

**Exploring the Shortcomings of Current Federal Regulations on the Environmental Impacts  
of SpaceX Rocket Launches in the U.S.**

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On my honor as a University Student, I have neither given nor received unauthorized aid on this  
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## **Introduction**

A live rocket launch is an event that many avid space enthusiasts hope to experience at least once in their lifetime. The countdown from the control center, the deep rumble as the engines begin to fire, the plume of smoke billowing up as the rocket leaves the launch pad, the trace of light in the sky as the rocket leaves Earth's atmosphere. These series of events, of course, only occurring when launches go according to plan. With more space-based projects taking place around the world, there are now hundreds of rocket launches per year, providing more opportunities to see one of these launches in person. However, in all the excitement from a launch, the environment is not usually at the forefront of the viewer's minds.

As space flight becomes more prominent in our society, with the rapid rise of private companies like SpaceX, it becomes more important to consider the environmental effects of repeatedly launching spacecraft. In 2023 alone, SpaceX launched 98 rockets, and plans to launch up to 144 in 2024 (Foust, 2023). SpaceX conducts most of their launches with reusable rockets, which reduce the cost per launch since the structure does not have to be rebuilt. One of these rockets is Starship, a large shuttle that uses a Super Heavy booster with the goal of being able to carry crew and cargo all the way to Mars in the coming years (Starship, 2024). SpaceX has also frequently used Falcon 9 rockets to launch Starlink satellites, with the goal of creating a constellation of thousands of small satellites to provide broadband internet coverage nearly worldwide (Starlink, 2023). With an undertaking of this scale, SpaceX is constantly launching rockets from several launch sites across the United States, and the company is looking to increase the number of rocket launches by building additional sites. Under the National Environmental Policy Act (NEPA), before a rocket launch can occur at any launch site in the U.S., SpaceX must submit mission proposals and detailed descriptions of their planned

operations so the Federal Aviation Administration (FAA) can issue permits and complete environmental evaluations in the form of Environmental Assessments (EAs) or Environmental Impact Statements (EISs) (Federal Aviation Administration, 2022).

With Starship beginning test launches in 2023 and with over 4,500 Starlink satellites in orbit, and potentially up to 42,000 total in the coming years, there is no sign that the frequency of SpaceX launches will diminish (Satariano et al., 2023). More launches also entail more launch sites to increase efficiency, but this development comes at a cost to the surrounding environment. As seen from multiple launch explosions in Boca Chica, Texas, new launch sites disrupt the local wildlife and failed launches due to inadequate environmental assessment have negative impacts that could potentially become irreversible if nothing is addressed at the federal level, or if commercial spaceflight companies fail to recognize and work to change these issues within their procedures (Kluger, 2023).

In this paper, I show that after the Boca Chica, Texas launch explosion in April, 2023, SpaceX has been able to function within current federal regulations while negatively impacting the environment because of a lack of motivation to improve environmental protection procedures at the administrative level, and deficiencies in regulations at the federal level. In order to make this argument, I conducted a thorough literature review to understand the necessary background information to build towards my thesis. This literature review investigates the relation of SpaceX's actions to Merritt Roe Smith's definition of technological determinism, the Starlink and Starship projects, the development of the current environmental regulations, and the recent Starship explosion in Boca Chica, TX. In my analysis, I look closely at this incident and how the FAA and SpaceX both failed to adequately anticipate environmental damage through

shortcomings in the required documentation, and how the results from this incident show an overall sense of disregard for environmental care in the space exploration industry.

## **Literature Review**

The Starlink project has the goal of creating a constellation of thousands of small satellites to provide broadband internet coverage nearly worldwide (Starlink, 2023). There are currently over 4,500 Starlink satellites in orbit, and the project is expected to continue up to 42,000 satellites in the next few years (Satariano et al., 2023). SpaceX has mainly used their reusable Falcon 9 rockets to launch Starlink satellites. Although the word “reusable” sounds more environmentally friendly, a single Falcon 9 launch uses roughly 336,000 kilograms of CO<sub>2</sub>, causes damage to the ozone layer from chemicals released directly into the atmosphere, and ejects black carbon particles, which trap roughly one million times more heat than CO<sub>2</sub> in the atmosphere (Kilgore, 2023; Ryan et al., 2022; Schmidt, 2011).

Starship rockets are the world's most powerful launch vehicles that are designed to be reusable and carry crew and cargo to the moon, Mars, and beyond (Starship, 2024). The National Aeronautics and Space Administration (NASA) has funded SpaceX with \$2.9 billion to develop Starship and a Human Landing System as part of the Artemis program to bring humans to the moon. Similarly to the Falcon 9 rockets, these launches have measurable effects on pollution levels. At the time of writing this paper, there have been three attempted Starship launches in April, 2023, November, 2023, and March, 2024, with the goal of conducting orbital, integrated flight tests of the Super Heavy booster and upper stage. Only the March launch had a successful launch outcome, although still blew up upon atmospheric re-entry, whereas the first two blew up

minutes after launch. The first two launches caused damage to the environment surrounding the launch site, and will be further detailed in this paper (Harwood, 2024).

Before investigating the environmental damage from the April Starship launch, it is necessary to understand the current environmental procedures and how they were developed. In the mid 1900's, as industrialization, urbanization, and the population all grew, people started to take notice of the strain on the environment. Additionally, in 1962, Rachel Carson published *Silent Spring*, which depicted the harmful effects of pesticides and helped launch the modern environmentalist movement. The 1960's saw critiques on the political response to industries' lack of environmental care, which then led to the enactment of the National Environmental Policy Act (NEPA) in 1970, which requires federal agencies to take into account environmental impacts and alternatives in their proposed actions (University of Southampton). Currently, under NEPA, the FAA requires an Environmental Assessment for any proposed action, but if there is a Finding of No Significant Impact (FONSI), there is no need for an Environmental Impact Statement, which is a more comprehensive version of an EA (Citizens for a Healthy Community). Additionally, some projects are categorically-excluded from environmental review under the Federal Communications Commission (FCC), omitting the need for an EA or EIS, meaning that the materials or fuel sources used are not regulated by any organization (Ryan, 2020).

As SpaceX has grown, so has their desire for new launch sites. In 2014, SpaceX announced they would begin constructing a new launch base in Boca Chica, TX, and began conducting test launches in 2020 (Hooks, 2021). The launch site sits next to the Boca Chica State Park, and since its development, launch activity has disrupted the local environment and has led to decline in populations of endangered species, such as piping plovers and sea turtles (Brown,

2023). Additionally, locals have been contesting the arrival of SpaceX, with the promised boon to the local economy coming at the expense of access to clean, quiet beaches, wildlife, and spiritually protected land (Hooks, 2021). On April 20th, 2023, SpaceX conducted a test launch of their Starship rocket. Less than four minutes after liftoff, the rocket blew up, damaging the surrounding area and spreading debris within 385 acres of the launch pad. The launch also ignited a 3.5 acre fire south of the launch site, within the state park (Kluger, 2023). In this case, the FAA had allowed SpaceX to conduct their own EA, and approved that document without requiring additional information in the form of an EIS, leading to legal backlash from various environmental groups (Martinez, 2023). After this incident, the FAA suspended SpaceX's launch license and required SpaceX to make 63 revisions to their assessment before allowing any additional launches (Federal Aviation Administration, 2023). SpaceX has since made those revisions and was able to launch again in November, 2023, and March, 2024 (Harwood, 2024).

Advances in SpaceX's technologies are driving the development of a social structure within the aerospace industry. They have set the standard of launching rockets every two to three days and have asserted themselves as a "leading player" in winning commercial launch contracts from organizations, such as NASA (Kelly et al., 2023). With the social and economic successes of their technologies, as seen with Starlink and potentially soon-to-come with Starship, SpaceX has been able to dominate this industry, even though the launches are known to have negative environmental impacts.

Overall, the space industry is quickly growing, leading to more space-based projects and subsequent launches. Satellite and payload launch services, satellite internet, and space tourism market values are expected to grow to \$1 trillion by 2030 (Kelly et al., 2023). Within such a booming industry, competition from other, similar companies means that SpaceX needs to

continue making progress in their technologies to stay on top. I analyzed this relationship using ideas from Merritt Roe Smith's *Technological Determinism in American Culture*. Technological determinism is the belief that "changes in technology exert a greater influence on societies and their processes than any other factor," as a driving force for progress in 19th century America (Smith, 1994, p. 2). For some of the foremost thinkers on progress, like Thomas Jefferson, "progress meant the pursuit of technology and science in the interest of human betterment (intellectual, moral, spiritual) and material prosperity" (Smith, 1994, p. 3). With new advances such as the electric telegraph, locomotive, and steamboat, many Americans saw technological determinism as a positive for society (Smith, 1994, p. 9). However, some argued that as technology continued to advance and industries started to boom, there was a sacrifice of "moral progress for material power" (Smith, 1994, p. 26).

## **Methods**

The primary methods I used in conducting this research were case study analysis and policy analysis. My case study was the April 20th, 2023 Boca Chica, TX, Starship launch explosion. I looked into what happened, who was involved, what policies were in place or lacking, what the specific incident was, and how it was handled. I observed photos from reputable news articles depicting the aftermath to investigate the visible, physical damage to the surrounding environment. I also used agency reports from the FAA and media accounts from various sources that documented this incident to distinguish responses from multiple points of view. In conducting policy analysis, my first step was to identify the specific agencies to investigate, in this case, the FAA and SpaceX. Then I investigated the specific laws and policies that exist and who they affect. I then examined these documents to look for any shortcomings

that led to certain issues with the rocket launches or that could lead to more environmental issues if nothing is changed. Lastly, I looked into SpaceX's policies and identified areas of potential insufficiency. In addition to agency reports from the FAA, I primarily investigated legal texts in the form of EAs, EISs, and FONSIIs to identify potential points of misconception or absences of information that allowed companies like SpaceX to not have to extensively consider their environmental impact for all launches and launch-related procedures.

## **Analysis**

Space exploration is the new frontier to be explored and the new technologies that allow us to get there create excitement for the possibilities of what we might find. NASA was at the forefront of U.S. space exploration, starting in the 1950's. The political pressure to beat the Soviet space program in the Space Race helped drive progress throughout the Cold War (Davis, 2023). Taking into account the political and social issues, NASA's primary mission is to "drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth" (Performance.gov). Now, as the private sector has risen and made great strides in technological advancement, space organizations, including NASA, have shifted towards focusing more on the technologies themselves, and less so on the political and social issues associated with problem-solving. SpaceX's mission statement is "to revolutionize space technology, with the ultimate goal of enabling people to live on other planets," reflecting Smith's portrayal of technological determinism in that although the end goal aims to better humanity, the focus is on revolutionizing the technology (Pereira, 2023). Thus the technology becomes an end itself rather than just a means to an end, and fails to properly account for relevant social and environmental issues.



SpaceX's dominance in the aerospace industry reflects an overall desire for profitability and furthering human space exploration that is stronger than the desire to fund more environmentally friendly alternatives. With SpaceX's next big step forward in space exploration being the drive to get humans back to the moon and on Mars, there has been a huge emphasis on successfully launching the Starship rocket, as shown by significant funding from NASA (Means, 2022). As a result, SpaceX has made a major push in their launch site towns, such as Boca Chica, TX, to regularly perform launches and attempt to purchase more land from residents to conduct their operations, even amidst push-back from these residents and environmental advocacy groups (Hooks, 2021). These actions indicate that although SpaceX faced the consequence of negative public perception, they still considered their technological advancements above environmental protection. Additionally, the government encourages the FAA to promote commercial space launches from the private sector, which shows that their motivations lie in supporting progress through developing technologies as ends themselves and upholding their relationship with SpaceX and other private companies rather than protecting the environment (Federal Aviation Administration, 2023).

The issue is not only with the rocket launches. With Starlink, the satellites are categorically excluded from environmental review under the FCC's policies, meaning there is no legal incentive to understand the environmental impacts from their production (Ryan, 2020). Although the Falcon 9 rockets frequently used for Starlink missions and the Starship rockets are designed to be reusable and therefore appear more environmentally friendly, there are still less overt, negative impacts. Reusable rockets make it easier to have more launches, which leads to using more fuel. The fuel consumption is the worst part, environmentally, of rocket launches since the kerosene mixture releases harmful soot into the atmosphere (Whitakker, 2018). Despite

these negative impacts, the FAA still allows SpaceX to conduct these launches, rather than using their approval power to motivate developing cleaner launch operations.

Shortcomings in the environmental policies allow organizations to act in accordance with the law while still causing measurable harm to the environment. As previously mentioned, the FCC deems Starlink satellites to be categorically excluded from environmental review, meaning the environmental impact from this technology's development remains unchecked by any organization. The fuel sources and production materials cause immeasurable harm to the environment, as well as spreading light pollution and altering the appearance of the night sky (U.S. Government Accountability Office, 2022). Under NEPA and the FAA's own guidelines, the FAA is the organization that is supposed to determine when an EA or EIS is needed, or whether something is categorically excluded in aviation-related proposed actions. However, they can still defer the decision to the company, in this case, SpaceX, and not face legal repercussions (Davila, 2023). Therefore, SpaceX can perform potentially harmful operations without conducting thorough environmental reviews because they are technically acting in accordance with the FAA's regulations. While the EA and EIS work to provide necessary, detailed guideline and documentation procedures, the Boca Chica, TX launch explosion shows that steps from these procedures are not fully comprehensive in practice (Federal Aviation Administration Office of Environment and Energy, 2023).

The Boca Chica, TX launch failure in April, 2023 indicates an overall disregard for environmental care in the aerospace industry. After analyzing the EA submitted by SpaceX, the FAA concluded that the proposed action of launching the Starship rocket would not result in significant environmental impact, so they approved the launch (Federal Aviation Administration, 2023). The language from the EA references "minimal" or "insignificant" impact in various

areas, such as “Biological Resources,” “Coastal Resources,” and “Hazardous Materials, Solid Waste, and Pollution Prevention.” However, these ratings are subjective to the documentor and the “monitoring” and “mitigation measures” are not outlined in the report, meaning they are not likely thorough, yet this information is sufficient enough for the FAA to grant a launch license (Federal Aviation Administration, 2022). If the environment were truly of consideration in this case, the FAA would require more detailed procedures and analysis in the form of an EIS. This point is further supported in that the Starship rocket exploded shortly after liftoff, causing measurable, unanticipated damage to the area and wildlife surrounding the launch site (Kluger, 2023).

The EA was not enough to properly mitigate the environmental effects from the launch and an EIS should have been conducted to more thoroughly analyze the potential environmental impacts, but was not done so due to a lack of priority from the FAA and SpaceX. After the launch, a collection of environmental groups filed a lawsuit against SpaceX and the FAA, calling for their launch license to be suspended and for the organization to conduct more thorough environmental reviews for future launches (Kluger, 2023). Although the FAA did suspend SpaceX’s launch license and investigate some of the claims, SpaceX and the FAA sought to dismiss the lawsuit and SpaceX was re-granted their license and able to launch another Starship rocket in November, 2023 (Martinez, 2023). These actions indicate that the FAA and SpaceX handle negative environmental impacts as more of an inconvenience that only need to be addressed when the public brings them to attention, rather than an important component of the design process.

The lack of substantial changes since the incident in Boca Chica, TX, is due to insufficient penalties and motivations for SpaceX to reduce their negative environmental impact.

Although the FAA recognized there were issues with the April launch, and worked with the U.S. Fish and Wildlife Service to require SpaceX to make revisions to their procedures before granting another launch license, the mishap investigation was closed once SpaceX made the 63 revisions (Federal Aviation Administration, 2023; Salinas, 2023). For the following Starship launch in November, 2023, the FAA still did not require SpaceX to conduct a more comprehensive EIS, and there was still damage to the environment from crowds that gathered to watch the launch (Fine, 2023). These actions indicate that the threat of not being able to launch and subsequent revisions were not sufficient for proper environmental care. Furthermore, the public backlash from this lawsuit did not motivate meaningful reductions to the launch's negative environmental impacts (Hargrave, 2023).

## **Conclusion**

There is an overall lack of urgency towards protecting the environment in the space exploration industry. Most companies, like SpaceX, are more concerned with displaying the capabilities of their new technologies and the pressure to meet deadlines and impress the public overshadows the need to focus on the environment. The FAA is just as indifferent towards protecting the environment, as shown by their reluctance to require more comprehensive environmental reviews from these companies. When environmental incidents do occur, like the April, 2023 Starship explosion in Boca Chica, TX, there are no meaningful repercussions, meaning there are no significant improvements, as the slap-on-the-wrist punishments are worth it for SpaceX to keep making progress on their Starship design. This research shows that there is a need for significant change in both administrative and federal environmental regulation procedures. In addition to the information about the federal environmental review procedures,

future research could focus on various space companies' environmental policies and examine how they differ and which have less harmful impacts. For example, NASA, in over 60 years of launches at the Kennedy Space Center in Cape Canaveral, Florida, which is near the Merritt Island National Wildlife Refuge, has not had any incidents near the level of destruction as seen in Boca Chica, TX. They also work with the EPA, FAA, and U.S. Fish and Wildlife Service, and any other interested parties, to assess potential environmental impacts not only for rocket launches, but also infrastructure work and maintenance (Kluger, 2023). With NASA funding SpaceX launch projects, they have the power to include stipulations in the contracts to guide SpaceX to adopt more environmentally-friendly practices within the procedures for the project. Researchers could use this information to propose the various conditions SpaceX must meet in order to receive funding that would help reduce harm to the environment. As these issues become more visible, more positive change is likely to occur. Many space companies are already working to develop more sustainable rockets and practices, providing a positive outlook for the environmental future of spaceflight.

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