Complacency around Failure in the US Space Program

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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

In our modern society, most people have nearly constant interactions with technologies that they cannot begin to understand from an engineering perspective. Whether it is the complex inner-workings of smart phones, vehicles, or even the buildings people work in, most people take the technologies around them for granted. And let us face it: if everything is working as it is supposed to, why should the majority of the population care about the minor technical details involved? It is usually only when people see something fail that they begin to pay attention to the potential issues that they had overlooked in the past and simply accepted as part of life. This sense of complacency can lead to normalization of deviance from professional organizations entrusted with engineering solutions. In time, this deviance allows preventable problems to pop up, some of which can be extremely expensive and even deadly (Vandermey, 2021). The problem is primarily propagated because instead of acting as a watchdog over institutions and small groups of people in charge of organizations, the public takes a back seat and allows these groups to have far more power and decision-making responsibility than they might deserve without the oversight that they need. While the public may not be informed enough to comment on technical aspects of engineering efforts, they can affect engineering oversight and sentiment that factor into the engineering process. Bringing the general population into the process of more consistently holding leaders and organizations accountable, as opposed to only doing so once there have already been problems, can help reduce the laxity found in many engineering efforts (Knutson, 2016).

One large example of this pattern of complacency and success being taken for granted is in a massive engineering effort that has been underway for decades: the US space program. Ever since 1955 at the start of the Cold War Space Race, the US government has had a large vested interest in space exploration - with an emphasis on manned spaceflight (Davis, 2021). Due to quick technological advances in the aerospace industry and an impressive pattern of successful spaceflight endeavors, the US quickly became a world leader in manned space travel. However, with this came an aura of extreme arrogance in the US space program and the propagation of preventable mistakes. In this paper, I will be investigating several “disasters” throughout the history of the US space program and the role that non-technical factors played in their occurrences. In order to complete this investigation, I will be examining how the various non-technical factors surrounding the well-known technical ones involved in the US space program can lead to expensive and deadly mission failures when they are mixed together.

To accomplish this, I will be making connections between failures and often-overlooked non-technical factors in the US space program. I will start by analyzing the engineering failures, and then trace these problems back to any management or organizational decisions that may have helped lead to them. Then, I will examine how the failures were perceived at the times they occurred in order to get an understanding of the public, engineering, and management perspectives for what went wrong in the moment. After this, I will explore what the actual

underlying causes of the failures were determined to be after extensive reviews, hearings, and investigative inspections in order to determine which groups or tactics are currently believed to have been at fault. With these three analyses I will look for trends in what the public's perception of the root causes of the problems were over time, what non-technical factors each failure had in common, and what solutions were designed each time in order to prevent these failures from occurring again.

Background

There are many organizational, political, and social factors involved in the space mission process, and not fully addressing them can lead to as many issues. Many people believe that the toughest and most perilous parts of the space mission process are the engineering and technical ones. While these are obviously very complex and can take decades to advance, they are also checked over numerous times and often have several backup systems in place in order to make sure that the mission can succeed. For the non-technical factors that are involved, they are often overlooked or taken for granted, especially in the eyes of less-informed groups like the general public.

One example of a non-technical factor that has led to space mission failure in the past is NASA management not heeding the warnings of experts regarding launch-day conditions (The Editors of Encyclopaedia Britannica, 2021). These issues may seem small and may still result in success most of the time, but the overconfidence in technology and engineering can lead to years of work, billions of dollars, and human lives all being lost. Another example of a non-technical factor that has led to space mission failure is US media's portrayal of the US space program as being an infallible project that will succeed no matter the circumstances due to outstanding engineering work (Moskowitz, 2012). While this does not directly affect any one mission, leading the US public to believe that missions are infallible has a trickle-down effect. The citizens pass this belief through their elected officials who then pass it into oversight committees and NASA management, and once this belief is held by people in positions of power it is much easier for small mistakes to be overlooked that could lead to complete mission failure (Howell and Dobrijevic, 2021). Confidence in NASA's space program and the belief that the people working there are the best and brightest in their field may have some truth to it, but it also leads to the erosion of backup systems put in place. Organizations such as NASA can sometimes be thought so technically advanced that it would be hard for ordinary governing bodies to understand their work well enough for proper external oversight. However, there are still many technical and non-technical aspects of what NASA and similar organizations do that need to be kept in check through external oversight, even if people may not fully understand the technical aspects involved.

When organizations like NASA have less oversight from external organizations such as Congress and the executive branch, they often lose valuable insight and responsibility that leads to preventable accidents. In the next sections, I will go over three of the deadliest incidents in the history of the US space program, each of which had a large effect on the supervision for and public opinion of the program: The Apollo 1 fire, The Challenger disaster, and the Columbia disaster.

Apollo 1 Disaster

The Apollo 1 command module fire was an issue that came about in 1967 during a launch rehearsal test on the ground. During the incident, 3 astronauts were in the command module which was also being used to test the use of pure oxygen within space capsule cabins (Williams, 2018). Although the module had been designed to prevent any sparks from being created by any of the internal equipment, damaged wiring created a spark that quickly turned into a large-scale fire in the oxygen-rich environment filled with flammable materials such as nylon and foam (Williams, 2018). Within seconds, the interior of the cabin became engulfed in flames, along with the astronauts inside. The hatch that they could potentially use to escape had been designed to open inward into the cabin in order to keep the astronauts and oxygen securely in the cabin. However, this also meant that when the flames began spreading and causing the pressure inside the cabin to rise quickly, it became impossible for the hatch to open (Williams, 2018). Within seconds, all three astronauts were burned to death and the US space program's plans for manned spaceflight were delayed for months in order to search for the causes of the disaster and design solutions (Moskowitz, 2012).

Following the disaster, the first US space program incident to involve the loss of human life, it became apparent that the program was not infallible - it was going to take more than just engineering feats in order to ensure safe space travel. When looking back at the incident, many people involved stated that they simply did not consider the test to be a dangerous one (Teitel, 2012). However, there had been four oxygen fires within US government testing in the five years preceding the Apollo 1 incident, one of which occurred when testing the Apollo Environmental Control System (Teitel, 2012). Multiple workers for the company contracted for the creation of the capsule, North American Aviation, came forward with concerns over both the potential for fire within the capsule and length of time it would take to open the hatch in case of an emergency (Beddingfield, 2022). However, all of the concerns were either brushed aside or ended in the employee being terminated, and at congressional hearings following the disaster the credibility of the employees was brought into question (Beddingfield, 2022). On top of the oxygen-rich environment, hatch design, and flammable materials, NASA was also lacking protocols for what to do in case of a fire during testing (Beddingfield, 2022). Even if there had been a good solution

for getting the astronauts out of the capsule before their deaths, it is likely that no one would have known to implement it until it was too late.

Frank Borman, who would go on to be an astronaut for Apollo 8, made the point that he was “confident in NASA and its engineers,” again highlighting the feeling of infallibility surrounding NASA at the time (Teitel, 2012). However, this was, in large part, a show put on for the American public. Behind the scenes of the testing and manufacturing for the Apollo 1 capsule are stories of terrible work environments, work ethics, and even astronauts quite concerned that they would be unsafe (Beddingfield, 2022). The shows of trust put on by the people involved with the program, as well as the fact that the incident made NASA capsule safety increase greatly over the following years, meant that the American public and much of the government still had a large amount of faith in the US space program.

Challenger Shuttle Disaster

The Challenger Space Shuttle disaster occurred in 1986 shortly after the shuttle took off from Cape Canaveral in Florida. The disaster resulted in an explosion engulfing most of the vehicle only 73 seconds after it lifted off, resulting in the death of all 7 astronauts onboard (The Editors of Encyclopaedia Britannica, 2021). The launch had been delayed for several days, and the night before the launch a cold wave swept across Florida. Despite warnings that certain components of the rockets were unlikely to respond well to the change in temperature, the launch was carried out (The Editors of Encyclopaedia Britannica, 2021). Upon later inspection, an O-ring seal that could not cope with the change in temperature allowed for an exhaust leak that deteriorated a booster over the first 59 seconds of the flight (The Editors of Encyclopaedia Britannica, 2021). After this, the leak expanded and a flame emerged from the hole it had created which in turn eroded one of three struts securing the booster to the main propellant tank. The vehicle explosion occurred when the strut fully gave out and the booster rammed into the main fuel tank, causing an enormous explosion (The Editors of Encyclopaedia Britannica, 2021). While all 7 seven astronauts likely did not die immediately from the result of the explosion, the capsule and other debris lacked oxygen at high altitudes and landed in the Atlantic ocean over the next hour at speeds in excess of 200 miles per hour, ensuring the fatalities of anyone who survived the initial explosion (The Editors of Encyclopaedia Britannica, 2021).

Even if this issue had been detected immediately during liftoff, there was no way to stop the boosters from firing and the backup high-speed shuttle detachment that could have allowed the shuttle to escape the explosion could not activate in the first 120 seconds of the launch (The Editors of Encyclopaedia Britannica, 2021). Before the Challenger disaster, NASA had never had any in-flight deaths, so people at the time had thought it so unlikely as to not consider it a possibility (Lucchesi, 2021). The Challenger explosion and the design of features and processes to make space shuttle launches safer meant that NASA did not send any astronauts into space for

another 2 years. The Challenger disaster is where the term “normalization of deviance” was coined, and it was because of the lack of in-flight failures that had occurred leading up to the incident (Vaughan, 1996). Normalization of deviance occurs as “acceptable” risks become more and more profound as deviance from correct behavior grows over time. The tolerance for deviations and small problems within the space program had increased over the years as nothing went wrong during flights, eventually paving the way for problems so large that even backup measures could not help. Initial opinions after the incident hinted at a turning point for how problems within the US space program were viewed the government and public – the first time that large numbers would have begun to think of the infallibility of NASA (Wilford, 1986). This does not mean that the public began to rethink whether NASA should be sending astronauts into space, but instead how the public perceived the space program as a whole.

The public still favored NASA missions continuing, but they began to realize that the people of NASA were not all infallible, and the space program along with the extraordinary technology it created were still created by people who were imperfect (Wilford, 1986). This was a starting point for the general public, as well as members of congress and government employees, to realize that they must place more emphasis on oversight of the space program. Following the disaster, president Reagan appointed a special commission in order to determine what went wrong during the launch and help develop solutions to prevent similar issues from occurring in the future (Lucchesi, 2021). In the hearings and reviews after the incident aimed at finding out the root cause of the problem, it became apparent that NASA was attempting to cover up the severity of negligence in its management’s decision making (Berkes, 2021). During one congressional hearing, a NASA official said that Thoikol, one of the engineering contractors on the project, had approved the launch. However, he did not mention the fact that Thoikol engineers had strongly opposed the launch, and only after intense pressure from company executives was NASA able to get them to sign off on the launch (Berkes, 2021). This could demonstrate that program management was unwilling to take the advice of trained engineers because they wanted to move the project forward instead of taking the time to be safe and cautious.

Columbia Shuttle Disaster

The Columbia Space Shuttle disaster occurred in 2003 when the shuttle disintegrated during reentry into the Earth’s atmosphere over Texas. At the time of the incident, the shuttle was traveling roughly 18 times the speed of sound, and at the time when the shuttle should have been setting down on its designated runway a local Texas news program was broadcasting footage of it disintegrating in the sky (Howell and Dobrijevic, 2021). All 7 astronauts on board the shuttle were killed as the shuttle lost cabin pressure and began to break up. The cause of the disaster was a piece of foam, with the intention of protecting the shuttle from the extreme

conditions of atmospheric reentry, that had fallen off and damaged one of the shuttle wings (Howell and Dobrijevic, 2021). From the ground, NASA noticed that the sensors on the left side of the craft began to go out as the shuttle was approaching the radio-blackout period of atmospheric reentry (Howell and Dobrijevic, 2021). Despite several attempts to get in touch with the astronauts on board the shuttle, no more contact was ever made with them. However, the cause of the incident had actually occurred 16 days earlier when the shuttle had launched into space (Howell and Dobrijevic, 2021). Merely 82 seconds into the launch, the piece of foam broke off and created a hole in the left wing's protective shell (Howell and Dobrijevic, 2021). Upon atmospheric reentry, the hole allowed for scorching atmospheric gasses to enter the shuttle and slowly destroy the shuttle.

Upon review of the incident, it was brought to light that pieces of foam often fell off of the shuttle during takeoff and were often ignored (Howell and Dobrijevic, 2021). NASA was immediately aware of the damage that may have been caused by the incident, and several NASA personnel pushed to have pictures taken of the damaged wing while it was in orbit in order to assess the issue's severity (Howell and Dobrijevic, 2021). The Department of Defense even offered use of orbital spy cameras in order to help assess the damage that had been done, but NASA officials declined the offer and continued with the mission without any further inspection (Howell and Dobrijevic, 2021). By declining an inspection of probable damage, NASA officials highlighted the infallible mindset that had been taken on within the program while jeopardizing mission and 7 lives. However, this time the public opinion again stayed with keeping NASA funded, and a majority of the US public still wanted space missions to remain manned (David, 2004). The public had even begun to accept that these things would happen if they were preventable with 70% saying that "something like this would happen again sooner or later," (David, 2004). This is an unsettling concept for many, especially in the face of lives being lost to negligence errors. It demonstrates how far public opinion had shifted since the Challenger disaster from one of an infallible NASA to one of space disasters being something that were just going to happen in the long run.

Upon first look at the incident, it does not seem that NASA could have done anything about the problem they had on hand. Even if they had taken images and found the hole in the thermal protection shielding of the space shuttle, or if they had informed the astronauts aboard about the potential problem, there is nothing that could have been done to repair the shuttle in orbit - the astronauts would have died either way (Sunseri, 2013). However, it was not until reviews of the disaster that it was fully uncovered that NASA had known about foam falling during liftoff for years (Sunseri, 2013). This had simply become a problem that NASA officials had come to accept as routine and unavoidable, never thinking ahead to the large problems that it could lead to. Following the incident, the Columbia Accident Investigation Board (CAIB) was created to determine root causes leading to the Columbia space shuttle disaster (Howell and Dobrijevic, 2021). The Board produced a "damning" assessment of culture at NASA and surrounding the space shuttle program, citing "cultural traits and organizational practices

detrimental to safety" being allowed to develop, as well as "reliance on past success as a substitute for sound engineering practices," (Howell and Dobrijevic, 2021). On top of these findings, the Board called for congressional action resulting in NASA receiving more predictable funding and support (Howell and Dobrijevic, 2021). This supports the idea that not only had the culture at NASA been slipping negatively, but also that congress had not been performing its necessary oversight duties (Howell and Dobrijevic, 2021). With the public, NASA, and congress each becoming lax in their roles for the space program, it became ineveitable that something was going to go wrong eventually. The Columbia disaster led directly to the retirement of the US Space Shuttle program following the release of these reports discussing cultural and technical problems within the program (Howell and Dobrijevic, 2021).

Discussion

Prior to the Apollo 1 disaster, the public thought of the space program as an enormous technological challenge that needed to be pushed through in order to stay ahead of the Soviet Union in the Cold War Space Race. This made the federal government push strongly for advancements in the program as it raced against the clock to get Americans to the moon by President Kennedy's deadline of the end of the 1960's. In turn, NASA and its contractors felt pressured to move the program forward at an advanced pace, allowing for preventable mistakes to crop up over time, including the Apollo 1 test disaster. Following the Apollo 1 fire that took the lives of three astronauts, the public was in shock. The tightly-knit group at NASA was essentially able to play the disaster off as an issue that no one would have seen coming. NASA management and engineers also used it as an opportunity to showcase how problems led to newer designs that greatly advanced the technology and safety features within the program. Aside from several regulatory hearings, the US space program continued on as planned and it seems that the public generally took the accident with a grain of salt. For a technological project as big and inherently dangerous as the space program, mistakes would eventually be made. However, the confidence exuded by NASA officials and engineers, as well as the idea that the disaster led to new technologies, helped the public to maintain faith in the program.

In the years following the Apollo 1 disaster, everything seemed to be going as smoothly as could be. There were no more deadly accidents, the US was doing well in the space race, and it seemed that NASA engineers and technology were infallible in their designs as the public breathed in the arrogance of the space program. However, NASA officials and engineers became arrogant as well and normalization of deviance began to appear. Where everything had needed to be perfect for a launch a decade earlier, unnecessary risks were being taken in order to meet launch schedules and advance the US foothold in space. After the Challenger Space Shuttle Explosion, the nation was stunned by how the infallible space program could have somehow messed up. The public was able to watch on television as their country's crown jewel of

technology burst into a fireball seconds after launch, prompting the question: how could it happen? Public shock and confusion went hand in hand with the inquisitive congressional hearings that followed the disaster, intent on discovering the root cause of the mishap. It quickly became clear that NASA and contractor leadership were attempting to cover up the disaster as being an unpreventable accident with fingers pointing in all directions. However, it also came out that many engineers had warned of the incident but had been ignored and overridden by management within the space program in order to stay on schedule. The obvious government and public disgust with these findings led to advisory commissions for NASA and the reinstallation of the idea that normalized deviance cannot be accepted on these scales. The public, and therefore the government, still wanted NASA to continue with its missions, but now everyone was aware of how fallible the system was and that the people of NASA were human - they made mistakes just like anyone else, so they needed to have oversight just like anyone else.

After the Challenger Space Shuttle disaster, one main thing started to change from the perspective of NASA; they now had stricter oversight, but the program essentially remained the same. While the shock of the Challenger had lit a small fire underneath the public and government, it had not made enough of an impact to trickle down fully into the organizational culture at NASA. The same patterns of normalization of deviation were springing up, and again nothing was changing because from an outside perspective the space program was coming along perfectly well. The Columbia Space Shuttle explosion shocked the nation once again, but this time in a different way. When oversight committees and the government in general were pushed into reviewing the situation in depth, they found mountains of evidence pointing towards organizational culture as being the cause of the disaster. NASA now seemed as fallible as ever, and the public was finally able to see that despite the astounding technological advances that had been made, it was still prone to the same issues found in any workplace. The public still favored NASA continuing with its missions, but the government and NASA oversight committees were now keenly aware that they needed to continually monitor the space program in order to make sure that normalization of deviance does not propagate again. Slightly different from the other disasters, polls demonstrated that the public had expected this type of disaster to happen again eventually. While this is likely due to the public perception of space travel being highly dangerous, it brings an unfortunate concept to light: not only had normalized deviance grown within the space program, but the public was tolerating disasters through a different form of normalized deviance within itself. The public was coming to accept that for one reason or another, the US space program was going to have mistakes from time to time - even if they are preventable.

Conclusion

The US space program is a complicated weave of technical and non-technical components that need to work together for success, but people often overlook the non-technical components due to the extremely sophisticated nature of the technical ones. By looking into massive turning points in the program, it is possible to see how these non-technical factors can rise to the surface of discussion and create enormous problems. The Apollo 1 training exercise fire, the Challenger Space Shuttle explosion, and the Columbia Space Shuttle disaster are all massive events in the US space program that led to changes in public perception, government oversight for the space program, and culture at NASA. In turn, the public, government, and NASA culture had varying responses to each issue that changed the program. Through these events, it is easy to notice several things: how the flow of action goes from the general public to the outcomes of government oversight and eventually NASA projects, how normalization of deviance sprung up within the space program allowing preventable disasters, and how the feelings of NASA infallibility and arrogance likely helped lead to deadly incidents.

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