Progress of the *Challenger* Case

Section 201 Green Team
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1 Introduction

Many engineers find effective communication difficult. Even the best communicators struggle with having the listener grasp the intended message. Not only does one have to work hard on crafting one's message, one must also consider how this message will be received by the audience. In the *Challenger* case, during the teleconference, breakdowns occurred at every stage in the communicative process. At the beginning of this process were the Morton Thiokol (or MTI) engineers who wanted to convince NASA to delay launch due to cold temperatures, and at the end were NASA managers who held the power to make the decision. At every stage in the process, these breakdowns—the engineers' failure to communicate potential problems to managers, the MTI managers' failure to listen to engineers, the inadequacy of teleconferencing, and the NASA managers' failure to understand safety concepts—resulted in a loss of signal in the flow of information from the MTI engineers to the NASA managers. This disrupted flow of information ensured that the engineers could not convince the NASA managers to delay the launch. After our analysis, we end with a description of how we constructed this report.

2 Preliminary Analysis

Contributing to the *Challenger* disaster is the disruption of the flow of information from the MTI engineers to the NASA managers. Figure 1 shows this process and the junctions at which breakdowns occurred. The concerns originated at the MTI engineers, who wanted to convince their managers and the managers at NASA of the problem. They did not effectively communicate their concerns to the MTI managers. The MTI managers, on the receiving end, did not completely listen to the engineers. At first, the managers did listen to the engineers, and together they tried to justify their recommendation over teleconference, which did not afford collaboration well. Had the engineers' message reached NASA perfectly, the NASA managers still would not have changed their minds due to their failure to understand basic safety concepts. Ultimately, due to this disrupted communicative process, MTI engineers could not convince the NASA managers to delay the launch.

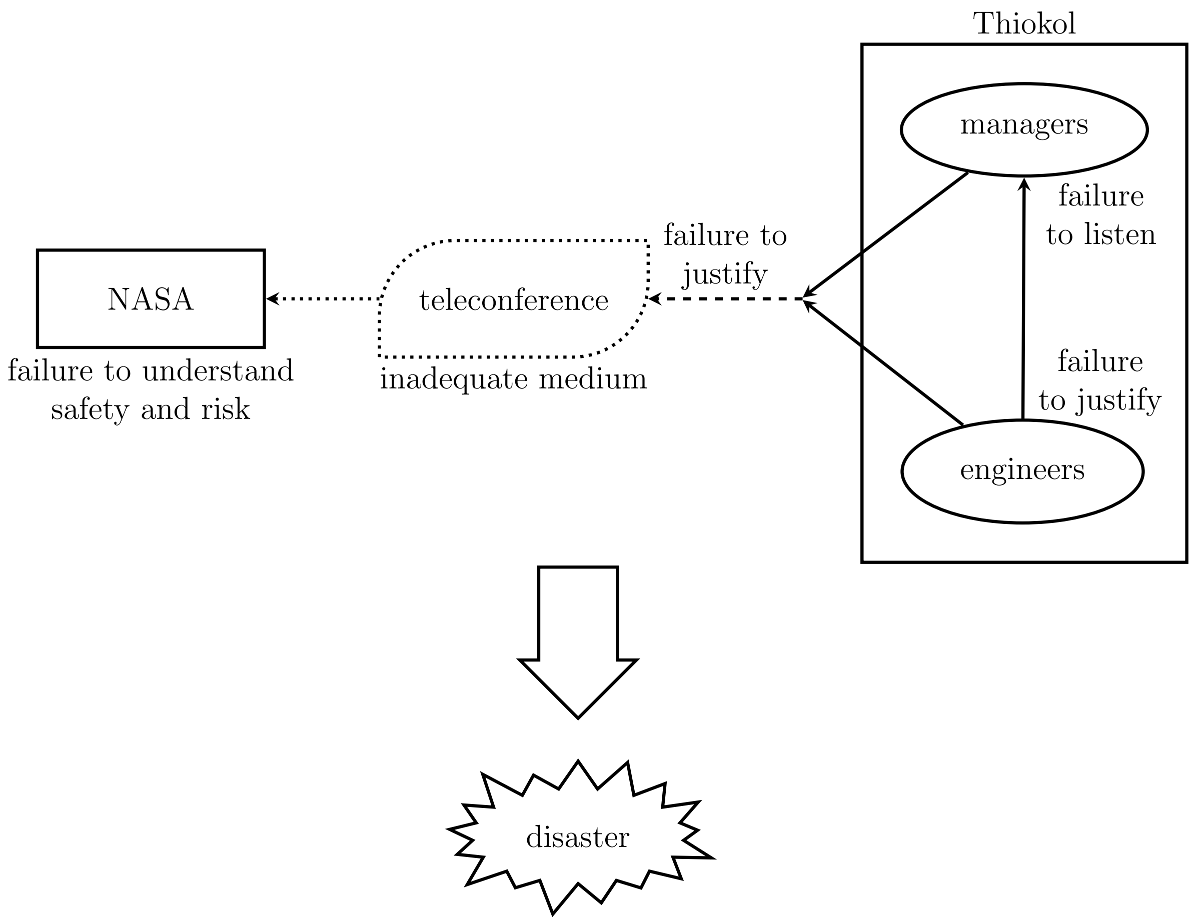

Figure 1: communication breakdowns during the teleconference

2.1 MTI Engineers' Failure to Communicate

At the origin of the concerns about launch conditions, the engineers at MTI did not properly communicate risk to managers at MTI and NASA when given the opportunity. One issue the engineers had was their lack of organization in preparing material, specifically for the first teleconference. During the first teleconference, the engineers were not fully prepared to discuss the details of their concerns for going through with the launch, and they did not even take an official stance on the issue (Vaughan 1996, 287). Ultimately, they needed more time to prepare evidence.

But despite this extra time the engineers had to prepare for a second teleconference, the material they gathered was presented in a manner such that the core issues in their data and analysis were not clear. A significant problem with their presentation was the lack of correlation between temperature and O-ring erosion. Although MTI had charts showing damage to O-rings, there was no visual showing a direct correlation between low temperature and erosion (Tufte 1997, 40). Instead of showing this correlation, MTI put focus on blow-by and mentioned that blow-by occurred under low temperatures. However, NASA read right through this claim during the teleconference and pointed out that blow-by also occurred at high temperatures, contradicting MTI's claim of a higher risk of launch at lower temperatures (Tufte 1997, 42). If instead MTI focused on the data of erosion, not blow-by, from past launches sorted by outside temperature, they may have had a more convincing argument. However, it is important to note that the erosion data does not directly show increased risk of a disaster, but rather a potential problem needing further investigation to see if something worse could happen if the outside temperatures were even lower. Even so, the engineers failed to highlight this potential problem, considering they had data showing a correlation between external temperature and erosion. As a consequence, their arguments were not entirely clear to the managers at MTI and NASA.

2.2 MTI Managers' Failure to Listen

At the receiving end of the engineers' concerns, the MTI managers did not listen carefully to the engineers' arguments. Even though problems with the O-rings were never perfectly clear, concerns with the design had been brought up as early as 1981 by engineers at MTI (Robinson 2002, 71). Engineers were worried about O-ring performance, but managers at NASA were comforted by the success of previous missions and the redundancy of the system. Looking back at the design of the SRBs and previous flights, managers at NASA formed a preconceived notion that O-rings couldn't possibly fail and placed a high burden of proof on the engineers at MTI. Instead of just casting enough doubt on the reliability of the seals at low temperatures, the engineers were almost expected to prove failure was inevitable. The managers still listened to what the engineers had to say, but convincing them to delay the launch due to safety concerns would have been an incredible feat.

During the second teleconference, Boisjoly explained that the rings would be harder and the grease would be more viscous, increasing the actuation time. Like the other engineers, Boisjoly was asked to quantify his concerns, but when he could not, he lost the attention of the managers and eventually stopped pleading his point when it was apparent no one was listening (Vaughan 1996, 318). MTI lacked a definite correlation between blow-by and temperature, but based on the advice of the engineers, initially concluded that any temperature below 53F would pose too great a risk (Vaughan 1996, 291). NASA managers, not wanting to delay the launch, saw the shortcomings of the argument and acted as if MTI was trying to establish a new launch criteria based upon incomplete data. Mason, like the other managers, believed that a management decision was necessary when the data could not resolve disagreements, so he began polling other managers (Vaughan 1996, 318). In the end, management made the decision to launch without ever having given the engineers a fair audience.

2.3 Inadequacy of Teleconferencing

Compounding the problem was the limited and outmoded medium of the teleconference. A teleconference, by its nature, only supports one type of information: audio. Audio is great for quickly conveying a large amount of words, but the message is not very precise. The message is prone to being disrupted by negative effects on the quality of the audio, such as noise, fragmented audio ("breaking up"), and just the general unfaithful reproduction of sound inherent in transmitting a large amount of information through a narrow band in real time. Coupled with the participants' unfamiliarity with everyone's voices, many people present could not identify, by voice, the speakers at the teleconference (Vaughan 1996, 300). If one doesn't even know who's talking, how can one correctly interpret the message?

Even worse is the lack of other types of information. At the top of this list is visual information, which is crucial to effective collaboration. A picture says a thousand words, but a video can say even more. Video helps people maintain situational awareness, that is, a mental model of the spatial elements, of the remote site, and conversational grounding, the interactive process through which conversation participants that they are referring to the same thing. The second teleconference in the *Challenger* case did not have a video feed. They had a poor substitute: fax. Fax is certainly an acceptable medium and conveys more information than pure audio, but it has high latency and therefore cannot be used in real-time. It cannot provide grounding; participants in the teleconference must rely on audio in order to point out facts on the charts, which becomes prone to error. This could not have helped with MTI's message.

With a lack of visual cues, visual information must travel through the audio channel, and certain cues, like body language or facial expression cannot be effectively transmitted through an audio channel. This can cause misinterpretation of the message: the listener may arrive at the completely opposite conclusion than the speaker intends. Indeed, during the second teleconference, Mulloy exclaimed, "My God, MTI, when do you want me to launch, next April?" (Vaughan 1996, 305). He was perceived to be forceful and stern, when he was simply remarking, as he later claimed, at the fact that MTI was creating a new Launch Commit Criterion on the eve of the launch (Vaughan 1996, 306). This can be explained by Joseph Walther's **hyperpersonal theory**, which states that in the absence of visual cues in an audio-only channel, the receiver forms more extreme attributions of the sender (Walther 1996).

Sometimes, even the audio channel was not present. During the caucus, the audio was on mute, while the managers and engineers at MTI debated about the problem (Vaughan 1996, 323). Thus, the other parties could not hear them, and they did not know that there were still disagreements at MTI. Had this been a face-to-face conference, any conflicts during a caucus would be obvious to other parties, as loud shouting cannot help but "leak" through the medium. In such a case, perhaps NASA would not have been so quick to accept MTI's reversed recommendation. More discussion could have carried out, and events might have unfolded differently.

2.4 NASA's Misunderstanding of Basic Safety Concepts

The quality of the engineers' data and the clarity of MTI's presentation of such information may not have mattered at all if the NASA officials did not understand basic risk management.

A good communication process in this case may not have prevented NASA from making the launch decision. Let's look at the scenario where MTI engineers were able to clearly present the data showing the risks of launching at low temperatures, where MTI managers listened to the arguments and strongly supported their engineers assessment, and where there was no hindrance from the medium of communication for the conference. Up to this point, the situation is ideal but NASA managers may still have disregarded MTI recommendation against the launch. This would have occurred simply because NASA faultily believed in the high reliability of their shuttle. NASA officials used faulty risk management techniques when assessing the risks of flight failures in two ways, a faulty method of determining safety factor and the assignment of impossibly small failure probabilities to flights and shuttle parts. Because of this, NASA consistently and dramatically underestimated risk and overestimated safety.

Comparing some NASA managers' definition of safety factor to what is universally understood as safety factor showed a flaw in their understanding of basic safety concepts. Safety factor is describes the capacity of a system beyond expected loads. It is defined as material strength, the ability to withstand force without damage, divided by design load, the maximum load that the system should ever expect to encounter. For example, there is a bridge that can hold a vehicle that weighs up to 50 tons without damage to the bridge's structure. Let's say the largest truck that would ever go over that bridge weighs 20 tons. The resulting factor of safety is the bridge's strength of 50 tons divided by the design load of 20 tons such that the factor is 2.5. This is not the method that the NASA managers used to find the safety factor of shuttle parts. For one of the earlier testing of the O-rings, the tests showed a third of the rings' radius being burned away. The managers stated the rings had a safety factor of 3 based on how much material was left in the ring (Rogers 1986, F1). This is clearly wrong. The O-rings being damaged at all meant that they had a safety factor of 0, not 3. This lack of understanding about the risks of the O-rings could have been a barrier at NASA in believing there would be any major problems for the O-rings regardless of temperature.

NASA's understanding of failure rates impeded their understanding of overall flight success. The probabilities of failure that NASA managers assigned to flights and shuttle parts simply were not feasible in comparison to the rates that MTI engineers calculated and to actual rocket failure rates. It's one thing to have a different methodology in assigning failure rates but it's a whole other problem when the probabilities have irreconcilable differences. Previous unmanned rockets flights revealed rockets failed at a rate of roughly 1 out 25 flights and engineers at MTI had assigned shuttle disaster probabilities at between 1 in 50 to 1 in 100 (Rogers 1986, F1). NASA claimed 1 in 100,000 (Rogers 1986, F1). NASA's number meant that the shuttle program could launch a shuttle every day for centuries without an accident. If the NASA managers truly believed in their flight success rates, then it would not have matter what MTI recommended since they believed the failure rate for shuttle was miniscule.

All combined, these four breakdowns in communication ensured that NASA did not appropriately consider the risk the O-rings posed under low temperature, leading to the ultimate poor decision to launch that resulted in huge losses for the shuttle program. This is a situation where a clear communication process could still fail.

3 Project Management

In this report, our group read various sources and became comfortable with certain technology to make sure the final version of a report was out as soon as possible. In assessing our effectiveness, we will briefly run through the sources used, the sources impact was on the report, the usage of technology to share information, the usage of technology to collaborate on assignments, how work was split up for the report, and the overall effectiveness of the team's performance in those areas.

Each of us read one or two sources, and contributed the notes from each source to the overall case study notes for the group. Jeremy read the first source, Rogers (1986), which highlights a lot of the technical details with the *Challenger* case. Jeremy's second source, Tufte (1997), summarized Tufte's claim, which stated that the MTI engineers could have done a better job at expressing data through their diagrams. The expression of data claim was contested by Jessica's article, Robinson (2002). In this source, the authors discuss how there was not enough data to show that low temperatures caused O-ring failures, and that the poorly designed diagrams are all to blame. Jack and Ian split the reading for the fourth source, Vaughan (1996), which gave a detailed timeline of the events that happened the evening prior to the launch, and nothing else. They functioned as our "*Challenger* disaster experts", and could confirm or deny an occurrence ever happening during the timespan of the teleconference and crash. Karan read the last two sources, both written by Winsor. The first, Winsor (1988), talked about how bad news failed to move up from the engineers to management, and this lack of communication played a role in the erroneous decision to launch. Winsor (1990), however, reflects Winsor's rejection of her assumptions made in the previous source. She tries to define knowledge, and the "passing of information", to be able to have the reader ask more intelligent questions about why the *Challenger* exploded. These two sources contributed the least to the progress report, and none of the claims stem from these theoretical articles.

After each group member read his own source on his own time, the team congregated and made certain decisions using Facebook. In sharing information, we used a Facebook group because it allowed every team member to start a thread which could be responded to. The group displayed who all has read the thread, so we would know who to contact individually by phone if something essential needed to be communicated. Also, Facebook is an application that we all already use day-to-day, so none of us were really going out of our way to check the group; the messages came to us. We used the group to talk about concerns we had in our work, meeting times, and even posted agendas for a meetings the day before we had them. Facebook brought us to meet twice a week, but didn't contribute much to the content of our submissions.

For collaboration, we used Google Drive. The drive is an online personal cloud space that is great for sharing common documents and other files. The best feature was the integration of Google Docs. What we did for the report was individually draft our own paragraphs in the same Google Doc, delineated by a section that had our name and our claim. After individually drafting, we would meet, merge the sections, and as a group revise the entire thing. It worked effectively, because none of us stepped over each other's toes, and when we were together, we could see the changes being made in real time.

More specifically for the progress report, Jack, Jessica, Jeremy, and Ian were each responsible for writing the body paragraphs of one out of the four claims. Karan, whose articles were the least pertinent to any of the claims, took charge in writing the project management section in its entirety. Together, we all met to edit the merged copy of everyone's individual claim paragraphs.

Overall, our use of technology to share and collaborate has been very effective. We have learned from our past failures, and now have an effective formula for accomplishing tasks. We meet as much as possible, usually in the evening, and try to get things done early so that we always have a class to meet with Sharon. These meetings help us confirm that we are on the right track, and that we followed all of the directions given to us. From now on, we need to be able to become more flexible in our meeting times. If someone is not able to meet, we should be able to go on without her, and fill her in on what she missed. Unforeseen absences may happen in the workplace, so we need to be able to adapt, and not lose time, especially when people's schedules are only going to continue to get more hectic.

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