Global Collaboration in Space Technology

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

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INTRODUCTION

Missions that utilize space technology are often affected by international affairs and geopolitics. Specifically, the relationships between the United States, Russia, and more recently China have become the key dynamics in the global space technology sphere. For nearly 50 years following the end of World War II, the United States and Russia fought for military, political, and technological supremacy. This led to the inception of rocket technology in both countries as a means of creating military missiles. Eventually, the primary goal of the technology evolved from defense to space exploration, and the space race was born (National Air and Space Museum, 2023). While China was not a key party in this initial space race that culminated in the 1960's, China would become a key player later on. In 2003, China joined the U.S. and Russia as the three countries to send manned rockets into space, and the country has seen more milestones over the past two decades, including multiple lunar orbiters and an unmanned probe to mars. (Reuters, 2020). Competition in space exploration between these three nations has significant implications for international relations, national security, and the advancement of technology. Space is becoming a new frontier for geopolitical rivalry (Zanidis, 2023).

While these nations are often associated with having tumultuous relationships with each other when it comes to space and space technology, meaningful collaboration still exists. The most prominent example of this evolution is the International Space Station, or ISS. Beginning construction in 1998, the ISS has served to advance science and global collaboration through the carrying out of scientific research and experimentation in space. The U.S., Russia, and China continue to collaborate on the space station to this day (NASA, 2023a). Global collaboration on the ISS can lead to enhanced research outcomes, faster experimental completion times, and shared research, (Hasbrook et al., 2017). It can also serve as a form of international diplomacy

between China, Russia, and the U.S. where the scientific collaboration is very strong despite geopolitical tensions (Mauduit, 2017).

While international collaboration is so important to the success of many present day space technology endeavors, there is not a clear framework in the United States to engage in international collaboration. The NASA Office of Inspector General highlights international collaboration as essential for the Artemis lunar program, but cites that NASA currently lacks a comprehensive strategy to manage international partnerships (NASA Office of Inspector General, 2023). On an international level, this problem also exists. Audrey Schaffer in *Acta Astronautica* highlights the lack of formalized international collaboration mechanisms for space exploration and argues that the informal collaborations since the 2006-2007 Global Exploration Strategy (GES) should be formalized (Schaffer, 2008). The goal of this research is to examine the international space technology landscape through case study research to develop a present day international collaboration framework.

STS THEORY

In order to analyze international space technology collaboration, I will be using the Social Construction of Technology framework from Bijker and Pinch. The essence of this framework is that technology is not just a product of scientific knowledge, but rather it is the manifestation of both science and the interactions between different people groups. In other words, technology is shaped by the people who use it. The particular success of a technology is determined by how it fits and functions within a social context, not by the inherent value possessed by a technology. (Bijker & Pinch, 1987). Bijker and Pinch establish many key concepts that are relevant to this

research. The first of this is relevant social groups, which are simply the people groups that are affected or interact with this technology in some way. For space technology, relevant groups could include government officials and agencies of various nations, space mission crews, researchers, and the general public. Whether making decisions, carrying out the missions, or being culturally affected by the development of space technology, all of these groups continue to play a role in how space technology functions in an international context. Another key term defined is interpretive flexibility, which is the idea that technology can be interpreted differently by different social groups. This is very important for this STS research, since each nation may see space technology to have inherently different opportunities to contribute to national security, culturual patriotism, or technological advancement. Understanding these interpretive differences is important to understanding how a framework could be formed that addresses how to deal with these differences. Closure is another concept introduced, and it is defined as the process by which technology becomes widely accepted. For space technology, it is important to determine what extent closure has been reached, and if not, how can these interpretive differences be reconciled in a framework.

Pinch and Bijker's introduction to social groups and closure would be expanded upon in Lee Humphrey's work. Humphreys points out how social groups contribute to social closure, which is an idea that individual technologies can reach a point where their general structure and outcomes are normalized and socially accepted (Humphreys, 2005). This idea will be key for developing an international collaboration framework, as reaching social closure on these technologies could be advantageous for making collaboration more efficient since users would be on the same page. Efforts that have contributed to social closure in the past will be studied and analyzed.

CASE CONTEXT

Currently, developments are taking place on the front of international space collaboration. The most notable of these is the decomissioning of the International Space Station and the development of its replacement. NASA has reported that they are planning to maintain the ISS through 2030 before deorbiting it. This decision will have implications for international space collaboration as NASA will shift its focus from developing proprietary solutions to partnering with private companies (NASA, 2024). Space collaboration and how it is governed will become more complex as domestic and international companies enter the fray, and this paradigm shift will need to be accounted for in the creation of a framework. Companies such as SpaceX, Blue Origin, United Launch Alliance, and Rocket Lab will be key players for the United States as they seek to use iterative approaches to outperform previous bureaucratic projects spearheaded by NASA. The US hopes that enabling private companies to lead the charge in space will allow them to keep pace with China who seeks to use their own Chinese Space Station to become the dominant space power (Ching, 2024). This political interplay between the US and China will be a key consideration for an international collaboration framework.

At an international level, the United Nations Office For Outer Space Affairs (UNOOSA) is committed to utilizing space technology advance the Sustainable Development Goals. They are seeking to facilitate international collaboration to solve some of the toughest problems regarding space technology, including space law, registering objects launched into outer space, equitable access to space, and various climate and sustainability related issues (UNOOSA, 2025). UNOOSA is the primary body of its kind seeking to facilitate international space collaboration that serves the greater good, and performing further research into their efforts will

be crucial when considering how an international collaboration framework that benefits not only the United States but its partners in space.

One of the United States' key partners in space currently is Japan. In January 2023, these two nations signed a space collaboration agreement. The nations have long been allies in space, but this agreement will assure that this alliance continues into the new age of space technology. The agreement primarily reinforces direct collaboration between NASA and Japan's space agency JAXA and highlights key areas of low-earth orbit and the moon. Along with Japan, the EU is a key ally for the US in space (NASA, 2023b). The US and EU have a history of collaboration and met as recently as 2023 to discuss how this will continue to evolve into the future. Key discussion areas included global navigation satellite systems and space situational awareness, and the meeting also gave time for both states to provide updates on policy changes in order to find specific ways for the EU and US to support each other (EU, 2023). Time will tell how these relationships the US has with the EU and Japan will influence corporate collaboration as the US shifts its focus to private sector space development, but regardless, these partnerships are paramount for all involved parties.

RESEARCH QUESTION AND METHODOLOGY

Further research into this area is to be performed to find an answer to the following question: Can an international collaboration framework be established, and how? Case study analysis will be used to accomplish this by focusing on the International Space Station as an example of international collaboration, particularly in the post-GES era since 2006. I will look into how working groups at organizations such as the United Nations and European Union have

approached how to handle ISS international relations and examine various policy briefs or publications that have come out of these efforts. Various ISS missions reports will be examined to learn how international collaboration played a role in their success. In both of these, successful mechanisms that can contribute to the formation of a framework will be discovered. In addition to the ISS case study, I will reference the Schaffer work to inspire more research into the GES and similar efforts to see what elements can be taken from these and applied to a present-day framework. All of this research seeks to enhance the development of a framework that will support the analysis of these case studies and highlight ways for the United States to leverage its unique economic, social, and political situation to be a global leader in global space technology. The Social Construction of Technology framework will allow the research to build upon the existing interactions between social groups and highlight how these groups will be the main facilitators in the current state of international space technology.

RESULTS

Performing research into space technology collaboration with an enhanced look at the ISS as a case study has yielded an answer to the research question; Yes, an international collaboration framework for space technology can be created, and the following recommendations serve as how. The first broad consideration is the encouragement and enabling of public-private partnerships. There is overwhelming upside in inviting the private sector into this space, as long as there are mechanisms for integration into private and public research, long term government commitment, and shared understanding of key bureaucratic hurdles. A second key takeaway is the need for compromise, both on small scale issues such as development of shared software and large scale issues such as economic and political dominance. The US has a

part to play both as a global power and global leader and should approach these issues with confidence and a bit of humility. A third takeaway is the overall upside of collaborating with other nations for enhanced scientific and logistical benefit. The US will benefit from this collaboration if information and process sharing is done properly.

Global Conglomerates and the ISS

From the UN's perspective, space technology has the opportunity to solve some of the world's glaring sustainability issues. Scientific research in Space is one way to do this, and the ISS is a key actor. A UN report on using space collaboration to support the SDGs identifies the ISS as being a key contributor to private sector space technology development. Areas such as commercial spaceflight and commercial analysis of space data are being done outside of the direct sphere of influence of government agencies, and the ISS can provide critical information to these actors. The article highlights the need for public-private partnerships between agencies like NASA and their private counterparts to make this happen. While identifying some needs, this paper also highlights some key challenges when working with space technology. When developing the technology, it is important to understand the ramifications of military use as well as its effect on market actors. The article elaborates on an example where space technology can be used to explore natural resources, but this could lead to information disparities and unfair contracts for those involved in the trade of said resources (United Nations Conference on Trade and Development, 2021).

These findings from the UN are particularly relevant for space collaboration for the US. The ISS has reached closure, and it has been constructed in such a way that it is now able to not only serve as a hub for performing science but also as a contributor to the rise of private sector develop. When developing a framework for the US, a key strategy will be creating information

sharing networks so that scientific data from international projects such as the ISS can make its way into both private and public research. Doing this will keep the United States at the forefront of space technology development. Another takeaway is the need for a vision for how space technology can provide military or economic advantage. Geopoltical relationships have led to the use of space technology for military gain, and the United States needs to continue to recognize this potential. A framework will need to consider sociopolitical rivalries and allow some room for individual adminsitrations to make decisions regarding using space technology to gain some sort of advantage over adversaries. A balance between global dominanve and global rapport, particularly with China and Russia, will be the key to allowing this piece of the framework to be successful.

Lessons can be learned from examining day-to-day functionality of the ISS. A NASA article elaborates on how planning the schedule for the ISS is a daunting task. The consolidated planning system (CPS) is used as the common scheduling tool. Some benefits of using CPS include lower overall cost per entity, commonality across sytems, and enhanced coordination between planning system developers. Tool sharing such as this also leads to the need for compromise, such as extra complexity needed within the tool to accommodate each entity's particular requests (Maxwell 2002). A separate report highlights the benefits gleamed from having international collaboration aboard the ISS. The report argues that benefits are limited if the nations simply use the ISS to do their own research rather than work together on the research. The ISS Program Science Forum is an effort to facilitate this kind of collaboration, and it has led to many benefits such as new perspectives being brought into a problem lower costs. Information sharing between countries using ISS open repositories and multilateral research publication databases have has also led to similar upside (Hasbrook et. al, 2017). Both of these articles

highlight how the nations involved in the use of the ISS have created an environment where selfish use of the ISS does not create the most upside. The ISS has reached some closure on this issue, as it seems that working together is the tried and true way for all parties to benefit, both in logistical ways and in quality of the research. A global collaboration framework will need to include ways for the United States to be a leader in facilitating collaboration through information and process sharing. This will allow projects such as the ISS to yield maximum benefit.

GES and Complementary Efforts

The International Space Exploration Coordination Group (ISECG), a forum of 27 agencies including NASA, ESA, and JAXA, created the 2007 Global Exploration Strategy (GES), which provides the basis for present-day space collaboration policy. Discussions surrounding partnering of public and private entities can be traced back to this document. It highlights the need for long term commitment, as well as shared understanding of issues such as property rights and technology transfer for the collaboration to be successful. The document also delves into specific ideas regarding global partnership, particularly how it can lead to enhanced understanding of internal interests, shared lessons to avoid mistakes, and collaboration on scientific data analysis and dicsussion. It also argues that global security will be increased as a result of collaboration between nations (ISEGC, 2007). While fairly broad in its language and reccomendations, the GES is pivotal step forward on this front and has led to subsequent documents being developed. It highlights the logistical hurdles with public-private partnerships as well as the need for international partnerships.

Along with the 2007 GES, ISEGC created a series of documents all titled The Global Exploration Roadmap. The most recent edition came in August 2024. The document highlights shared goal of these agencies in exploring the cosmos, such as affordability, benefit, partnerships, and robustness. Affordability and benefit go hand in hand, as the technologies should seek to use reliable and reusable systems while providing value to the general public of the world. Regarding partnerships, the article highlights the need for considering the long term goals and aspirations of invidiual partners while pointing out the the benefit of working with the private sector. The idea of robustness here is very critical, as plans and vision should be able to withstand unplanned programmatic or political changes while offering flexibility to adapt to these scenarios (ISEGC, 2024). The involvement of key government agencies in space technology has led to the industry seeking to become as efficient, economical, and productive as possible. The general public plays a big role here as a social actor since they demand taxpayer dollars be spent in a smart manner. Taxpayers also desire results, which has led to robustness being a key priority for ISEGC. The key takeaways here for a framework for the US are the need for making sure particular technologies or missions are sustainable, provide tangible scientific advancement or discovery, and can be carried out across administration and political changes. As a result of its increased influence on space technology, private sector partnerships should be encouraged within the framework, as they can be beneficial in enhancing all three of these points. Using the private sector to enhance the efficacy of space technology will be crucial for keeping the taxpayers satisfied with the work that NASA and its industry contractors are doing while maximizing the utility of the taxpayer dollar.

DISCUSSION

The Social Construction of Technology and theory on social groups was instrumental in performing this research. The key recommendations and findings consider how the social groups have and will continue affect space technology. For example, the greater public and their tax dollars have influence on this technology, so I recommended that technologies priotirize scientific value and sustainability. The private sector has become a greater influence in the greater space technology ecosystem, so I highlighted ways for it to have a larger role while prioritizing equity and research. International rivalries in space have existed since the days of the space race, so I included evidence regarding how the US can both gain dominance and serve as a leader in the space while being conscious of other nations goals.

It is important to note that this research is very limited in scope. A space technology collaboration framework simply cannot be developed by one research effort. Recommendations from this research, however, could serve as functional and thoughtful additions to a new domestic framework for the US. In performing future research, I would hope to expand to creating framework recommendations for other nations such as China and Russia or maybe even specific agencies such as NASA or ESA. Developing a framework for the United States is a great starting point to more research and a way to explore the international collaboration piece of the research more broadly. As I become a working professional, I hope these lessons allow me to have an enhanced view of engineering ethics as I make career decisions, design decisions, or even influence policy decisions as an Aerospace Engineer. Specifically, I desire for this research to inform decision-making and encourage me to continue to educate myself on how the greater social actors in technology influence how it evolves and impacts society.

CONCLUSION AND FINAL THOUGHTS

Space technology and its use internationally is complex, and key considerations can be found in research from a variety of sources and institutions. I hope this research serves as an introduction to larger conversations and policy developments where considerations such as these are made. Despite the research done here, this issue is not going to be solved by one paper or framework. Due to its nature, space technology will continue to evolve and provide new opportunities and challenges. As these arise, adjustments will need to be made both domestically and globally to maintain space technology as a space where science and the greater good remain at the forefront. Political and military conflicts will also never go away, and managing how space technology functions in this setting will be difficult as it becomes more robust. Particularly, the continuing conflict between Russia and Ukraine is an example of how space technology could further complicate a war. A future where nations such as the US and Russia have access to high level space technology will be a tumultuous one requiring careful and thoughtful policy and diplomacy efforts to ensure space technology is used for greater societal good.

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