A Virtue Ethics Analysis of the Events Leading to the *Challenger* Space Shuttle Disaster

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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

On January 26, 1986, the *Challenger* Space Shuttle accident became one of the most fatal incidents in space flight history. Seven crew members, one of whom was a teacher, were killed instantly after the explosion caused by failing solid rocket booster O-rings on the space shuttle (Mars 2021). There had been unusually cold weather at Kennedy Space Center that had already delayed the launch of the *Challenger* several times. Under political pressure to be on schedule with the launch, NASA management proceeded with the launch, despite the fact that the O-rings were insufficiently tested in cold temperatures. During liftoff, the O-rings became stiff due to the cold weather, causing them to seal improperly. This led to hot gas leaking from the side of the booster and burning through the external fuel tank. Within seconds, the space shuttle exploded ("Engineering Ethics: The Space Shuttle Challenger Disaster"). Although the immediate cause of the space shuttle explosion was due to the technical failure in the O-rings, thorough investigation revealed that there were also managerial and communication issues that arose in the events leading to the launch of the *Challenger*. The disaster ultimately changed the way management decision making was done in the aerospace industry.

The *Challenger* incident is one of the most studied cases of all time, mainly because it serves as a reminder of how one error caused by at least one individual can cause an impact on an entire society. There is moral responsibility to each individual's actions. Most of the arguments at the time focused blame on management and the companies working on the space shuttle as a whole, rather than on the individual engineers in charge of the O-ring designs. By assessing the reasoning behind the engineers' decision making and the role of public pressure on the engineers, my analysis offers a new perspective on the moral responsibility on the engineers who were working on the mission.

I will examine the *Challenger* case study using virtue ethics, which is a specific ethical framework that investigates the morals behind an individual's decision making. I will reveal how the engineers' actions were morally irresponsible due to the lack of character traits needed to become a moral professional engineer, which includes expertise and professionalism, clear and informative communication, and willingness to make compromises. Without having these necessary traits, there were flaws in the engineers' decision making, leading to one of the most disastrous events in space flight history. The character of the moral actor determines how their actions are carried out. An investigation report on the *Challenger* mission was carried out by Congress in 1986 and I will be primarily using the information from this resource to support my analysis.

Literature Review

Over the last 35 years since the incident, there have been various scholarly sources that analyze the causes of the O-ring failures. These sources often focus on the management within the technological companies responsible for the O-rings. Due to the fact that there was a design flaw causing the explosion of the space shuttle, it is clear that there was insufficient testing done by the individuals in charge of the development of the technology. Although the following scholarly sources analyze the judgement and decision-making processes of management and corporations, they neglect assessing the morality of the engineers involved with the development of the O-rings.

In *Autonomy, Interdependence, and Social Control: NASA and the Space Shuttle*, Diane Vaughan explains how organizational patterns within NASA and its contractor companies were overlooked. Vaughan describes how this goes on to cause companies to fail to identify problems before an accident occurs. She uses concepts of autonomy and interdependence to analyze the social controls and safety regulatory enforcements at NASA and its contractor companies. She then determines that changing these management procedures and the technical design would have prevented the *Challenger* tragedy (Vaughan 1990). Although Vaughan provides an excellent observation about management patterns within NASA and its contractor companies, she fails to analyze individual engineers who were in charge of the technical design process.

Similarly, in *Organizational Behavior and Disaster: A Study of Conflict at NASA*, Timothy Bond, Robert Dimitroff, and Lu Ann Schmidt describe how groupthink behavior and bulletproof attitudes among NASA officials were the direct causes of the *Challenger* accident. They then proceed to explain how small flight risks became tolerated by management; as a result, safety was compromised to satisfy schedule and budget constraints. They also focus on the conflicts and pressures that led to the disorganization of management (Dimitroff et al. 2005). While Bond, Dimitroff, and Schmidt cover the risks and responsibilities of management and NASA officials, they fail to cover the risks and responsibilities of the engineers who worked directly with the booster designs.

Even though both journal articles emphasize the importance of the moral responsibilities of management, they do not cover the moral responsibilities of the individuals who worked on designing the technology for the space shuttle. As a result, a full analysis of the *Challenger* accident has not been performed since there are important actors in the mission that are neglected within those studies. In this paper, I will use virtue ethics to further investigate the morality of the actions of the engineers who worked on the mission for the *Challenger* mission.

Conceptual Framework

To structure my analysis of the engineers involved in the *Challenger* mission, I will use the ethical framework of virtue ethics. Virtue ethics is defined as an ethical theory that concentrates on the character of the moral actor. It focuses on excellent qualities and virtues of character that individuals should possess in order to behave morally and obtain a good life. Virtue ethics originated in ancient Greece and was first defined by Aristotle. He believed that the final goal of humankind is to strive for the highest good. It is up to the individual to bring himself or herself to become a good person. Aristotle envisions the good in terms of happiness and well-being; the path of well-being is the cultivation of virtue. Virtue is the middle path between two extremes. For example, courage is the middle path between cowardness and bravery (van de Poel & Royakkers, 2011).

According to the theory of virtue ethics, humans are rational by nature. Therefore, they should use reason in order to live morally or virtuously. However, different scenarios can call for performing different virtues. Individuals have to use reason to choose virtues for different circumstances. Although virtues such as responsibility and honesty are more general ones, there exists a set of virtues that are essential for engineers. Michael Pritchard has identified certain virtues that are necessary to possess as a morally responsible engineer. They are listed below (van de Poel & Royakkers, 2011):

- Expertise/professionalism
- Clear and informative communication
- Cooperation
- Willingness to make compromises
- Objectivity
- Being open to criticism

- Stamina
- Creativity
- Striving for quality
- Having an eye for detail
- Being in the habit of reporting on your work carefully

Although this list does not comprehensively discuss the implementation into engineering practice, it serves as a general guideline for quality and ethical integrity of an engineer's work. There may be instances when engineers may have to consider more virtues in their area of expertise depending on the nature of their work. As a result, it is ultimately up to the engineer to decide what additional virtues they might need to assess the morality of their actions. In this paper, I will use Pritchard's Virtues for Morally Responsible Engineers in order to determine whether engineers in the *Challenger* mission had behaved morally. I will use this list as a guideline to assess what traits engineers lacked in their work and why this led to errors contributed to the disaster.

Analysis

In engineering, engineers use virtue ethics to ensure that they are acting morally by cultivating professional dispositions of character and promoting the safety of the general public (Jordan 2006). In the NASA *Challenger* mission, engineers were expected to apply certain virtues in order to protect the safety of the public while maintaining the high standards of engineering practice. In this instance, the engineers failed to apply certain virtues articulated by Pritchard's Virtues for Morally Responsible Engineers. As a result, they risked the safety of the public and compromised the quality of their work. Using virtue ethics, I will highlight three main virtues that the engineers failed to implement in their decisions: expertise and professionalism, clear and informative information, and willingness to make compromises.

Expertise and Professionalism

One set of virtues the engineers failed to use in their work was expertise and professionalism. Expertise and professionalism are important for engineers to display while working on a project. Expertise is defined as the expert skill or knowledge of a professional within a particular field. Professionalism is defined as the concept of how engineers practice or conduct themselves in their work and society ("Engineering Professionalism"). In the National Society of Professional Engineers (NSPE) Code of Ethics for Engineers, it states that engineers should "perform services only in areas of their competence" ("Code of Ethics"). There were instances when engineers in the *Challenger* mission failed to use expertise and professionalism in their actions. Therefore, it is important to consider the technical background of the accident. As the figure below demonstrates, the space shuttle is made up of an orbiter (the 51-L orbiter and the *Challenger*), an external tank, and two solid rocket boosters.

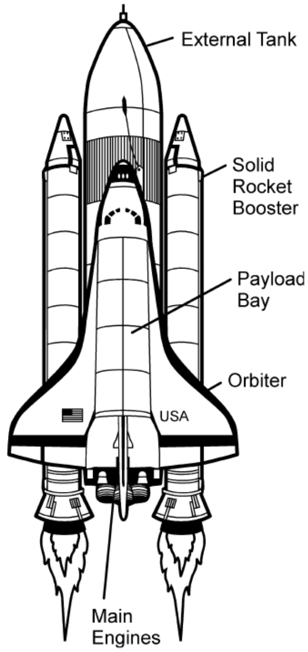

Figure 1: Diagram of the Space Shuttle

The rocket boosters work in parallel with the main engines for the first two minutes of launch, in order to create thrust to escape the gravitational force of the Earth. When the altitude of the shuttle reaches about 144,000 feet, the rocket boosters separate from the shuttle and descend to the Atlantic Ocean, where they are recovered. Sealing the boosters is a device called an O-ring. Early testing data suggested that the O-rings could fail in cold temperature. On the morning of the *Challenger* launch there were considerably low temperatures. The heat gained by the joint was not sufficient enough to raise the temperature of the material on the O-rings so that it would seal the joint. As a result, a hot gas leak occurred in the O-rings and broke the O-rings, leading to the explosion of the *Challenger* (Committee on Science and Technology 1986).

According to the Congressional report on the investigation of the *Challenger* accident, it was found that there had been a decrease in staff in various departments, such as quality assurance and flight. As a result, there were individuals who held positions that they were not qualified for due to the lack of expertise they had in the field they were working in. For several years at NASA and Thiokol, the engineering contractor company that NASA used, there were poor technical decisions that permitted an unsafe solid rocket booster design. For example, the engineers issued a performance specification that did not consider cold weather conditions. Additionally, there was a new joint design that was not tested prior to use in the *Challenger*. The engineers also failed to take recommendations from John Miller, who was Chief of the Solid Motor Branch (Committee on Science and Technology 1986).

Due to the lack of expertise some of the workers had in specific fields, they were not fully qualified to hold the positions they were in. As a result, the lack of expertise caused the engineers to make technical decisions that led to the failed design of the O-rings. This is considered to be morally irresponsible according to virtue ethics because they did not have the certification to make certain decisions relating to the technical design of the rocket boosters. The engineers also failed to conduct performance specifications and research, which posed a major problem for the mission. Had the engineers had performed additional research and tests on the new designs and weather conditions, that would have certified their knowledge and work on the technical designs for the solid rocket boosters. It would have also prevented a technical design failure in the actual mission if an error was detected in the tests beforehand. The engineers overlooked this aspect, which shows that they neglected to address their limits on their knowledge. According to the Institute of Electrical and Electronics Engineers (IEEE), engineers are supposed to continue their renewal of knowledge with professionalism (“Engineering Professionalism”). Since they did not consider the new recommendations from Miller, they failed to execute that aspect of professionalism and neglected to address their limits on their knowledge over the technical design. This can be deemed immoral because they failed to take new developments and plans into consideration, which could have prevented technical errors in the process. These events show how the engineers lacked virtues of expertise and professionalism in their work.

Some may argue that the disorganization of NASA and Thiokol management led to the engineers' poor assessment and technical decision making with the technology. In the article by Bond, Schmidt, and Dimitroff, they explain how psychological tendencies of groupthink caused NASA management to tolerate more amounts of acceptable risks (Dimitroff et al. 2005). Although this view assesses NASA's management style, it fails to assess the engineers working directly with the technology. It was found through Dr. Feynman and Congress that there was a shift towards decreasing safety in the Space Shuttle Main Engine (SSME) program and that there was not a sufficient understanding of the blade cracks and fractures on the SSME (Committee on Science and Technology 1986). This reveals that the engineers working on this part of the mission failed to show moral responsibility by not acknowledging the decrease in safety in this department and their limits on some subjects. If they were to recognize these problems early on, technical problems could have been identified earlier and they could have prevented these problems from persisting throughout the mission.

Clear and Informative Communication

Clear and informative communication is also a vital virtue to have as an engineer. The NSPE Code of Ethics for Engineers states that engineers should "issue public statements only in an objective and truthful manner, act for each employer or client as faithful agents or trustees, and avoid deceptive acts" ("Code of Ethics"). Engineers can accomplish this by communicating clearly and informatively with other individuals in their area of expertise and their supervisors.

Based on the *Challenger* report conducted by Congress, there were many instances when the engineers failed to communicate clearly with management.

The Congressional report shows that there were many opportunities to raise problems if needed. NASA claimed that special meetings and teleconferences were scheduled at set times. At these meetings, statuses regarding the mission, pressing problems, and program specifications were discussed (Committee on Science and Technology 1986). Large amounts of information were also communicated on a regular basis with no emphasis on important discussion points to management. In a recent review with Bob Ebeling, one of the engineers who worked on the technical design for the solid rocket boosters, he mentioned that the data the engineers presented were not argued well enough (Berkes 2016). Furthermore, NASA managers assigned responsibility for making technical decisions to lower-level managers and assistants, including the engineers. In addition, there was evidence of miscommunication of top-level decision makers and the engineers. The top-level decision makers explained how the messages they received were completely different from what the lower-level managers and assistants intended to communicate (Committee on Science and Technology 1986).

Based on information received from NASA and Thiokol management, it appears that communication by the engineers was not conveyed clearly or properly to their supervisors. Since there were regularly scheduled meetings to discuss urgent issues, the engineers had multiple opportunities to raise important issues regarding the technical designs of the solid rocket boosters. According to virtue ethics, the engineers acted morally irresponsibly because they did not bring up the problems until the last minute. Since communication was presented in large amounts and not argued well, it was difficult for the supervisors to determine which points were crucial to the mission. Due to the lack of coherent and concise information, the engineers failed to communicate clearly with their management. They held a significant moral responsibility to communicate clearly with their supervisors so that technical problems could be addressed in a timely manner. The engineers had an important responsibility to make technical decisions and inform the upper-level management of these decisions. People in management claimed that they received information that was completely different from what the engineers attempted to communicate. Based on the Congressional investigation, it appears that communication problems arose from the lack of clear information from the engineers. It can be argued that the engineers did not fulfill their virtue ethics with communication, resulting in immoral actions in their work. In terms of virtue ethics, the engineers did not fulfill their duty to communicate clearly and informatively.

Some might think that the incompetence behind the management structure at NASA led to poor communication between the engineers and their supervisors. In Vaughan's article, she argues that the engineers knew about the problems with the solid rocket booster joints but NASA administrators failed to acknowledge that they were hazardous to mission safety and pushed to launch early (Vaughan 1990). However, it should be noted that the engineers have direct access to the technologies since they are the ones working with them rather than management. Even though the engineers claimed that they were coerced by management to proceed with the launch, they presented evidence in a briefing on August 19th that indicated that it was safe to fly the shuttle as long as the joints were leak checked at a stabilization pressure of 200 psi. (Committee on Science and Technology 1986). Upon closer investigation, it is up to the engineer's responsibility to conduct safety tests and note of any errors during the testing. The management only followed protocol based on the evidence and analysis they received. Since the engineers did not mention any large concerns at this briefing, the management assumed it was safe to proceed with these joints. As a result, the engineers failed to display professional behavior when they failed to conduct further testing on the O-rings at different stabilization pressures and clearly communicate any errors they found in their testing that could have halted the launch.

Willingness to Make Compromises

The willingness to make compromises is a significant virtue to possess. There may be situations where engineers have to sacrifice one aspect of their project in order to save another aspect. According to the NSPE Code of Ethics for Engineers, the first and most important fundamental canon engineers must abide by "hold paramount the safety, health, and welfare of the public" ("Code of Ethics"). This means that the safety, health, and welfare of the public must come first before any other aspect of an engineering project. In the *Challenger* mission, the engineers failed to prioritize the safety of the crew by moving forward with the mission despite knowing about cold temperatures and the poor technical design of the rocket boosters.

In the interview with Ebeling, he mentions that he was afraid to come forward to take responsibility of the disaster because it meant risking losing his job (Berkes 2016). (Insert quotation) Further, according to the Congressional report, there was no risk assessment team due to budget and time constraints at NASA and Thiokol. Additionally, NASA and Thiokol employees felt public and political pressure to prove that they knew that they were doing. They also wanted to prove that their objectives could be accomplished within a specific timeframe (Committee on Science and Technology 1986).

Since engineers like Ebeling felt hesitant to take responsibility over the errors in the mission in fear of losing their jobs, this suggests that they were morally compromised. They refused to prioritize the safety of the public in order to protect their reputation of their job, in which public safety is the most important factor. Furthermore, since there was no risk assessment team, technical errors compromised the design and ultimately contributed to the accident. This can be considered immoral because it meant risking the general public's health and safety. Although there was pressure from the public to execute the launch on time, it was morally irresponsible for the engineers to prioritize a time constraint set by the public over the safety of the crew. Based on the NSPE Code, protecting public safety should have been the top priority in their work. It can be claimed that the engineers failed to use morality in their actions throughout their work for the *Challenger* mission by refusing to acknowledge risk assessment and protect the public's safety.

Based on the theory of virtue ethics, the engineers at NASA and Thiokol failed to apply important virtues that are stated in the Virtues for Morally Responsible Engineers, leading them to morally reckless behavior. Specifically, they failed to use expertise and professionalism, clear and informative communication, and willingness to make compromises to serve the public good in their work. According to Pritchard, meaning safety of the crew. Many workers were placed in positions they had little background knowledge in, or they did not conduct enough research tests to make sure the O-rings worked properly in cold weather conditions. There were also many opportunities to bring up urgent issues in administrative meetings and different ways to convey an idea clearly to their managers. Additionally, the workers' reputation and budget and time constraints were valued more than the public health and safety, which should have been the top priority in their work. Their actions would eventually cause them to lead to the technical failure of the O-ring and the *Challenger* accident.

It could be argued that political pressure and economic constraints within NASA management led to NASA and the engineers to sacrifice public safety. In her article, Vaughan mentions that incentives for NASA's contracting companies are designed to minimize costs and meet scheduled times rather than meet operational safety. NASA also had to demonstrate a Shuttle flight rate to 24 per year to reduce the costs for a flight and to demonstrate a routine access to space (Vaughan 1990). Although this view considers the economic and political pressures on NASA management, it fails to consider what could have been compromised if technical problems were brought up by the engineers early on in the mission design. The Congressional report states that there was never a formal risk assessment or statistical data presented on the performance of the components related to sound engineering judgment conducted throughout the mission (Committee on Science and Technology 1986). This shows that the engineers working on the technical aspects on the mission had opportunities to assess the risks behind their work and determine if these risks could impact the safety of the mission. As a result, a lack of a formal risk assessment and statistical data shows that the engineers failed to display professional moral behavior in their work because they failed to make compromises with the safety of the crew in the mission.

Conclusion

In this paper, I have used the ethical framework of virtue ethics to show that the engineers working on the *Challenger* space shuttle mission failed to demonstrate character traits/qualities in their judgement and decision making. Using virtue ethics, I argued that the engineers failed to demonstrate key professional virtues, such as expertise and professionalism, clear and informative communication, and willingness to make compromises. As a result, they performed unethical actions in their work on the *Challenger* that resulted in one of the most devasting events in space flight history. My analysis underscores not only the managers and supervisors that failed to act morally, but also the engineers. The *Challenger* disaster highlights how important it is for engineers to strive to use their profession in ways that will allow them to prioritize the welfare of the public while promoting the industry. It is urgent that engineers not only prioritize their technical work, but also their responsibility of protecting society.

Word Count: 3981

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