploration and use were undertaken overwhelmingly by governmental entities, with operational networks operated by Intelsat, Inmarsat, Eutelsat, Arabsat, and Intersputnik as inter-governmental organizations formed by "hard law" multilateral treaties. By the 1980s, the plate tectonics of technological evolution toward digital communications began to bulldoze a new legal topography. To enhance their competitiveness in a digitizing services marketplace, nations began to liberalize their telecommunications infrastructures domestically and to open up markets for international commercial satellite communications firms, such as PanAmSat's challenge in the late-1980s to Intelsat's cozy "country club" of governmental telecommunications monopolists (Economist, 2005). The pace of change accelerated in the 1990s as *packet-switched techniques* de-centralized conventional circuit-switched analog network and market architectures. A plethora of terrestrial and space-based commercial firms sought regulatory reform that de-centralized governance in synch with the Internet's pack-switched network architecture. However, loosened governmental network and market oversight also brought about the awareness of the Internet's open access architecture's vulnerability to disruptive "hacking." Outer space digital networks would not be spared (Bergamasco, et. al., 2020).

1.2. Mapping the *Policy* Topography

In the 21st Century, political, economic, and strategic power is concentrated in evermore vulnerable digital networks. Today, billions of people are constant consumers of outer space navigation and Internet services. With deployments of thousands of mega-constellation satellites providing direct access to Internet services, many of the billions of smartphones and other information appliances (a.k.a. the "Internet of Things" (IoT)) will access and use the Internet through space segments provided by commercial entities seeking profit maximization in highly competitive markets and militarized settings. As noted above, a malware cyber-attack resulted in thousands of users losing access to Internet connectivity and services as the Ukrop shut down the ViaSat network, allegedly due its use by Ukrainians during the first military operations of the Russian-Ukrainian War (Erwin, 2022). Some of the first warning signs of an imminent Russian attack were detected by Hawkeye 360 commercial reconnaissance satellite that mapped GPS jamming in late February 2022 (Everstine, 2022).

1.3. Cyber-Conflict is Creating a New Governance Regime for Outer Space

This paper seeks to demonstrate how cyber-conflict is re-shaping the legal and policy topography of the outer space governance regime. More specifically, this paper argues that cyber-conflict is compelling the focus of outer space governance to shift from long-standing "hard law" treatybased governance based in the UNCOPUOS and the ITU to a multi-stakeholder governance regime based on principles of Internet "soft law" network management amongst a plethora of governmental and commercial entities. The paper's analysis will consist of three steps; first, an examination of how cyber-conflict is challenging the jurisdictional boundaries and competencies of outer space legal governance, and, two, how cyber-conflict is re-shaping the environment for commercial space regulation on both national and international policy dimensions. In its conclusion, this paper argues thirdly that mechanisms of Internet governance will increasingly characterize the overall topography of outer space governance, as outer space itself becomes an appendage of the Internet infrastructure (Blount, 2019).

2. Legal Dimensions of Cyber Conflict in Outer Space

Legal governance of space-based telecommunications takes place on two levels of jurisdiction: (1) national regulatory legislation, and (2) international treaty. This section examines the relationship between legal arrangements initially established in the circuit-switched analog world of the 1960s-1970s and how the subsequent technological evolution of packet-switched Internet global telecommunications shifted the legal dimensions of governance to a predominately "soft law" regime.

2.1. National Cyber and Space Legislative Regulation

States exercise sovereign legal prerogatives in the promulgation and enforcement of telecommunications (i.e., "cyber") regulations governing the use of electronic devices and the radio frequency spectrum amongst network operators and users within their territorial jurisdictions. The Outer Space Treaty's Article VI obligates states to exercise "continuing supervision" of their registered entities exploring and using the outer space realm. A growing number of states (>34) have adopted legislation authorizing a national space agency to enforce licensing and supervision obligations required by the legislation and international agreements, such as the Radio Regulations and the Outer Space Treaty. UNOOSA, 2022).

2.2. International Cyber and Space Treaty Regulation

International regulation of telecommunication networks and radio spectrum allocations has been the purview of the International Telecommunication Union (ITU), established in 1865 initially as the International Telegraph Union, and as such, serves as the longest continuously operating intergovernmental organization. The ITU Constitution and Radio Regulations are "hard law" legal treaties stipulating states' obligations for overseeing how telecommunications networks under their purview inter-connect with space-based satellite systems for a wide range of services utilizing orbital positions and altitudes, while acting to prevent harmful radio spectrum interference.

Cyberspace and outer space are areas of human activity created by technology. Governance, as a combined effort by authorized entities to promulgate, enforce and interpret principles, rules, and regulations affecting the long-term use of cyberspace and outer space, must, from the outset, take technological factors in account. While technological determinism is usually an oversimplification, the emergence of large constellation satellite infrastructures represents a technological evolution with far-reaching implications for governance (Kello, 2017).

2.3. Technological Factors Compelling Digital Legal Governance

A major component of the Internet's disruptive influence on the evolution of outer space governance is due to its very nature as a *digital* telecommunications infrastructure. In replacing the pre-existing and highly secure *analog* infrastructures, the Internet's packet-switched digital network architecture also brought with it a highly decentralized and non-governmental management arrangement represented by a wide range of voluntary organizations that developed networking standards and inter-connection software protocols. The emerging packet-switched digital architecture brought with it a management process representing the polar opposite from the earlier governance regimes during the state monopolist analog era of telecommunications (both terrestrial and space) regulation that was in effect during the promulgation and entry into force of the "hard" law space treaties in the 1960s-1970s.

One other systemic difference marks the digital era as different from the analog with regard to cyber-conflict. *While it was possible to tap into analog networks for purposes of monitoring, there was almost no opportunity for "hacking" the network's electro-mechanical analog components*. With the introduction of computerized electronic switches in the late-1960s, some parts of the public-switched network converted to digital technology and thereby became a preferred target for "hackers." In an oft-told story, two college students in 1970s California used inexpensive hobbyist electronic components to mimic digital signalling tones in "dorm room prank" manipulations of AT&T's worldwide "Touch-Tone" digital switching technology. The two students later went on to establish the Apple computer company (Wikipedia, 2022).

2.3.1. Analog Was More Secure

Analog "circuit-switched" telecommunication techniques require an "always-on" discrete communication pathway between communicators. The dial tone heard on conventional landline telephone systems indicated to the subscriber that the copper wire link was operating to the network provider's central office switch. That electro-mechanical switch created discrete pathways between subscribers or between subscribers connected through a series of central office switches. The economics of "natural" monopolies dictated a highly centralized structure for network operation, administration, and regulation. As a consequence, communication satellites were "bentpipe" extensions of the existing terrestrial analog circuits between switches and subscribers. In most cases, the same governmental telecommunications monopolist (usually the Poste, Telegraph and Telephone – "PTT") represented a particular state party in the promulgation of the ITU Radio Regulations or the UN's space treaties regulating use and operation of satellite networks. In an operational sense as well, governmental monopolist operators dominated both the major satellite communication providers (Intelsat, Intersputnik, Inmarsat, Eutelsat, Arabsat, among others). Networked access to GSO satellite links was accomplished through large, very expensive earth stations, owned and operated by the very same governmental-monopolist entities that represented the state parties in the ITU and UN negotiations leading to "hard" law treaties.

Moore's Law predicting dramatic reductions in information transaction costs brought about by revolutionary technological advances in hardware and software disrupted the cozy governmental monopolist-driven regime. Translating analog information into digital ones and zeros allowed network operators to exploit computer efficiencies that obsoleted centralized analog switches. Voice, video and data could be electronically packaged into digital "packets" that could be sent between voluntarily inter-connected computerized routers constituting what became the "internetwork network," or the "Internet". The nearly seamless integration of computing with network interconnections proceeded through an administrative structure *legitimized by the binary performance of the inter-connection (does it work, yes or no?)*.

2.3.2. Digital is Less Secure

Easy sharing of data is never secure. And today, as the Internet enters its middle age, sins of the past now manifest themselves as long-standing challenges to the health and security of the entire infrastructure. The Internet (initially named ARPANet after the Department of Defense entity sponsoring its deployment, the Advanced Research Projects Administration), in contrast to analog networks, is the regulatory off-spring of a U.S. governmental "hands-off" gestational process conducted by universities working with commercial digital network providers and data processing vendors. From the 1969 origin of ARPANet, the U.S. Government and universities sought to foster an open access packet-switched data infrastructure that allowed university and governmental researchers to transparently share data by connecting their campus networks to the ARPANet using the voluntarily adopted TCP/IP interconnection protocol. The ARPANet's horizontal multistakeholder *ad hoc* regulatory process that grew up to become the Internet co-existed outside of the highly hierarchical regime structure characterized by governmental-monopolist analog network operators seeking to maintain their dominance in the inter-governmental organizations (i.e., ITU and UNCOPUOS) constituting the state-centric cyberspace and outer space legal regimes (ICANN, 2022). However, the plate tectonics of Internet commercialization began to expose *legal fault lines* between the Internet and the state-centric analog regime with the emergence of the World Wide Web as an electronic mass medium in the mid-1990s. Data transparency made the Web easily accessible and a monumental commercial success and engine of growth, all without serious consideration of the inherent cyber-vulnerability an open and transparent network offers. Profits usurped prudence.

By the second decade of the 21st Century, the Internet of Things (IoT) now encompassed billions of Internet-connected devices from door bells to smartphones, many with little or no network security built in. The outer space regime's legal fault lines mentioned above, were revealed in June 2016 as the UNCOPUOS and the ITU both grappled simultaneously with the regulatory challenges posed by proposed mega-constellations of satellites for radio spectrum interference and space debris, among other issues.

2.3.3. Spectrum Allocations and Coordinations

Beginning in the analog era of the 1960s-1980s, most public-switched telecommunications infrastructures utilizing geostationary low-power satellites were connected through massive terrestrial antenna facilities operated by governmental monopolists (epitomized by the INTELSAT "Standard A" earth station). (Intelsat, 2022) As noted above, satellites were "bent-pipes" allowing the interconnection of discrete analog communication pathways between central office switches dispersed over the satellite's hemispheric footprint. ITU World Radio Conferences allocated spectrum and specified the procedures for coordinating simultaneous use of frequency bands among contending users (chiefly in the C-, Ku-, and Ka- frequency bands) of satellite systems in the geostationary orbit. The ITU Radio Regulations were binding "hard" law legal agreements that assigned specific rights to interference-free spectrum use and geostationary orbital slots. Cases of spectral interference would be "coordinated" among the different governmental monopolist claimants to a particular spectrum band and orbital slot(s) as specified by the ITU Radio Regulations and other ITU constitutive agreements (ITU, 2022).

3. Policy Dimensions of Digital Governance of Outer Space

While technology began to shift the assumptions underlying "hard law" national legislation and international treaties constituting the legal regime, this section focuses on the policy dimensions of regime change.

3.1. Threats to Reliable Operation

The policy dimension is shifting in response two factors intensifying the cyber-conflict challenge to the outer space regime: (1) the physical threat posed by space debris, and, (2) the electromagnetic threat posed by radio spectrum interference and software disruption.

3.1.1. Physical Threat: Space Debris

Historically viewed, large satellite constellations have long been an intriguing option for telecommunications providers seeking to exploit the "high ground" of space for reliable worldwide links. Probably the most extreme example of a "passive" large satellite constellation was the *Project West Ford* in 1963 that deposited "millions" of 1.8cm copper wires into a 3,500 kilometer polar orbit. (Hanson, 2013) Each copper wire was theorized to operate as 8 GHz dipole antennas for the purpose of reflecting radio waves between terrestrial communicators with unreliable results. Successful experiments in the early 1960s with "active" satellite relays in LEO (Telstar) and at geosynchronous altitudes (Syncom) obsoleted plans to test large satellite constellations until the early 1990s, when Motorola presented its proposal to operate a 66-satellite Iridium LEO network. Iridium was followed by deployments of Globalstar and Orbcomm LEO satellite constellations beginning in the 1990s (Wikipedia, 2022). Although the three LEO constellations eventually demonstrated their ability to provide a cellular-like service to underserved areas, their customer appeal was limited due to terrestrial cellular's deployment Internet-capable smartphones.

In the early 1990s, Iridium was the first proposed LEO constellation of 66 satellites to communicate among terrestrial Iridium telephone subscribers. A few years later, Teledesic was the first LEO constellation specifically designed to provide Internet connectivity. Its ambitious aims to provide global Internet access through a constellation of up to 840 LEO satellites was suspended in 2002, but not before receiving a worldwide spectrum allocation in the Ka-band from the ITU (Wikipedia, 2022).

Although not a cyber problem per se, hundreds or even thousands of small satellites pose a physical challenge to the legal goal set by the Outer Space Treaty for long term sustainable access to space for all countries. Space debris that now threatens to make unusable huge swaths of the most favorable near-earth orbital regions between 300 and 2000 kilometer altitudes. Thousands of pieces of debris created by anti-satellite tests conducted by Russia, China, United States, and India point to how physical debris in orbit threatens the operation of all space missions, both crewed and uncrewed as mega-constellation operators such as Starlink, OneWeb, and others, seek to maximize their commercial marketability through ubiquitous Internet provision on a global basis. Thus we have a classic "tragedy of the commons" collision in orbit between the commercially-driven new entrepreneurs who want to take advantage of the miniaturizing technologies and the larger collective good of preserving orbital regions clean of space debris.

3.1.2. Electromagnetic Threats: Jamming and Hacks

Cyber industries are upsetting the conventional space governance applecart, especially in terms of electromagnetic security. For one, the cyber sector is financially huge, much larger than space. NASA's current budget is about $24 billion. In April 2022, SpaceX CEO Elon Musk is in the process of buying Twitter for $54 billion, about twice the NASA budget. Apple reportedly has over $300 billion in cash. To paraphrase, one could today observe that 'cyber wags the space dog.' Now cyber giants Google, Facebook, Amazon, and their ilk are bulldozing a new space governance topography by launching thousands of small satellites into low earth orbits to bring the Internet from space directly 'to a smartphone near you, hackers and all.' (This Week in Technology (TWiT), 2022)

The bifurcated ITU-UNCOPUOS regime's attention is shifting from its long-standing focus on the geostationary satellites which are big and relatively few in number and operated by big governmentally-linked operators, to the much smaller and numerous commercially deployed entrepreneurial systems commonly called "New Space." And here is where the policy process is proving to be very sticky with great amounts of governmental inertia slowing the shift to a new set of "rules of the road" for the nimble space-Internet entrepreneurs.

Perhaps the most pressing problem threatening the operation and future of the Internet is cyberconflict, intrinsic to all digital technologies. For wireless networks such as satellites, cyber-conflict was during the analog era confined chiefly to "jamming." Jamming, or "intentional harmful interference" (IHI), disrupts the communication pathway through transmission of a strong electromagnetic signal that (1) blocks the earthbound receiver's ability to capture the intended satellite signal, or, (2) blocks the satellite receiver's ability to receive and re-transmit the intended signal back to earthbound receivers. (Author's Notes, 2016) IHI is illegal under ITU Radio Regulations and the ITU Constitution. (ITU, 2022)

As reported by speakers at the June 2016 ITU symposium on satellite interference issues, IHI may also be on the wane. (Author's Notes, 2016) Digital signal processing techniques enables satellite receivers to discriminate between desired and jamming signals. Improved signal forensics can quickly identify the IHI perpetrator, as well as equipment with embedded signal identifiers. As older generations of analog satellites are retired and placed in graveyard orbits, the IHI threat may significantly diminish further. Moreover, better training and certification of earth station operators will avoid many instances due to incompetent personnel. However, the electromagnetic vulnerability of new generations of digital satellites to malicious software hacking in all orbits is growing. (Baylon, 2014)

Jason Fritz, in his 2013 article, “Satellite Hacking: A Guide for the Perplexed,” categorizes four kinds of malicious hacking: (Fritz, 2013)

> *Satellite hacking can be broken down into four main types: Jam, Eavesdrop, Hijack, and Control.*
>
> *Jamming is flooding or overpowering a signal, transmitter, or receiver, so that the legitimate transmission cannot reach its destination. In some ways this is comparable to a DDoS [Denial of Service] attack on the Internet, but using wireless radio waves in the uplink/downlink portion of a satellite network….*
>
> *Eavesdropping on a transmission allows a hacker to see and hear what is being transmitted. Hijacking is the unauthorized use of a satellite for transmission, or seizing control of a signal such as a broadcast and replacing it with another. Files sent via satellite Internet can be copied and altered (spoofed) in transit…*
>
> *The copying of files is eavesdropping, while spoofing them is hijacking, even though the access point and skillset used for file spoofing fits better with eavesdropping. This illustrates the ability, in some cases, for hackers to move seamlessly between categories, and the difficulty of placing strict categorization on types of satellite hacking…*
>
> *Controlling refers to taking control of part or all of the TT&C ground station, bus, and/or payload – in particular, being able to manoeuvre a satellite in orbit* (Fritz, 2013).

Satellite vulnerability was evidenced by alleged hacking originating from Russian territory of a US-German research satellite, “ROSAT,” in 1998 rendering it useless after commanding its ultrasensitive sensor to point to the sun (Fritz, 2013). Efforts to secure satellite communications from outside interference was demonstrated on August 16, 2016, as China successfully launched and operated the “Micius” satellite, an experimental testbed for using *quantum encryption* employing principles of photon entanglement derived from quantum theory (Techcrunch, 2016).

Mega-constellations for provision of Internet connectivity to potentially billions of users poses direct challenges to existing legal procedures and precedents for outer space governance in general, and cyber-conflict in particular. First, such constellations are organized around digital decentralized network architectures. The Internet’s packet-switched digital architecture is intrinsically de-centralized in administration and control, but highly susceptible to unauthorized use and hacking. In this way, any satellite system so intimately integrated into Internet infrastructures would itself be highly vulnerable to network disruptions as exemplified by the disruption to the ViaSat network during the Ukrainian War. The analog era division between the satellite communications payload and the satellite’s engineering platform no longer exists, creating the potential cross-hacking now evident for example in automobiles and perhaps even aircraft. Secondly, large low-earth orbital constellations will seek to use spectrum being used and sought by terrestrial digital mobile and geostationary satellite network providers.

The engineering complexity and inevitable failures among hundreds of small satellites makes spectrum conflicts inevitable. Thirdly, the large constellations pose a significant vulnerability in terms of space debris and as a target for malicious hacking and IHI. In sum, the ITU-UNCOPUOS dichotomous "hard law" outer space regime will increasingly be absorbed into a system of "soft law" governance currently being developed by the Internet community.

4. The Internet Model for Outer Space Governance

The Internet as a legal entity does not exist. Instead, what is commonly referred to as "the Internet" is, in reality, an "inter-connection of networks" undertaken voluntarily by network operators. Each network operator allows their users to access other networks "transparently" using the TCP/IP software protocol. In this way, the Internet is a voluntary association of network operators adopting the TCP/IP software protocol and Open Systems Interconnect (OSI) set of seven levels of software and connection standards. Thus, Internet governance is uniquely voluntary whose existence is legitimized by its successful functioning. Internet governance is represented by the Internet Corporation for Assigned Names and Numbers (ICANN), a private entity initially established by the U.S. Department of Commerce in 1998 as a private corporation licensed by the State of California. Over the past decades, ICANN has shed its legal ties to its U.S. Government parent, becoming a multi-stakeholder private international organization representing the constituencies providing and using Internet services (ICANN, 2022).

The "flat" and open access structure for the multi-stakeholder Internet community has proved highly resilient to efforts by traditional "hard law" governmental entities to subsume it within an enclosing traditional institutional structure dominated by governments and their authorized network providers. Instead, the ITU itself has become much more oriented to a more open multistakeholder organizational structure. The UNCOPUOS has also inched towards a more open organizational architecture. The UNCOPUOS at its June 2019 meeting adopted the *Long Term Sustainability Guidelines*, promulgated on a purely voluntary basis, most significantly setting the "rules of the road" for the issues of space militarization, space debris, and capacity building. Notably, consensus agreement on cyber-conflict guidelines is not part of the "low hanging fruit" achieving consensus approval (Armstead, et. al., 2018).

In an economics perspective, the world is only now beginning to fully realize the depth and breadth of the paradigm shift transforming governance brought on by the information revolution (Rifkin, 2014). The hard shell of the traditional Westphalian sovereignty model of the nation-state fits neatly with hard law versions of top-down treaty governance. Circuit-switched analog networks were dominated by governmental monopolists and these were replicated in outer space. Digital technology responds to disintermediating networking strategies biasing investments towards selforganizing intelligent "mesh" networks imbued by their creators with increasingly sophisticated levels of intelligence for self-management. What is needed is transparency in order to ensure security. As large constellation satellite networks take on ever greater attributes of shared mesh network configurations, governance will likewise shift, in Rifkin's words, towards a "collaborative commons." (Rifkin, 2014).

4.1. Future Commons Directions: ICANN, Space Data Association, Internet of Things

The desired ubiquity of Internet connections required for modern commerce and communications is already driving business models towards an increasingly diversified range of satellite infrastructures and large constellations in GSO, MEO, and LEO orbital regions for customized provision of Internet connectivity through mega-constellations such as OneWeb and Starlink (de Selding, 2016).

4.2. Telecommunications Is A Much Larger Market Than Space

The sheer financial clout of the Internet sector will increasingly come to dominate discussions over outer space governance as they relate to hacking, spectrum, debris, and interference issues. As noted above, Elon Musk's current attempt to buy Twitter for a reported $54 Billion dwarfs the newly enlarged NASA annual budget of $26 Billion. The key conclusion is that outer space governance will be increasingly dominated by factors originating in the cyber sphere with a very different legal heritage. As a result, outer space governance *in toto* will in coming decades come to resemble current Internet governance characterized by voluntary, non-binding agreements that mirror market dynamics. The over-riding concern of the firms dominating the Internet sphere both as suppliers and users now focuses on cyber-security which will concomitantly dominate the dialogue over future directions of outer space governance. What will that outer space regime look like?

4.3. Components of the Emerging Outer Space "Soft Law" Regime

An increasingly "crowded, congested, and competitive" commercializing outer space realm prompted private satellite operators and governments in the 1990s to take steps towards a multi-stakeholder approach to governance. Two organizational examples illustrate this evolutionary legal and policy transformation: The Space Data Association and the Consultative Committee for Space Data Systems (CCSDS), while two international agreements, the *Long-Term Sustainability Guidelines* and the *Artemis Accords* provide an overview of the emerging regime topography for outer space increasingly dominated by commercial space entities engaged in exploration and exploitation of outer space:

4.3.1. Space Data Association

The Space Data Association (SDA) exemplifies the flat and voluntary organizational response to governance of space debris. As a non-governmental organization established in 2009, the SDA serves as a clearinghouse for information about orbital objects, their trajectories, and possible collision threats. It relies on orbital parameters voluntarily supplied to it by its members about their launches and orbital operations. Proprietary information about satellite operations is anonymized, while making it possible to forecast and detect actual collision threats. Similar directions in Internet governance are taking hold as cyber-vulnerabilities of Internet-connected networks and appliances provide a widening diversity of targets to hackers (Space Data Association, 2022).

4.3.2. Consultative Committee for Space Data Systems

Formed in 1982, the Consultative Committee for Space Data Systems (CCSDS) was charged by its founders to provide a forum and institutional memory for the “discussion of common problems in the development and operation” of space-based telemetry, telecommunications and hardware. Today, the 11 member agencies, 32 observer agencies, and more than 119 industrial groups use the CCSDS as a policy platform for voluntary data standards to ensure secure and inter-operable spacecraft operations. The success of the CCSDS standards setting work is illustrated by the ability of Mars landers and rovers to use the fleet of orbiting Mars spacecraft to relay telecommunications to Earth and back (Consultative Committee for Space Data Systems, 2022).

4.3.3. Long-Term Sustainability (LTS) Guidelines

In June 2019, the UNCOPUOS arrived at a consensus approval of the Long-Term Sustainability Guidelines and endorsed a continuing process and Working Group to further examine voluntary “rules of the road” for issues arising through trends in technology and space security. Notably, the approved guidelines (“low hanging fruit”) did not include proposed languge focusing on software interference with space systems (Martinez, P., 2018).

4.3.4. Artemis Accords

The Artemis Accords “establish a framework for cooperation in the civil exploration and peaceful use of the Moon, Mars, and other astronomical objects.” (Wikipedia, 2022d) The Accords in Section 11 specify a “Deconfliction of Space Activities,” specifically referencing the Long-Term Sustainability Guidelines with regard to ensuring non-interference with space activities (NASA, 2020).

5. Concluding Observations

This paper argues that cyberspace conflict is already re-shaping the outer space regime, as space becomes the “high ground” battlefield for 21st Century global dominance, a transformation unfolding as demonstrated by multiple cyber-conflicts on earth and in space, accelerated due to the exigencies of the Russia-Ukraine War. According to Blount:

> *Cyber’s role in defining outer space security is a remarkable story that persistently flashes ever more prominently onto the radar screens of science-challenged social and mainstream media. To address dismissive “fake news” social media trolling, it is important to note the definitional starting point underlying this analysis: “Cyber” is electronic communication between billions of inter-connected devices (a.k.a., the “Internet of Things” (IoT)), whose operation is determined by software code. Cyber “security” is the effort to deter deployment of unauthorized software code manipulations intended to disrupt the operation of billions of devices and networks crucial for vital societal or security infrastructures. Cyber is a story of growing commercial momentum and increasing disinformation, as analytically opaque as the trillions of lines of code running this digitizing planet. For behind the headlines of “Stuxnet” in 2009 or of the North Korean attack paralyzing Sony’s networks in 2014, or the stomach-lurching rollercoaster ride of Game Station stocks in 2021, lurks the on-going story about the greatest transformation of world power since the*

> *development of the atomic bomb in the late 1940s. In short, cyber is transforming "Space Force" visions of an outer space "high ground" battlefield of kinetic weaponry into one where projections of stealthy cyber power reorder the logic determining planetary power configurations and outer space governance (Blount, 2019).*

Cyber-conflict is changing the governance regime for the Internet with wide-ranging implications for global and state management of vital security, economic, and societal functions increasingly dependent on reliable and resilient Internet connectivity (Blount, 2019). As satellite systems become increasingly integrated into Internet infrastructures, the cyber-conflict and security challenges complicating Internet governance will likewise become an integral component of the outer space legal and policy governance regime. This will result in a decentralized governance topography marked by "soft law" voluntary agreements such as the Artemis Accords, the Space Data Association, the Consultative Committee for Space Data Systems, and the Long Term Sustainability Guidelines operating alongside Internet management organizations focusing increasingly on cyber security. For the rest of the 21st Century, cyber security is outer space security (Scroxton, 2022).

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Collaboration Potential and Possibilities With APSCO

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1. Introduction

The main objectives of the Asia-Pacific Space Cooperation (APSCO) are to promote cooperation and strengthen the joint development of space technology and its applications, carry out research in space science, promote education and training, tap the potential of member states, and contribute to the international cooperative activities for the peaceful uses of outer space.

APSCO is an independent, non-profit, intergovernmental, regional, and full international organization. It was established in 2008, and its headquarters are in Beijing, China. APSCO has a legal status by the convention registered under Article 102 of the Charter of the United Nations and granted the status of a Permanent Observer on the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) on 12 June 2009, during the annual meeting of the Committee held in Vienna. APSCO also holds Observer status at Group on Earth Observation (GEO) and the International Committee on Global Navigation Satellite Systems (ICG); having membership in International Astronautical Federation (IAF) and International Institute of Space Law (IISL).

The full members of APSCO are Bangladesh, China, Iran, Mongolia, Pakistan, Peru, Thailand, and Turkey. Indonesia is the signatory member state. and Mexico, Inter-Islamic Network on Space Sciences & Technology (ISNET) are the observers of APSCO.

All APSCO member states are developing countries. They have all-natural disasters of different or similar nature. All member states are in different time zones, and that's why APSCO covers a vast geographical area on the Earth. Most of the member states lack the budget, technology, and trained human resources in terms of space science, technology, and application

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development. But, all APSCO members' total population is about 2 billion, which is 1/4 of the world's population.

2. How Do We Work?

According to the APSCO Convention (APSCO, 2005), the organization's highest decision-making body is the Council, the board of directors. The Chairman of the Council is rotated by the member states in alphabetical order every two years.

The Board of Directors, Council, convenes a meeting at the end of each year to make decisions and decide on organizational development, projects, finances, and activities.

The Secretariat is the executive body that organizes projects and activities, and the Secretary-General is the organization's international legal person (Figure 1).

There are five departments in the APSCO Secretariat:

1. Department of External Relations and Legal Affairs
2. Department of Strategic Planning and Program Management
3. Department of Program Operation and Data Service
4. Department of Education and Training
5. Department of Administration and Finance

APSCO Convention provides the legal and administrative framework for cooperation.

APSCO Activities are divided into two main categories, which are defined in the Convention of APSCO (APSCO, 2005):

- *Basic Activities:* These include undertaking fundamental research in space technology, extending applications of advanced technology, organizing Training and conducting space education activities, and managing and maintaining branch activities and other necessary activities as approved by the Council. All member states are required to participate in basic activities. APSCO's annual budget is utilized for basic activities, meaning member states do not have to contribute additional financial contributions to projects under this category.

- *Optional Activities:* Optional Activities are those activities that do not fall under the category of Basic Activities. Optional activities are open to those member states which choose to participate in such programs. Funding for Optional activities is not provided from the annual budget but on the contribution of participating member states on the principle of return on investment. The commercial return on an Optional Activity is shared among participating countries in proportion to their investment.

Figure 1. The Structure of the Apsco Secretariat

3. Development Vision 2030 of APSCO and The Development Plan of Cooperative Activities of APSCO (2021-2030)

APSCO has established quite strong fruitful years since 2008, carrying out numerous cooperative activities in the fields related to space research, space technology development, capacity building of the Member States, and knowledge building in space law and policy. APSCO celebrated its 10th Anniversary with a high-level Forum under the “Community of Shared Future through Space Cooperation” theme in Beijing between 14th-16th November 2018. More than 100 official representatives from 24 Countries and eight space-related international organizations attended this Forum. During this vital milestone, APSCO Council Members endorsed “APSCO Development Vision-2030”, which will guide the organization in adhering to in-depth international exchanges and cooperation in outer space, based on peaceful use, equality, mutual benefit, and inclusive development (APSCO, 2018). Based on the principles of peaceful use of outer space, mutually complementary and beneficial cooperation, equal consultation, and benefiting the public, APSCO enhances capability in its Member States in the domain of space science, space technology, and space technology applications; establishes the basis of cooperation through sharing of data; promote talent cultivating by constantly conducting various education and training activities.

In 2020, APSCO established a new Development Plan Committee to lead the organization to the next level and plan the next ten years between 2021-2030. The Development Plan Committee (DPC) is a standing committee that handles drafting, reviewing, amending, updating, maintaining, and evaluating APSCO development plans and supporting actions and implementation plans. The DPC has prepared “the Development Plan of Cooperative Activities of APSCO (2021-2030),” and In December 2020, the 14th APSCO Council Meeting approved the Development Plan of Cooperative Activities of APSCO (2021-2030). This 10-year strategic plan will be used as the main guideline for implementing APSCO activities in the next decade, including cooperative projects, education and training, and space law and policy.

In the Development Plan of Cooperative Activities of APSCO (2021-2030), seven main action areas cover all related topics for any project in APSCO. These are:

3.1 Space Technology Applications
- 3.1.1 Earth observation applications
- 3.1.2 Navigation and positioning applications
- 3.1.3 Communication applications
- 3.1.4. Experimental Technologies and Applications
- 3.1.5. Data Sharing Service Platform (DSSP) and Its Applications

3.2 Space Technology Development
- 3.2.1 Satellite System Technologies
- 3.2.2 Satellite payloads Technologies
- 3.2.3 Ground system engineering Technologies
- 3.2.4 Support Technologies for space projects

3.3 Space Science and Exploration
- 3.3.1 Space environment, space weather, and solar physics
- 3.3.2 Study on Astronomy and deep space exploration
- 3.3.3 Study on space life and microgravity
- 3.3.4 Suborbital Scientific Payload

3.4 Space Debris Mitigation
- 3.4.1 Space observations, monitoring, and mitigation Technologies
- 3.4.2 Space Debris Data Center
- 3.4.3 Capacity Building on Space Debris Mitigation

3.5 Space Law and Policy

3.6 Education and Training
- 3.6.1 Short training program
- 3.6.2 Distance education program
- 3.6.3 Degree education program
- 3.6.4 Space education development program
- 3.6.5 Space education for the future generation
- 3.6.6 Space education resources network development program
- 3.6.7 Space education international cooperation development program
- 3.6.8 Professional Masters/Diploma Program

3.7 Capacity Building
- 3.7.1 Data and information sharing and service capacity
- 3.7.2 Mission planning and implementation capacity
- 3.7.3 Infrastructure construction and management capacity
- 3.7.4 Standardization and policy coordination capacity
- 3.7.5 Space training and education capacity

These action areas are significant. Anyone who wants to propose project topic should fall into one of these action areas.

4. How to Propose Projects to APSCO and Some General Examples

4.1. Mechanism

There is no time limit to sending a project proposal to APSCO. The only policy is that any project proposal should be sent to APSCO through the Focal Organisations of the related member state. The project proposals must be forwarded to APSCO by the relevant focal organization by the end of the year, by the last day of December, whichever year you are in. If a project proposal reaches APSCO on 01 January, that project will undergo initial processing the following year.

After receiving a project proposal, it is first evaluated by the Development Planning Committee (DPC) in the year following its proposal. The project proposals are discussed and scored by the members of DPC. This is the very first step of the process. After this step, the related projects go to Administration Head Meeting (AHM) for review and recommendation of the Council Meeting (CM) and CM for review and approval. If the Council approves the proposed project, the related project joins our project bank to be initiated when the time comes.

All projects are collaborative or should have a collaborative nature in APSCO. APSCO member states are quite different countries, bringing extra effort to collaborate. All the members are developing countries, and their needs and capabilities are slightly different from each other. APSCO's main intention is always to bring and meet all member states' common interests and benefits in the space area. Having different capabilities is an excellent opportunity to share experiences and knowledge.

While the projects are presented, they should include one or more subjects among the seven main action areas mentioned above. In addition, the party proposing the project should also indicate in which area the relevant project is proposed. While the initial project evaluation is carried out in DPC, DPC members can make new proposals for the proposed area and request changes if necessary. This process clarifies which general directorate will follow the evaluated projects after acceptance. These general directorates are Strategic Planning and Program Management (SP&PM), Education and Training(E&T), Program Operating and Data Service (PO&DS), External Relations and Legal Affairs(ER&LA).

The action titles 3.1, 3.2, 3.3, and 3.4 are mainly in the SP&PM responsibility areas, 3.5 in ER&LA, and 3.6 in E&T General Directorates. The General Directorate of PO&DS manages shorter-term implementation projects related to data sharing for each member state and provides satellite data that member countries need in emergencies. However, when a project is completed in the SP&PM Department, it ends, and data generation begins. All subsequent operations of the relevant project are transferred to the PO&DS Department. That's why the action titles of both episodes are almost the same.

4.2. Targets and Achieved Moments

Education and Training are among the most active and fruitful parts of APSCO. This part governs all educational platforms, such as degree education, short-term Training, distant

Training, hands-on Training, and new-generation cultivation, consisting of Space Science Schools, international competitions, and space contests.

Under the degree programs, APSCO is collaborating with the universities for Master's and Ph.D. programs. Within the framework of these programs, students in various fields are admitted to master and doctoral programs in cooperation with Chinese universities, using Chinese state scholarships. Such contributions are also expected from universities and institutions in our other member countries.

By nature, APSCO is an intergovernmental organization that brings many space-related regulations between the member states and other states. Besides, APSCO is one of the space-related organizations, one of two organizations by nature. The other is European Space Agency (ESA). That's why space law is one of the main topics in APSCO's Development Plan for 2021-2030. APSCO focuses on the following areas in the field of space law and policy (APSCO, 2018):

a) Capacity building in space law and policy.

b) Active participation of APSCO at the Legal Sub Committee of UNCOPUOS and other international important forums related to space law and policy.

c) Organizing executive courses for senior management of Member States.

d) Cooperation with UNOOSA for Legal Advisory Services to support the Member States in drafting national space law.

e) Cooperation with the Member States and international organizations on knowledge enrichment and focused capacity building for drafting National Space Policy.

f) Cooperation with the International Telecommunication Union (ITU) to support Member States for a deeper understanding of ITU regulations and related guidelines through joint workshops/activities.

g) Creating an alliance with institutes/organizations of space law in the Member States and other renowned international organizations to support research work in space law and policy, sharing of resources among the Member States, and availing opportunities for participation in each other's events, such as conferences, workshops and support publications of articles, etc.

h) Research contemporary issues in space law and policy through alliances and active participation in developing new laws and guidelines at the UN level or any other crucial international forum and assist the Member States on contemporary issues. A pool of experts shall also be created to support these activities.

Before the new development plan, APSCO contributes to building space law and its member states' policy capacity. APSCO has been biennially organizing the "Space Law and Policy Forum" since 2011 as part of its two knowledge-exchange platforms (APSCO, 2018).

Space law can be described as the body of law governing space-related activities. As a regular international law, it comprises a variety of international agreements, treaties, conventions, United Nations General Assembly resolutions, and rules and regulations of international organizations.

The five international treaties and five sets of principles controlling outer space that were created under the auspices of the United Nations are the ones that are most frequently linked to when the phrase “space law” is used. Many states also have national laws controlling space-related activity in addition to these international agreements.

Space law covers a wide range of topics, including the protection of the Earth’s environment and that of space, the use of space-related technologies, international cooperation, the resolution of disputes, the rescue of astronauts, and the accountability for harm caused by space objects. The idea that space is the domain of all humans, the freedom of exploration and use of space by all states without restriction, and the idea of non-appropriation of space are just a few of the fundamental principles that govern the conduct of space operations.

With this perspective, APSCO is in collaboration with the European Space Agency (ESA) and China Institute of Space Law (CISL) and organized the Space Law Workshop in Sanya, China, on 6-8 September 2021, themed “Regional Cooperation Schemes on Space Law and Policy”. Participants from 10 Chinese institutions as well as ambassadors from member countries’ embassies in Beijing, attended the event. In addition, the workshop featured online participation from over 100 delegates from APSCO Member States, ESA Member States, and officials from space organizations and institutes from almost 40 nations.

Thirty-eight space organizations, institutions, and colleges from the APSCO Member States met to consider forming the APSCO Space Law Alliance (ASLA). This proposal will be discussed at the 16th Council Meeting in November 2022.

Additionally, in February 2022, APSCO and UNOOSA agreed to collaborate on organizing a technical workshop on national space legislation for the member states of APSCO. The program will include complete capacity building for APSCO Member States to draft National Space Legislation in four implementation phases.

The symposium “Space Popularization for the Next Generation” was organized by APSCO during the fifty-ninth session of the STSC in February 2022. Renowned international speakers presented their initiatives and worked on knowledge-building and space popularization. The symposium has inspired the youth, professionals, and participants to pursue their space dream.

With the approval of the Council, APSCO has established a partnership with the National Space Science Center (NSSC), Chinese Academy of Sciences and Land Satellite Remote Sensing Application Center (LASAC), Ministry of Natural Resources of the People’s Republic of China, for expanding cooperative filed in Space Science, and expanding data recourse for APSCO Data Sharing Service Platform.

APSCO is also planning to take the initiative of a CHARTER-like disaster responding service among the Member States and establish a supply chain to facilitate its Member States to develop space capacity.

An opportunity for APSCO Member States to deliver their payloads to the Chinese Moon

Mission and involve their specialists in collaborative research on lunar samples and the International Lunar Research Station has been made available by the China National Space Administration and APSCO (ILRS).

5. Conclusion

Considering the rapid development of the space sector and the challenging nature of regulatory perspectives of space activities, the role of international and regional organizations in space has become more critical. Regulations and policies at the national, regional, and global levels provide the necessary basis for their space activities. It is critical to identify regional space cooperation programs and their impact on developing countries, regions, and the space industry as a whole.

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Restructuring ATASAM R&D Infrastructure in the Framework of Space Sciences Ecosystem

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1. Atatürk University Astrophysics Research and Application Center (ATASAM)

Atatürk University Astrophysics Research and Application Center (ATASAM) is a university center in Erzurum and its fields of study are basically space sciences, optics, and related technologies. ATASAM establishes the R&D infrastructures of the Eastern Anatolia Observatory (DAG) and the Optomechatronics Research Laboratory (OPAL) within its administrative structure. The sustainability of these types of R&D centers is important and indispensable. In terms of the sustainability of these R&D infrastructures, the efforts to transform their status into legal entities have been initiated within the scope of Law No. 6550 on research infrastructures. This process seems to be the best example of creating an ecosystem in space sciences in Turkey.

ATASAM has mission and vision statements, respectively:

- To give direction to national studies and to have a say at the international level in space sciences, optics, and related technologies.

- To be an innovative, competitive, and desired research infrastructure in the international arena in space sciences, optics, and related technologies.

The aims and activities of ATASAM can be summarized as

- Establish and operate DAG and OPAL R&D infrastructures.

- Provide observation and R&D infrastructure services.

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- Establish national and international collaborations.

- Engage in R&D activities.

- Carry-out education and awareness activities.

2. 2023 Vision in Space Sciences

In terms of ATASAM, the 2023 vision in space sciences can be summarized as follows:

- To create Turkey's largest fundamental science investment as Turkey's 2023 Vision,

- To establish Turkey's largest and first infrared telescope as space sciences,

- To establish the largest mirror coating system in Turkey and Europe as optics science and technologies,

- Filling the great observational gap on Earth as a science strategy,

- To increase international scientific and technological cooperation in the field of science diplomacy,

- To conduct competitive and high-quality research as a pioneer and with scientific prestige,

- To carry-out interdisciplinary studies as scientific diversity and awareness,

- Developing new technologies as scientific and technological competition,

- Creating competent human resources and developing domestic technological products as scientific competence and sustainability.

3. Creating Space Science Ecosystem

The reasons for creating an ecosystem and the important and fundamental values in the structuring process are given below:

- 11th Development Plan,

- National Space Program,

- UN - Sustainable Development Goals,

- Research Infrastructures Law (6550),

- Strategic Goals,

- Priority Working Areas,

- Mission, Vision, Aims,

- R&D, Education, Social Contribution

4. Requirements for Space Science Ecosystem in Turkey

Some requirements for the space science ecosystem in Turkey and its dimensional analysis are summarized in Table 1.

Table 1. Some requirements for space sciences ecosystem in Turkey

Stages / Dimensions	Requirements / Criteria
Strategic Program - Objectives	Observation Service, R&D, Product, Infrastructure
Transparency - Openness Policy	Commercial Legal Entity, Financing, Information, Purpose
Internal/External Stakeholders - Users	Public, Private Sector, University, Individual
Service - R&D Product	Observation, Data, Infrastructure, Product, Device
Technology - Innovation	Technology Transfer, Innovative Products
Internationalization - Cooperation	Observation, R&D, Education, Device, Technology
Horizontal - Vertical Technologies	Being an Interdisciplinary Study Infrastructure
Competition - Sustainability	Technology, Service, Finance, Human Resource, R&D
Coordination - Governance Policy	Stakeholder, Demands, Dynamic Structure
Systemic - Project Working Policy	Update, Project Based Works
Human Resources - Team Policy	Competent Multidisciplinary Human Resource, Being a Team
Intellectual Property - Patent Policy	Observation, R&D, Product, Method
Open Data - License Policy	Astronomical / Atmospheric Data Service and Sharing
Social Contribution - Publication Policy	In / Out of Service Activity, Publication / Thesis

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