

# An Evaluation of the General Public's Perception of the Commercialization of Space

Patrick Brady<sup>1</sup> and Jennifer Orlinski<sup>#</sup>

<sup>1</sup>Norwood High School, Norwood, MA, USA

<sup>#</sup>Advisor

## ABSTRACT

In the past decade, commercial companies have rapidly expanded their presence in the space industry. Notably, SpaceX comprises the entirety of NASA's crewed launch capacity as of 2020 and approximately splits uncrewed launches with the United Launch Alliance. As interests in space quickly grow, the power of these companies has the potential to grow troublesome. The purpose of this study was to evaluate the public opinion of these private space companies, as the implications of their operations could change life for the human race significantly. Changes such as satellite constellations, space tourism, asteroid mining, and colonies on the Moon and Mars will alter life for our species; future operations, legislation, and regulation must be created with the views of all humanity considered. Previous research has concluded that Americans generally support space exploration, but this work lacks specificity in increasingly relevant fields, such as satellite constellations. This study reinforced previous findings while drawing conclusions on new topics, utilizing a survey where participants were asked questions evaluating six Topics of Inquiry. Using a combination of descriptive and inferential analysis, the researcher found that most people support space exploration and would like to see more funding and resources put towards it. Broadly, most participants have a positive perception of these private space companies and believe in a need for moderate government oversight. Large satellite constellations were widely supported, suggesting an overall positive attitude towards the utilization of space, given that participants were informed of particular risks imposed by constellations such as SpaceX's Starlink.

## Introduction

Unbeknownst to many Americans, a rapid change in the United States space exploration industry has occurred, leading to what many call a second Space Race. Unlike the 1960s, however, this competition is not about the strength or superiority of nations but the ingenuity and perseverance of commercial companies who have entirely redesigned space exploration. Space Exploration Technologies Corp., or SpaceX, was founded in 2002 to create reusable rocket technologies to expand access to space. Despite the optimism provided by the growing technologies involved with Space Exploration, there is cause for concern over the rise of commercial companies in the space industry as they could create more problems than they solve. Issues such as space debris, the operation of large satellite constellations, ethical concerns regarding the exploration of Mars, crew safety, and the need for government overreach, among others, all present questions that humanity will need to begin answering as new developments occur. In a similar vein to Climate Change, these issues affect all of humanity—there will need to be consensus on these issues to protect our people's safety and our solar system. This study analyzed the rise, achievements, strategies, and goals of SpaceX in conjunction with survey data from the general public in order to form conclusions of the general public's opinion of the Commercialization of Space.

This study was conducted with the goal of answering the question, "How significant is the general public's perceived threat of the Commercialization of Space?" The researcher performed a survey of the opinion

of a wide range of individuals in the general public, a group of random individuals defined by a lack of participatory criteria. The choice was made to narrow the scope of the study to material only about SpaceX, given their notoriety in recent events such as the test flight of the Falcon Heavy and the Launch America event. Within the context of SpaceX, the researcher began to identify controversial topics involving the operations and goals of SpaceX, which were able to be explored as specific examples of changes or issues in the Space Industry. Research was conducted in order to understand particular topics of inquiry, to better inform the researcher. However, before detailing issues in SpaceX's operations, the accomplishments and progress made by SpaceX are equally as crucial to the construction of context in this field.

## Literature Review

### SpaceX Accomplishments

SpaceX themselves note several key events that define their accomplishments in the Space Industry on the "mission" page of their website (SpaceX, 2021)—In 2008, the Falcon 1 rocket became the first privately owned and operated liquid fuel rocket to reach Earth Orbit. In 2012, the company made history by delivering the first private spacecraft to the International Space Station, and in 2015 SpaceX accomplished its long-time goal of being the first to land an orbital-class rocket booster. The following year, SpaceX built on its previous accomplishments by landing the first stage of their Falcon 9 rocket on an autonomous drone ship. In 2017, the company became the first entity to reflly an orbital class rocket, and almost a year later, SpaceX launched its newest rocket, the Falcon Heavy, recognized as the world's most powerful operational rocket. In 2020, SpaceX became the first private company to launch astronauts into orbit, returning spaceflight to the United States after the Space Shuttle Program ended in 2011. While these accomplishments might seem irrelevant to the average person, the culture of success and innovation within SpaceX is notable. Rapidly developing safe, reliable, and reusable technologies is a clear priority for SpaceX, as demonstrated by their record-breaking résumé. The company has made significant advancements in the Space Industry by carrying out impressive missions and shifting the scope of what is possible in space.

### Identified Issues with SpaceX's Operations and Goals

As they have developed new technology and practices in the Space Industry, SpaceX has pushed the boundaries of what is believed to be possible. However, SpaceX had always faced criticism for its ambitious goal of ultimately establishing a colony on Mars using reusable rockets—this doubt had even plagued the company's CEO, Elon Musk, who once said, "'When we started SpaceX, they said, 'Oh, you are going to fail.' And I said, 'Well, I agree. I think we probably will fail,'" in an interview with CNBC (Clifford, 2020). While these doubts continue to exist, there are also growing concerns regarding the strategies SpaceX has outlined for developing their 'path to Mars'.

#### *Starlink and Kessler Syndrome*

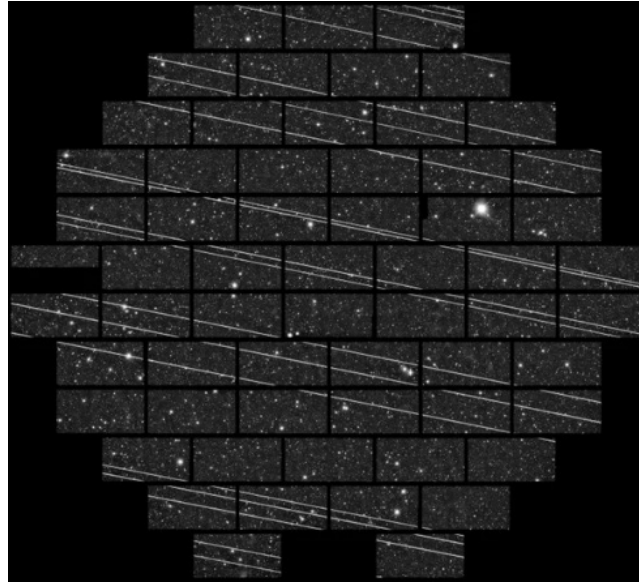
SpaceX has been developing a satellite constellation designed to deliver high-speed and low-latency internet connection with near-global coverage. This constellation works by sending signals between satellites placed in strategic, almost weave-like orbits to connect users with ground stations. As the constellation relies on the ability to connect between satellites rapidly, a large number of satellites is needed to ensure the advertised data speeds of 50Mb/s to 150 Mb/s (Starlink, 2021). In November of 2018, the Federal Communications Commission (FCC) granted SpaceX approval to launch 7,518 satellites in addition to the 4,425 previously authorized—the now Acting Chairwoman of the FCC, Jessica Rosenworcel, gave a statement on the authorization supporting

the promotion of internet connectivity and specifically the "next-generation space race [with]... [new] commercial models, players, and technologies... coming together [to rapidly multiply] the range of satellite services", while also explicitly noting the positive aspect of increasing internet availability across the globe. (Federal Communications Commission, 19). Despite her praises of Starlink's potential, Rosenworcel also warns that the increased number of satellites in orbit could pose a threat to innovation, noting how "[this] should concern us all—because junking up our far altitudes will constrain our ability to innovate, connect, and make progress with satellite systems" (Federal Communications Commission, 19). As of February 25, 2021, the United Nations estimated that 10,520 satellites are in orbit around the Earth, 1,031 operated by SpaceX ("Outer Space Objects Index"). In total, filings for upwards of 42,000 Starlink Satellites have been received by The International Telecommunication Union (ITU), with the aforementioned ~12,000 satellites already approved (Information 'As Received'). Overall, SpaceX would more than quadruple the total number of satellites in orbit around Earth, presenting a clear paradigm shift in how space is to be used by commercial companies. Many scientists and members of the space community alike are worried that the Starlink satellites, along with the rising quantity of space debris, will contribute to an effect known as the Kessler Syndrome. Defined by NASA as the event when "collisions create more debris creating a runaway chain reaction of collisions and more debris," or 'collisional cascading,' Kessler Syndrome threatens to effectively make low-Earth orbit (LEO) unusable, the altitude in which Starlink satellites generally operate (Corbett, 2017).

### *Starlink and Astronomy*

In addition to concerns about the rising quantity of objects in space, many astronomers are finding that Starlink satellites are obstructing the views of observatories across the world. A report was produced by the National Science Foundation and the American Astronomical Society on the growing issue of satellite light pollution, drawing conclusions from the Satellite Constellations 1 (SATCON1) workshop, which consisted of over 250 experts in the field. The report concludes that constellations of satellites in low-Earth orbit (LEOsats) have the potential to ensure that "[nighttime] images without the passage of a Sun-illuminated satellite will no longer be the norm," further warning that a growing number of satellites could result in "no combination of mitigations [being able to] fully avoid the impacts of the satellite trails" on observatories (Walker, C., et al. 3). SATCON1 conducted intensive simulations to measure the impact of prominent LEOsat constellations and found that nine different 'representative science cases and genres of sky observations' are vulnerable to negative impacts by the Starlink and One Web (a competing company proposing to launch 48,000 satellites) constellations. The report gave ten recommendations to both observatories and constellation operators to alleviate potential obstructions for observatories due to collaboration between SpaceX engineers and expert astronomers. As a response to the rising criticism of Starlink's negative impacts on astronomy and the numerous discussions and workshops conducted on the matter, such as SATCON1, SpaceX modified one of their satellites to include a darkening treatment designed to reduce reflectivity (Henry, Caleb). This specific satellite, STARLINK-1130, was observed by astronomers and compared with observations on STARLINK-1113, a satellite with no darkening treatment, to measure the impact made by the modifications. Astronomers with the *Astronomy & Astrophysics* journal found that the Darksat is roughly two times dimmer than traditional Starlink satellites, but also found that the satellite "does not meet the requirement needed to mitigate the effects that low orbital mega-constellation LEO communication satellites will have [on observatories]," calculating that Starlink would need to dim their satellites up to fifteen times beyond the original model (Tregloan-Reed, J., et. al.). As a result of the subpar results of DarkSat, SpaceX has developed a further modified version of Starlink, dubbed VisorSat due to the use of visors to reduce reflectivity—SpaceX's vice president of satellite government relations announced that sunshades would be included on all future Starlink satellites after mid-2020 (Henry, Caleb). The actions of SpaceX to alleviate these issues is suggestive of their dedication to collaboration and problem solving—however, the issue of light pollution was included in this study as these are outstanding issues not completely solved, or at least

confirmed to be solved, and other similar proposed constellations from companies such as Amazon and One-Web have not publicly developed solutions to these issues with light reflection. Therefore, this specific issue was decided to still be relevant to the conversation around the commercialization of space and subsequently this study.



**Figure 1.** 19 Starlink Satellites blocking the view of a Chilean observatory (Martínez-Vázquez and Johnson, 2019).

### *Government Oversight*

Space has long been a domain of government entities, inaccessible to companies working independently—one of the questions that must be answered with the rise of commercial companies in this sector is of government control and oversight. Since SpaceX began operations, there have been several instances where a government had to intervene with an issue involving SpaceX. In September 2019, SpaceX's Starlink 44 was projected to be on a collision course with Aeolus, an observation satellite operated by the European Space Agency (ESA) (Johnson, 2020). A collision would likely destroy both satellites, but it would also risk creating a "significant amount of debris in LEO," which would negatively contribute to Kessler Syndrome. According to the ESA, these collisions are often mitigated by communication via email between the two operators of the satellites, which their Head of Space Safety calls an "archaic process that is no longer viable as increasing numbers of satellites in space mean more space traffic" (ESA Spacecraft). As collision probability quickly rose beyond the ESA's threshold, they attempted to contact SpaceX, but due to a software issue, the company did not receive the message (Johnson, 2020). The collision was averted when the ESA commanded their satellite to alter its course by 350 meters. As their Head of Space Safety later explained, "No one was at fault here, but this example does show the urgent need for proper space traffic management, with clear communication protocols and more automation"—as companies continue to operate in space, there is a growing need for a central authority to govern space (ESA Spacecraft).

In a similar vein, the Federal Aviation Administration (FAA) has encountered some issues surrounding the development of Starship, SpaceX's latest rocket which is being developed to carry humans to Mars. In December of 2020, the first full-scale prototype of the rocket known as SN8 was launched without permission from the FAA, violating the launch license, which could have posed a risk to public safety. SpaceX's CEO, Elon Musk, denounced the FAA for having a "broken regulatory structure," which he believes will make it

impossible for "humanity... [to] get to Mars" (Davenport, 2019). As a result of the launch violation, the FAA conducted an investigation and later approved the subsequent launch of prototype SN9. Ultimately, this conflict with the FAA demonstrates the potential for commercial companies to cause harm to public safety, which points towards the need for government oversight in this industry.

## Related Studies

This specific field of research, conclusions on survey data from a wide range of individuals living in the United States with a focus on the commercialization of space, is woefully sparse given the importance of these changes in our world. The lack of conclusions or even basic understandings of public opinion on the commercialization of space is worrying because of the implications of these changes—sending humans to another planet is just as controversial as launching thousands of satellites into orbit. These issues will define humanity as we move into the future, and it is critical that we, as a race, have conversations on these issues. The Pew Research Center, a non-partisan "fact tank" that polls Americans to explore public opinion on various topics, conducted a study in 2018 in which they interviewed roughly 2,500 participants with a variety of questions on the commercialization of space. Their study found that 65% of respondents believed that NASA should still play a "vital role in the exploration of space," while a third believe that "private companies will ensure enough progress [is made] in this area... without NASA's involvement" (Funk and Caiazza). This continued support for NASA is notable as it is in a very different environment than the days of the Apollo program and the Space Race against the Soviet Union. Despite this radical shift in the space industry, the study found that 80% of respondents believed the International Space Station was a good investment for the United States, and 72% of participants believed that the U.S. must continue to be a "world leader in space exploration" (Funk and Caiazza). The study went to great lengths to ensure that their results contained no errors at a 95% confidence level while ensuring that their study was demographically reflective of the United States as a whole.

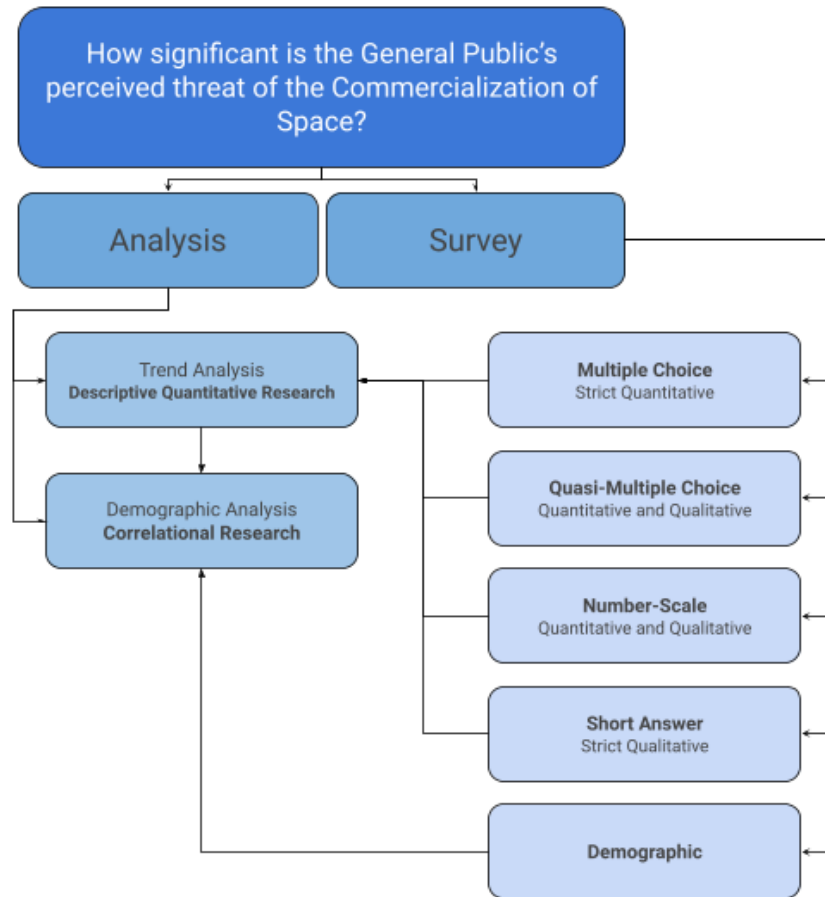
The previous research conducted in the field provided a basic understanding of American support for space exploration, with figures on the overall support of NASA and the United States' presence in space serving as proof of the Administration's importance. Despite this vital groundwork, a significant amount of research is yet to be done in this specific field. Therefore, the researcher was able to design survey questions to further understand the general public's perceived threat of the commercialization of space with in-depth analysis of particular issues while also aiming to reinforce the findings of the Pew Research Center through broad-subject questions.

## Methodology

### Study Design

This study was designed to quantify participants' opinions with descriptive quantitative research while also uncovering trends among participants using demographic data collected from participants and comparing it with the results of the subject-focused questions with correlational research. As demonstrated in the literature review, the Pew Research Center surveyed a nationally representative panel with over 2,500 participants from across the United States—using their data, they coupled the demographics of the participants to identify trends among certain groups of individuals. The methodology of the Pew Research Center was adapted for this study. This two-part, mixed-method approach is critical to understanding the opinions of the subjects involved with this study and detecting potential relationships between certain opinions and demographic qualities. This analysis design was built to better understand how the participants felt about the issues presented to them, which then could be examined to discover commonalities between the participants. These commonalities would be

matched with demographic information also submitted to identify trends, with potential forecasting use on larger populations. As very little research has been done to identify public opinion on the commercialization of space, the researcher attempted to reinforce the previous study's findings while also working on expanding the field of inquiry with more in-depth subject matter.



**Figure 2.** Two Part Mixed-Method approach

The researcher identified six Topics of Inquiry (TOI) that would be focused on in this study. These six topics were researched and were then applied to study participants as part of a public-opinion survey. This study finds a gap as The Pew Research Center's study primarily focused on the Importance of Space Exploration. This first category was adapted for use in this study to reinforce the findings of the previous research, and the five additional categories were added to expand the understanding in this field to new subtopics.

Using a survey, participants were asked for their opinion on the six TOI, which were researched in the literature review. Not all TOI required in-depth research. A survey was chosen as the data-collection method for this study as they are easily distributed through virtual means, which was especially important given the restrictions imposed by the COVID-19 pandemic. Surveys are also highly efficient methods of quickly gathering data from a wide range of participants, which is ideal for a study with the aforementioned research purpose.

**Table 1.** The six Topics of Inquiry (TOI)

Topics of Inquiry
1. Importance of Space Exploration
2. Perception of Change
3. Further Exploration



4. Governments in Space
5. Satellite Constellations
6. Safety and Ethics

## Participants and Procedures

This survey was targeted towards all U.S. residents above the age of 12; however, the survey was heavily distributed within the geographical area of the researcher—that being Massachusetts. To distribute the survey, the researcher utilized social media, a survey distribution website named SurveyCircle, and the researcher communicated with all parents/guardians within the school district to ask for their voluntary participation in this study (Appendix A) via the Superintendent of Schools. Per the regulations put in place by school officials, all research involving students can only be conducted after the student, and their guardian completed an Informed Consent Form (Appendix B), provided and reviewed by the researcher. For non-student participants, Informed Consent was gathered through a statement before the survey began (Appendix C). As this study researched human subjects, the researcher applied to an Institutional Review Board (IRB), which granted permission to conduct the study after reviewing an application and the content of the survey. The survey was conducted between the 26th of January, 2021, and the 1st of March 2021. In all, the study found 89 participants who had completed the survey. Before a participant could begin answering subject-related questions, they had to answer Yes to the question "I consent to participation in this voluntary and anonymous research study," which was asked after the Informed Consent Statement included on both student and adult surveys.

## Survey Details

The survey utilized 19 subject-related questions (Appendix D) to understand public opinion across the six TOI. Some questions were written in conjunction with research on the TOI and were varied in structure as a way to reinforce the Mixed-Method Approach of this study. All questions were written to contribute to a specific TOI. Some questions of TOI1 and TOI3 were based on those of the Pew Research Center in an attempt to reinforce the findings of the previous research while also making new, varied conclusions. While these questions were not always worded or executed in the same way, the questions are similar in objective from a research perspective. The questions of the remaining TOI were written after research on the topics were conducted, allowing for the questions to be informed by the research. These questions would be written to make new inferences in the TOI, which were not previously surveyed in other studies. Some of these questions used supplemental information to reinforce understanding of the question and topic (Appendix E). These pieces of information were written with an emphasis on minimizing potential bias. A question, now labeled question \* was considered to be potentially influenced by this supplemental information and was subsequently unconsidered in analysis. The 19 subject-related questions used in this study varied in structure to adapt to different types of data collection: multiple-choice, quasi-multiple choice where a 'short answer' selection was made available, numbered-scale, and short-answer formats were all used in different parts of the survey.

**Table 2.** Questions to reinforce previous research, (Funk and Caiazza)

Pew Research Center question	Question with similar objective
In your view, do you think it is... <b>ESSENTIAL that the United States continue to be a world leader in space exploration</b>	Do you believe that Space Exploration is an important priority for the United States? <b>Yes</b>

<b>NOT ESSENTIAL that the United States continue to be a world leader in space exploration</b>	<b>No</b>
Do you think the space station has been... <b>A GOOD investment for this country</b>  <b>NOT a good investment for this country</b>	Do you believe that NASA is worth the \$23.3 billion allocated in its 2021 Budget? <b>Yes, and the funding should be increased.</b>  <b>Yes, but the funding should remain the same.</b>  <b>No, and the funding should decrease.</b>  <b>No, and NASA should have no funding.</b>
How would you rate each of the following priorities for NASA's space efforts? <b>(Using provided examples)</b>	I believe that the primary priority of NASA should be: <b>(Short Answer)</b>
Which statement comes closer to your views — even if neither is exactly right? <b>It is essential that NASA continue to be involved in space exploration</b>  <b>Private companies will ensure that enough progress is made in space exploration, even without NASA's involvement</b>	I believe that: <b>Private Companies will make enough progress in Space Exploration without NASA's involvement.</b>  <b>NASA must still be involved in Space Exploration.</b>
Sending human astronauts to explore the moon <b>Should be a top priority</b> <b>Should be an important but lower priority</b> <b>Should not be too important</b> <b>Should not be done</b>	Should returning astronauts to the Moon be a top priority for the United States? <b>1 - Not Important at all</b> <b>2</b> <b>3</b> <b>4</b> <b>5 - Top Priority</b>
Sending human astronauts to explore Mars <b>Should be a top priority</b> <b>Should be an important but lower priority</b> <b>Should not be too important</b> <b>Should not be done</b>	Should sending astronauts to Mars be a top priority for the United States? <b>1 - Not Important at all</b> <b>2</b> <b>3</b> <b>4</b> <b>5 - Top Priority</b>

Beyond the 19 subject-related questions, 7 demographic questions were also asked in order to allow for a comparison of demographic trends against responses (Appendix F). These questions collected demographic data about age, gender, ethnicity, educational background, annual household income, political view, and religious participation. The researcher decided these seven categories to be the most potentially influential factors on opinions of the commercialization of space because they help define one's socioeconomic status.

### Analysis Methodology

After the data-collection period had closed, the researcher assigned an identifier string to each response as a way to reference a response easily. These Identifier Strings were randomly generated ten-digit combinations of



lowercase and uppercase letters, as well as numbers. Next, the researcher began to sort through responses to create a group that could be researched in a correlational manner for demographic analysis. In this way, the data was broken into three stratum. Stratum A was defined as all responses, consisting of 89, and was not used in the analysis portion of this study. Stratum B was created by removing all responses that skipped one or more subject-related questions, consisting of 65 responses. Stratum C was created for the sake of demographic analysis, consisting of all responses from Stratum B that did not select "Prefer not to answer/say" on a demographic question. Stratum C was made up of 44 responses. Grouping responses in such a manner allowed for organization in the analysis portion of this study while also filtering the optimum samples for demographic analysis (responses that answered each question).

**Table 3.** Response Stratum

Stratum	Criteria	Responses
Stratum A	All responses.	89
Stratum B	All responses that did not skip a subject-related question.	65
Stratum C	All responses that did not skip a subject-related and did not select "Prefer not to answer" on a demographic question.	44

### *Trend Analysis*

The trend analysis portion of this study began by using Inductive Coding to categorize responses to Question 18: "I believe that the primary priority of NASA should be," a short answer question included for qualitative data in TOI1. The Inductive Coding was done by categorizing responses into many categories observed by the researcher and then were narrowed down into eleven final categories, which best balanced the number of specificities. This balance ensures that meaningful analysis can be pulled from these responses—the breakdown is not too general or too vague.

For the remaining questions, the researcher used a variety of different visual representations of the data in order to analyze the data. This analysis was mainly conducted by dividing the occurrence of an answer by the total number of responses in Stratum B.

**Table 4.** Inductive Coding of Question 18. Note: The categories *Space Exploration* and *Research, Science, and Education* often appeared alongside more detailed responses—some responses will be considered twice, once in these two "general" categories and again in the more specific categories. Bracketed numbers indicate responses as part of this first consideration.

Codes	Stratum B Counts	Stratum C Counts
Space Exploration	27 (5)	21 (4)
Research, Science, and Education	27 (13)	19 (9)
Climate Research	6	3
Militaristic Purposes	6	4
Send humans to Mars	4	1
Search for human-compatible planets	2	2
Search for other life	1	1
Space Debris Removal	1	0
Civilian access to space	1	1
NASA should not exist / is not a priority	1	1
Unsure / NA	3	3

### Demographic Analysis

The demographic analysis portion of this study began by creating 126 two-way tables with responses from Stratum C, crossing responses to all subject-related questions with the participants' demographic responses. The two-way tables allowed the researcher to begin detecting connections between responses and participants' demographic information. The researcher analyzed each table and recorded any apparent trends that were seen. For each question, the researcher recorded an overall conclusion of demographic factors on the responses, which could then be combined with the conclusions on other questions to draw conclusions for each of the seven demographic criteria.

17 V Gender I have a ____ opinion of SpaceX:	What gender do you identify as?		
	Female	Male	Grand Total
I have a negative opinion of SpaceX.		4	4
I have a positive opinion of SpaceX.		6	12
I have a slightly negative opinion of SpaceX.		1	3
I have a slightly positive opinion of SpaceX.		9	15
I have no opinion of SpaceX.		9	10
<b>Grand Total</b>		<b>29</b>	<b>44</b>

**Figure 3.** Example of a two-way table made for crossing responses to Question 17 with demographic information of the participant's gender.

## Results

Once the Stratum were finalized, the researcher began to perform the trend analysis, followed by the demographic analysis of the data. Due to a lack of diverse participants in the study, the Demographic Analysis results were left unconsidered in the analysis. Such limitations will be further evaluated in the Discussion section of this paper.

### Trend Analysis

With a large number of questions included in the study, heavily analyzing each of them would not be an efficient use of time, so the researcher sought to choose one or two questions representing each TOI. Questions numbered 2, 6, 17, 8, 5, 16, 14, and 12 were used in this analysis. Using various visual representations of the data displayed below, conclusions were drawn by the researcher.

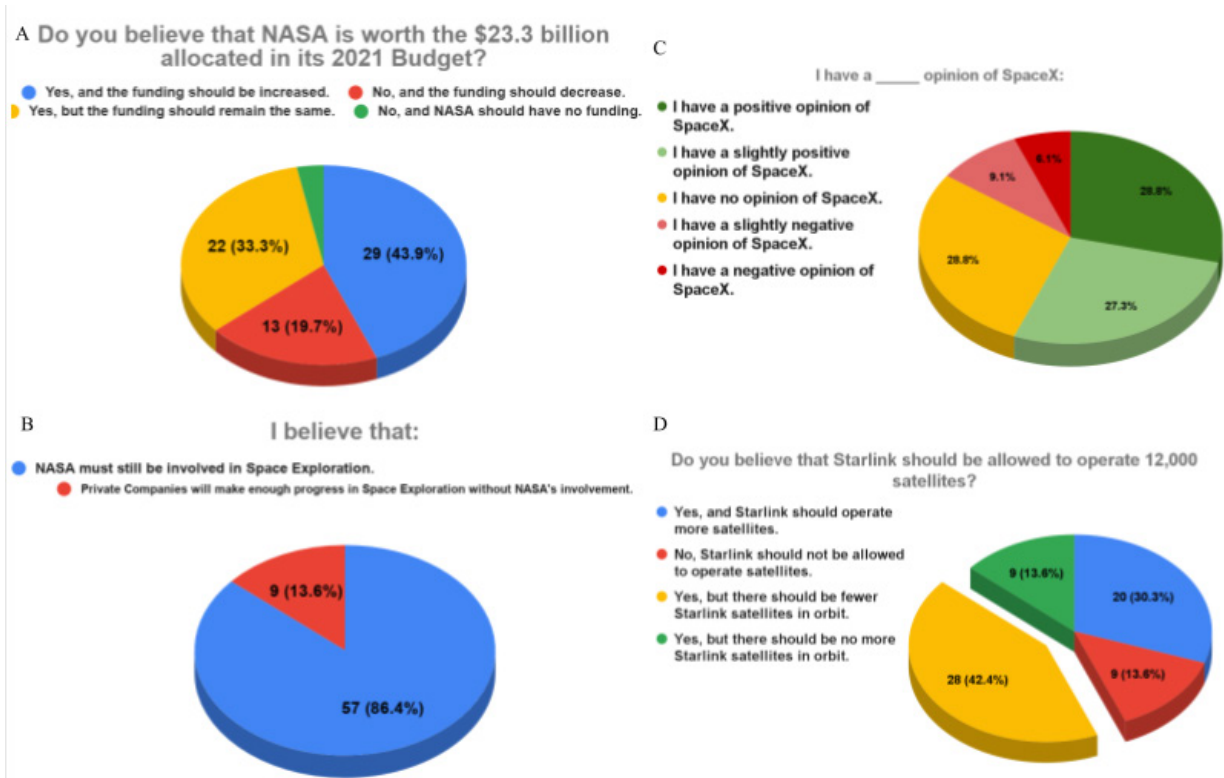


Figure 4. Trend Analysis of questions 2, 6, 14, and 17 used to analyze TOI.

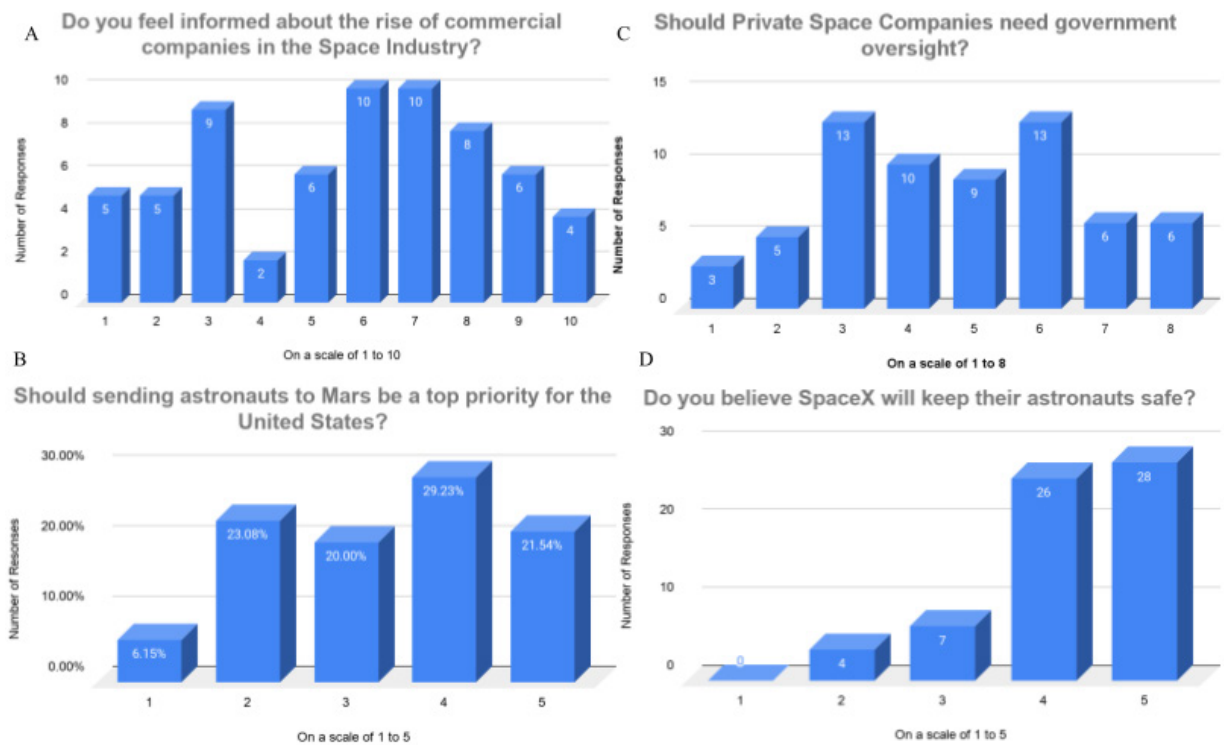


Figure 5. Trend Analysis of questions 8, 5, 16, and 12 used to analyze TOI.

Figures 4a and 4b investigate the Importance of Space Exploration in conjunction with the Pew Research Center's previous work. In Figure 4a, depicting participant's support for space exploration, 44% of participants support an increase in NASA's budget, while an additional 33% of participants support the current budget of NASA. Only 23% of participants reported a lack of support for NASA's spending, a clear indication that many believe space exploration is worth their tax dollars. The Pew Research Center, who's research also focused on support for space exploration found that 80% of their participants support funding for the International Space Station—while these two questions do differ, they have a similar research objective and suggest a common thread between these two studied, as 77% of respondents in this study support NASA's spending. Figure 4b displays the results from another question similar to that of the Pew Research Center. In the question, roughly 86% of participants reported the belief that NASA must still be involved in space exploration, while ~14% of respondents believe that private companies will make enough progress on their own. The Pew Research Center found that in their study, 33% of participants believed private space companies would make enough progress on their own. This difference of 19% between the two studies is significant and may be attributed to regional differences.

Figures 4c and 5a investigate the Perception of Change. Figure 4c is a breakdown of the opinion that participants have of SpaceX, with 56% of participants reporting varying (both full and slight) positive opinions. Only 15% of respondents reported a varying negative opinion of SpaceX, while 30% of individuals have no significant opinion. These results demonstrate that most participants in this study have a positive perception of SpaceX, which suggests that a majority of people have a positive perception of this change to the industry or are at least indifferent. To further understand participants' perceptions of change, the researcher also investigated the awareness participants had of this change. In Figure 5a, a majority of participants reported that they were well informed, around 6-7 out of 10, while another large spike occurred at 3, demonstrating varying degrees of awareness across this population of participants. Another thing to note is that responses of 8, 9, and 10 decrease in frequency as the scale (1 to 10) increases, suggesting that fewer people feel very well aware of the change to the industry.

Figure 5b was used to analyze Further Exploration and shows a majority forming at 4 out of 5. However, the subsequent most common response is 3, indicating that there is a split in opinion among participants. Generally, however, there is demonstrated support for sending astronauts to Mars as the frequency of responses increases with the scale.

Figure 5c is a breakdown of Government Oversight, and shows another split among participant opinion, with shared majorities at 3 and 6 out of 8. Very few participants responded on the extremes of this question, showing that there is likely increased support for moderate government oversight over private space companies. The majorities at 3 and 6 are interesting as they suggest this split, but also are placed equally from the 1 and the 8, supporting this idea of belief for moderate oversight.

Figure 4d demonstrates public opinion of Starlink's satellite constellation, and is likely the most significant research in this study for the current moment as Starlink is actively being developed and deployed. A majority of participants support Starlink to some degree, only ~14% of participants saying Starlink should not be allowed to operate satellites. However, there are differences in the ways of support. A majority of participants, ~30%, believe that Starlink should be allowed to operate more than 12,000 satellites, while ~42% believe that Starlink should operate a lesser number of satellites. Another ~14% believe that Starlink should stop at 12,000 satellites. These results are interesting as they suggest that the general public does support this large-scale satellite constellation.

Figure 5d displays data about Safety and Ethics, the vast majority of participants are not worried about a lack of safety. The majority of responses were at 5 out of 5, while the second-highest response was 4 out of 5. No participants answered at a 1 out of 5.

## Discussion

## Findings

Ultimately, this study was conducted with the six TOI as an underlying guide to focus the research. Due to this, the researcher decided to draw conclusions on each TOI as they represent the research as a whole.

In TOI1, the Importance of Space Exploration, it can be concluded that a majority of people support space exploration, including government spending towards NASA. It is also notable that the vast majority of participants believe that NASA must still be involved in space exploration, possibly a result from a perceived reliability of a government-backed organization. Understanding that space exploration is supported among the general public is vital as it will ensure that NASA can still operate in space while also promoting future Exploration.

On the topic of the Perception of Change, TOI2, most participants noted that they feel relatively knowledgeable about the change to the industry, which, when considered with the overall either positive or indifferent opinions of SpaceX, could indicate that most participants have a positive perception of this change. This is an important conclusion as private companies are expanding their reach with each passing day through government contracts and private ventures.

As for Future Exploration, TOI3, a majority of participants do support sending astronauts to Mars. While some participants are not as supportive, there is a clear majority towards sending astronauts to Mars, which is critical to understand as the focus of NASA and private companies, specifically SpaceX, is centered around the colonization of Mars.

In terms of Government Oversight, TOI4, the data suggests that most participants support moderate government oversight over private space companies. As governments place more trust in these companies, with more expansive and novel missions, having control over the actions of these companies will be very important. Many problems are left unsolved and could be best suited with government bodies to administrate, such as the growing number of satellites and space debris. Support for oversight, in any sense, will be necessary as companies like SpaceX begin to innovate beyond the limits of history.

Large satellite constellations, TOI 5, are widely supported by the participants in this study, which suggests that most people are willing to risk issues such as light pollution and the Kessler Syndrome, both of which participants were informed of, for improvements for the human species. Given these constellations are novel in nature, there is a great chance that there are unforeseen risks involved—early support for these projects and most specifically Starlink are telling of the attitude people have towards space.

The final TOI (6), Safety and Ethics, was relatively dominated by the strong belief that SpaceX will keep their astronauts safe. Given the risks associated with space travel, with government agencies and private companies alike, there is a clear sense of trust towards SpaceX. This will be very important to understand as SpaceX has already begun to launch astronauts into LEO, with plans to send astronauts to the Moon and Mars.

## Limitations

One of the most significant limitations in this study was the lack of diversified participants in the study, and specifically Stratum B. For example, 66% of participants in Stratum B were women, which is far from the national average. 84% of participants were self-identified as Caucasian, again far from a diverse group of individuals. This lack of diversity in participants made it difficult for many meaningful conclusions to be made from the data, as it was made more challenging to highlight differences between demographic factors. In this way, for example, conclusions on ethnicity were not of any reasonable confidence as a vast majority of participants self-identified as Caucasian, with very few or no participants of other ethnicities to compare. Another limitation presented in this study is the increased distribution of the survey in the researcher's geographic area due to difficulties gathering participants at a national level. The distribution to parents and guardians at the

researcher's school likely influenced the average geographic region of participants, therefore introducing regional differences into this study. These limitations made it difficult to use inferential analysis for an accurate nationally representative scale.

## Implications

Ultimately, this research suggests that the majority of people support space exploration and would like to see even more funding and resources put towards it for a plethora of reasons. This understanding is crucial as private companies will be expanding the borders of humanity in the near future, with upcoming rockets from companies such as SpaceX, Blue Origin, The United Launch Alliance, and RocketLab, as well as many nations. The market has quickly become saturated with hundreds of companies, from billion-dollar giants to brand new startups, and understanding public opinion about these changes will allow us to sculpt these developments as they occur before actions in space by private companies are irreversible. Operations in space have the capability to be either enormously beneficial to humanity, or detrimental to life on Earth, and lawmaking bodies must be prepared to regulate this growing industry with public opinion in mind. This study was conducted with the idea that all people should have a voice in this growing conversation, which is the focus of public-opinion research in this field. These changes include massive satellite constellations, colonies on the Moon and Mars, space tourism, asteroid mining, and more scientific missions, which will permanently change humanity.

## Areas for future research

There is a distinct need for future research in this field, given the enormous scope of topics still left uncovered in the analysis of the public opinion of the commercialization of space. There are very little demographic conclusions in this field, and they hold the key to extrapolating results to a larger body of people. Without future research that would include large and diversified groups of individuals, these important conclusions could not be made. These extensive conclusions from a wide pool of participants would allow lawmakers and regulators to fully understand the extent to which people want space to be utilized. Future research can continue with these six TOIs or could expand into more niche topics such as the colonization of Mars, for example. Mars is of growing relevance to this research as humanity moves closer to having the ability to send astronauts to the planet.

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