STS Thesis Prospectus

A Thesis Prospectus submitted to the Department of Engineering and Society

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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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Comments and Peer Reviews

Throughout the process of drafting and writing my prospectus, I received helpful feedback from a number of sources, including Professor Gorman and a couple of my peers. Professor Gorman offered much insight, both when I was searching for a topic that I was passionate about, and when I needed to take my argument even further. Specifically, when I discuss the issue of social pressures that result in normalized deviance in space companies, he suggested that I look further into the use of automated systems that would potentially reduce the risk that human astronauts would face somewhere far from home (i.e. the Moon or Mars).

Feedback from my peers was also helpful to my prospectus process. For example, Matthew Denecke suggested that I look further into instances where normalized deviance could have been the cause of specific failures in past SpaceX flights. Following this advice, I researched specific flights of the commercial space company. And while I was unable to find any examples of normalized deviance that could be directly attributed to the failures of any specific launches, I did come across a very interesting report that the Aerospace Safety Advisory Panel published highlighting a potential concern regarding the fueling of SpaceX rockets. This goes to show that the suggestion helped me probe deeper and more conclusively into the matter, furthering my understanding of the topic.

I'd also like to just mention that this prospectus ended up being much longer than I had originally anticipated, but after reading through, I didn't feel that I should cut anything from the final draft. So, it has ended up almost as a mix of a prospectus and a thesis.

Introduction

Space travel has been a controversial subject throughout its brief history. While there have been many successes, there have also been many disasters, with all resulting in the loss of billions of dollars, and many losing the lives of human astronauts. This prospectus will examine both the past and future of space travel through the lens of normalized deviance. Specifically, it will talk briefly about the concept regarding the Challenger disaster, as first coined by Diane Vaugh in her book *The Challenger Launch Decision: Risky Technology, Culture and Deviance at NASA*. Then, its attention will be turned towards the future, specifically examining how the main economic, social and peer pressures that contribute to normalized deviance can be minimized.

The Challenger Disaster

The Challenger Disaster refers to the 10th flight of NASA's Challenger Space Shuttle. On January 28th, 1986, just seconds into the flight, the world saw puffs of black smoke appear around the solid rocket boosters. Less than a minute later, the first flames appeared around the boosters. These flames quickly grew in size until finally the flames reached the liquid fuel tanks resulting in the shuttle being engulfed in a massive hydrogen-fueled fireball.[1] This disaster was captured on live television and is still considered one of the worst space-related disasters in U.S. history, along with Apollo 1 in 1967 and Columbia in 2003.

After this tragedy, a Presidential Commission was formed to investigate what exactly went wrong during Challenger's takeoff. After significant investigation, William Rogers, the head of the commission, concluded that the primary cause of the "loss of the Space Shuttle Challenger was caused by a failure in the joint between the two lower segments of the right Solid Rocket Booster".[2] Conventionally, these joints between segments of the solid rocket boosters are known as O-rings.

While the Challenger commission determined that the cause of the explosion was the faulty design of the O-rings, it did leave some question as to *who* was responsible for the disaster. Many of the top-level NASA administrators were cleared of guilt, as there was no indication that they had any knowledge of the design.[3] However, many of the middle-level managers did know about the faulty components. Bob Ebeling, an engineer at NASA contractor Morton Thiokol, had reportedly tried to stop the launch by calling NASA and explaining that there was a serious flaw in the shuttle's design, and that if the issue were not addressed, disaster could strike. Despite this Ebeleing and other engineers' warnings, their managers at NASA decided to push forward with the launch anyways.[4]

This decision is where Vaughn's book comes into play. She examines the Challenger disaster through a different lens than simply what went wrong technologically, and instead tries to understand what drove the managers to ignore the warnings of their engineers below them. To

[1] Dunbar, B. (2016, January 19)
[2] Report of the Presidential Commission of the Space Shuttle Challenger Accident. (n.d.)
[3] Vaughn, D. (1996)
[4] Berkes, H. (2016, January 28)

properly address this phenomenon, Vaughn coined the term "normalized deviance." She states that this concept occurs when people or actors within an organization become insensitive to "deviant" behavior that it no longer feels wrong. However, this is not a concept that occurs instantly – it often takes years of negligence and insensitivity stacking up before an actual disaster strikes and the normalization of deviance can actually be seen.[5] This can come about from various social, economic and even peer pressures. Vaughn argues that normalized deviance is what was ultimately responsible for the Challenger Disaster. In the next section, this prospectus will take her frame of reference in the context of humanity's current plans for the future of space exploration and examine if normalized deviance is still present, and if so, how the various actors at play plan to combat it in order to prevent another challenger disaster.

Future of Space Travel

Today is an extremely exciting time in regards to space travel. SpaceX and Elon Musk have repeatedly shown the world that the idea of reusable rockets is not just some farfetched sci-fi fantasy but reality and will be the future of any and all missions to planets other than our own. In addition, the public's opinion of space is currently quite high. According to the Pew Research Center, 72% of Americans believe that U.S. needs to remain a global leader in space exploration. Additionally, 58% of people believe that human astronauts are essential to the future of the U.S. Space Program.[6] While there is not a large amount of public interest in actually sending humans to the Moon and Mars (around half of the population believes that these goals are "important but lower priorities"), this hasn't stopped either NASA or private space companies such as SpaceX or Blue Origin from pushing the envelope. Recently, NASA has announced their plans to put the first humans back on the moon in the 21st century with their Artemis program and have also announced their goal of having humans on Mars by 2030.[7]

NASA and private space companies may currently have positive public approval, but as we enter into this new age of space exploration, it is important that the past mistakes of space travel are addressed so that they are not repeated. Examining space travel through the various pressures that can lead to normalized deviance serves as an adequate method to try and prevent these mistakes.

Economic Pressures

First, we will inspect the immense economic pressures that come into play when dealing with space exploration. There is no way around it – space travel is incredibly expensive. Between 1960 and 1973, NASA is reported to have spent nearly $28 Billion to get men on the moon. Adjusted for inflation, today that is equivalent to almost $300 Billion.[8] It is worth noting that this was back during the space race, when all of the technology for space travel was in its infancy and the U.S. was competing with Russia for domination of space. However, a Los Angeles Times article from 1986 asserts that the Challenger disaster cost the U.S. $3.2 billion (without

[5] Vaughn, D. (1996)
[6] Johnson, C. (2019, July 17)
[7] Artemis. (n.d.)
[8] How much did the Apollo program cost? (2019)

inflation).[9] This immense loss of tax-payer money, coupled with the appalling loss of human life, resulted in outrage from society.

Economic pressure from society and investors is a major factor in the presence of normalized deviance. It was certainly present in the past with the Challenger disaster. In Vaughn's book, there are two controversial NASA decisions during the early stages of shuttle development. One of these decisions was NASA's certification of the solid rocket boosters as flightworthy, even though they violated three industry standards. According to Vaughn, "These actions were interpreted by analysts as evidence that NASA managers were engaged in deviance and rule violations early in the program, acting as amoral calculators who knowingly gave economic goals priority over safety even in the earliest phases of the program."[10]

However economic pressures are not simply a thing of the past. There will always be that looming threat that a project will be canceled if the benefits do not outweigh the costs. NASA receives their funding from Congress, and if they can't deliver what they promise, Congress can easily pull that money and divert it elsewhere. Just like with Challenger, if NASA engineers or managers fear that they won't be able to deliver results in a timely fashion, they might forgo safety checks and designs in order to live up to expectations.

SpaceX has seen this problem as well. Because it is a private company, instead of answering to the government, it answers to its investors. In the beginning, SpaceX experienced three massive launch failures for various technological reasons in the span of three years. Each failure after the last put even more financial pressure on the company and on Elon Musk to prove that they could successfully launch rockets before the company went bankrupt. Another part of the economic pressure the private space company experienced was later on in 2015. A rocket was launched carrying two payloads for NASA. Unfortunately, this rocket exploded mid-flight, allowing NASA to renegotiate future contracts with SpaceX for less money. Not only did SpaceX lose billions in the cost of the spacecraft, but they also lost future income from contracts, all of which could contribute to the rise of normalized deviance in the company.[11]

However, despite all of the setbacks, SpaceX was able to flourish and accomplish what for years had just been science fiction: they launched a rocket into space, and then landed it back on Earth. This feat is astonishing for a multitude of reasons. But we will focus on the economic benefits that have and will continue to arise from the accomplishment. Reusable rockets will exponentially decrease the cost of space travel in the future. Previously, NASA had to spend billions creating new rockets for every single mission they launched into space. But now, instead of billions, SpaceX spends millions[12], and while that still is a large amount of capital, in the future, SpaceX plans to have the cost of each flight down to even less than that.

This price reduction means a lot from the perspective of normalized deviance. If the price per launch continues to decrease, it could effectively eliminate the economic pressure contribution to

[9] Challenger Cost: $3.2 Billion. (1986, March 11)
[10] Vaughn, D. (1996)
[11] Anslow, L. (2016, September 2)
[12] Grush, L. (2018, May 9)

the normalization of deviance in space companies. NASA would no longer have to worry about risking billions every flight and could instead dedicate more time to creating science and data collecting instruments to send to space. Or they could devote much more time to the safety of the flights and astronauts. Without having to spend all of the time and money that they previously did on the rockets themselves, both NASA, and SpaceX for that matter, could devote a much larger percentage of their resources towards safety, thereby decreasing the effect or presence of normalized deviance within the companies.

Social Pressures

In addition to economic pressures, social pressures can play a large role in the presence of normalized deviance within companies. Take the Challenger Disaster for example. Not only did the explosion claim billions of tax payer dollars, but more importantly, it claimed all seven lives of the shuttle's crew.[13] As one would imagine, this loss of life resulted in a public outrage and it was unsure what would happen to the human space program. In hindsight, it is clear that the program did continue, but the social pressures exerted on space travel companies by society cannot be underestimated.

Increasing public scrutiny of space companies regarding astronaut safety is for the best. If NASA and SpaceX want to keep sending people into space and furthering space travel, the safety of their astronauts will be of utmost importance – if another disaster were to occur, the aforementioned positive public opinion of space and space exploration would plummet. Therefore, one further way to reduce normalized deviance would be to encourage the public to hold space companies accountable for their actions. If they vocalize their opinions and make it known that carelessness and poor work in the sake of saving money or time will not be tolerated, it will be clear that they need to deliver their best possible work. Obviously, this idea is much easier said than done. However, it still stands that the public holding space companies accountable would be instrumental in reducing normalized deviance in those companies.

Peer Pressures

Finally, we consider the peer pressures involved in normalized deviance in space companies. And once again, to begin, consider Challenger. Vaughn (and others) believe that the higher ups at NASA are not entirely to blame for what happened in 1986.[14] Instead it was the middle managers who seem to be the most responsible for what happened. They were the ones who received reports from engineers beneath them that something might be wrong or compromised, and they made the decision to continue on with the launch despite this information.

In hindsight, it is easy to say that they were wrong and should have done the right thing. However, in reality, it is not that simple. Consider a middle manager at NASA during the challenger project. They are working in one of the most competitive and intense industries in the world and there is little to no room for mistakes. When the night of the launch comes around, and they receive the reports from the engineers below them, they have a decision to make. At this

[13] Vaughn, D. (1996)
[14] Vaughn, D. (1996)

point, the launch has already been pushed back days. It is also the tenth flight of the Challenger shuttle, meaning nine flights have preceded this one. Furthermore, their higher ups are likely feeling the brunt of the anger from Congress about them wasting tax payers' money and time due to the delays. So, they can either bring this to their higher ups and push the already delayed launch back even further and have congress' anger trickle down to them, or they can hide the information, cross their fingers, and proceed as normal. Clearly, they made the wrong decision. However, the pressure they felt from their peers must have been immense, and should not be ignored.

Though perhaps less obvious than economic or social pressures, peer pressure is a factor in normalized deviance that must be addressed, especially in the space industry. And there is no easy way to accomplish this. One way might be to encourage these space companies to create environments where it is encouraged for an underling to approach their superior and bring to their notice anything that might affect the launch or safety of astronauts instead of being punished for it. However, once again, this is much easier said than done. Peer pressure might be the hardest factor of normalized deviance to minimize. We can only hope that with the reduction of economic and social pressures that peer pressure would follow suit.

Conclusion

The U.S. and humanity have already decided to push forward with space travel. NASA has plans to send humans to the moon once again mission Artemis and SpaceX is revolutionizing space travel in general with their reusable rockets. However, normalized deviance is a problem not yet solved.

Following the advice of a peer, I conducted research investigating whether or not any specific SpaceX flight failures could be attributed to normalized deviance. After some time searching, I was unable to find anything that would indicate that that were true. However, I did come across a very interesting report that the Aerospace Safety Advisory Panel published, highlighting a potential concern regarding the fueling of SpaceX rockets. In particular, SpaceX uses super-chilled liquid oxygen immediately before launch to maximize the power potential of the rocket. However, the report states that this fueling technique with a manned vessel is "not adequately understood".[15] This serves as an example of modern-day normalized deviance, caused by the attitude of "nothing is more important than results".

Furthermore, this demonstrates that even in a company like SpaceX, who is taking steps to eliminate normalized deviance from within itself, it can still appear. However, in this case, as opposed to that of Challenger, adequate testing has resulted in this report being published *before* any disaster could occur, which indicates progress in the right direction.

It is important that we learn from our past mistakes in space travel. Normalized deviance can slowly root itself into the very culture of companies. And if they are not careful, this behavior can lead to disastrous results. To truly mitigate normalized deviance, the economic, social and peer pressures that all contribute to it must be routed and minimized. If this is accomplished, the

[15] Masunaga, S. (2017, January 13)

future of space travel can progress as planned, without disaster, and our species can become a spacefaring one.

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