



The Challenger Disaster

On the night of January 27, 1986, the pre-launch teleconference involving Morton Thiokol and the Marshall Space Center was filled with tension. Morton Thiokol engineers conveyed their recommendation against launching the *Challenger* space shuttle the next morning. This recommendation was based on their worries about the ability of the O-rings to seal at low temperatures.

Chief O-ring engineer Roger Boisjoly knew the problems with the O-rings all too well. More than a year earlier he had warned his colleagues of potentially serious problems. The O-rings were part of the sealing mechanism between the segments of the booster rockets. If they lost too much of their resiliency, they could fail to seal altogether. The result would be the escape of hot gases, ignition of the fuel in the storage tanks, and a fatal explosion.

The technical evidence was incomplete but ominous: there appeared to be a correlation between temperature and resiliency. Although there was some leaking around the seal even at relatively high temperatures, the worst leakage was at 53 degrees. With a predicted ambient temperature of 26 degrees at launch, the O-rings were estimated to be at 29 degrees. This was much lower than the launch temperatures of any previous flight.

The teleconference was temporarily suspended. The Space Center had questioned Morton Thiokol's no-launch recommendation, and Morton Thiokol had requested the suspension to allow their engineers and management time to reassess their recommendation. The Space Center would not fly without approval from Morton Thiokol, and Morton Thiokol management would not recommend launching without approval from their managers.

Jerald Mason, senior vice president at Morton Thiokol, knew that NASA badly needed a successful flight. He also knew that Morton Thiokol needed a new contract with NASA, and a recommendation against launch was probably not perceived as enhancing the prospects of obtaining the contract. Finally, Mason was aware that the engineering data were inconclusive. The engineers could not give any firm figures as to the precise temperature at which it would be unsafe to fly. They were relying on the apparent correlation between temperature and resiliency and their tendency to be conservative on serious safety O-ring issues.

The teleconference with the Space Center would resume shortly and a decision had to be made. Turning to Robert Lund, the supervising engineer, Mason directed him to "take off your engineering hat and put on your management hat."² The earlier no-launch recommendation was reversed.

Roger Boisjoly was deeply upset by this reversal of the engineers' recommendation. As a human being, he no doubt felt concern for the well-being of the astronauts. He did not want to be a part of something that could lead to death and destruction. But, Boisjoly was not just a concerned citizen—he *was an engineer*. It was his *professional* engineering judgment that the O-rings were not trustworthy. He also had a *professional* obligation to protect the health and safety of the public, and he evidently believed that this obligation extended to the astronauts. Now his *professional* judgment was being overridden.

Boisjoly also did not believe it was appropriate to take off one's engineering hat in such circumstances. His engineering hat was a source of pride, and it also carried with it certain obligations. He believed that *as an engineer* he had an obligation to render his best technical judgment and to protect the safety of the public, including the astronauts. So he made one last attempt to protest the decision to reverse the no-launch recommendation, pointing out the low-temperature problems to Thiokol management. He frantically attempted to persuade management to stick to the original no-launch recommendation, but his protests were not heeded. Thiokol managers reversed the original no-launch decision.

The next day, just 73 seconds into the launch, the *Challenger* exploded, taking the lives of the six astronauts and schoolteacher Christa McAuliffe. In addition to the tragic loss of human life, the disaster destroyed millions of dollars' worth of equipment and severely tarnished NASA's reputation. Boisjoly had failed to prevent the disaster, but he had exercised his professional responsibilities as he saw them.³

The *Challenger* case is another controversial example of the conflicting prerogatives of engineers and managers. In a teleconference on the evening before the fateful launch, Robert Lund, vice president of engineering at Morton Thiokol and both an engineer and a manager, had recommended against launch, in concert with the other engineers. The recommendation was based on a judgment that the primary and secondary O-rings might not seal properly at the low temperatures at which the vehicle would be launched. NASA officials expressed dismay at the no-launch recommendation, and Thiokol executives requested an interruption in the teleconference to reassess their decision. During the 30-minute interruption, Jerald Mason, senior vice president of Morton Thiokol, turned to Lund and told him to take off his engineering hat and put on his management hat. Lund reversed his no-launch recommendation.

In admonishing Lund to take off his engineering hat and put on his management hat, Mason was saying that this should be a managerial decision. Testifying before the commission that investigated the *Challenger* accident, usually referred to as the "Rogers Commission," Mason gave two reasons for this belief. First, the engineers were not unanimous: "[W]ell, at this point it was clear to me we were not going to get a unanimous decision."²⁶ If engineers disagreed, there was presumably not a clear violation of the technical or ethical standards of engineers; and, thus, it could be argued that neither requirement of the PMD was being violated.

There are reasons to doubt the factual accuracy of Mason's claim, however. In his account of the events surrounding the *Challenger* disaster given at MIT in 1987, Roger Boisjoly reported that Mason asked if he was "the only one who wanted to fly."²⁷ This would suggest that he did not have evidence at this point that other engineers wanted to fly. Whatever validity Mason could give to his argument that some engineers supported the launch (and therefore that the opposition of the engineers to the launch was not unanimous) was apparently based on conversations with individual engineers after the teleconference. So Mason probably had little justification at the time of the teleconference for believing that the nonmanagement engineers were not unanimously opposed to the launch.

Nevertheless, Mason may be correct in maintaining that there was some difference of opinion among those most qualified to render judgment, even if this information was not confirmed until after the event. If engineers disagreed about the technical issues, the engineering considerations were perhaps not as compelling as they would have been if the engineers had been unanimous. Thus, the

first part of the PED criterion may not have been fully satisfied. Those who did not find a technical problem probably would not find an ethical problem either. So the second criterion of the PED may also not have been fully satisfied.

Mason's second reason was that no numbers could be assigned to the time required for the O-rings to seal at various temperatures:

Dr. Keel: Since Mr. Lund was your vice president of engineering and since he presented the charts and the recommendations not to launch outside of your experience base—that is, below a temperature of 53 degrees for the O-rings—in the previous 8:45 Eastern Standard Time teleconference, what did you have in mind when you asked him to take off his engineering hat and put on his management hat?

Mr. Mason: I had in mind the fact that we had identified that we could not quantify the movement of that, the time for movement of the primary [O-ring]. We didn't have the data to do that, and therefore it was going to take a judgment, rather than a precise engineering calculation, in order to conclude what we needed to conclude.²⁸

This might also be a reason for holding that the decision to launch did not violate (2) of the PMD, and that it did not clearly satisfy (1) of the PED. The fact that no calculations could be made to determine the time it would take the O-rings to seal at various temperatures does not necessarily justify the conclusion that a management decision should be made. Surely the fact that failure of the O-rings to seal could destroy the *Challenger* implies that the engineering considerations were of paramount importance, even if they could not be adequately quantified. The engineer's concern for safety is still relevant.

Again, however, Mason's comment may make a valid observation. Given that engineers generally prefer to make judgments on the basis of quantitative calculations, they may well have been uncomfortable with the fact that there were no precise numbers for the degree of degradation of the O-rings at lower temperatures. As a result, the engineering judgment did not have the same degree of decisiveness that it would have had otherwise. All that Roger Boisjoly could argue was that the degree of degradation seemed to be correlated with temperature, and even the data he used to back up this claim was limited.

Mason's arguments, taken together, might be seen as an attempt to meet criterion (2) of the PMD. If the decision to recommend launch is not a clear violation of engineering practice, an engineer does not violate his technical practices by recommending launch. Thus, Mason's argument could be seen as a claim that the decision whether or not to launch was at the very least not a paradigm instance of a PED. A paradigm PED would be one where (among other things) the experts clearly agree and where there are quantitative measures that unambiguously point to one option rather than another. Thus the recommendation to launch was at the very least not a paradigm case of a violation of technical engineering practices.

Mason might also have argued that criterion (1) of the PMD was satisfied. A renewed contract with NASA was not assured, and failure to recommend launch might have been the decisive factor that persuaded NASA officials not to renew

the contract with Morton Thiokol. Thus, the well-being of the company might have been substantially harmed by a no-launch recommendation.

Despite these arguments, we believe that the launch decision was properly an engineering decision, even though it perhaps was not a paradigm case of such a decision.

First, criterion (1) of the PMD was not as compelling a consideration as Mason might have supposed. There was no evidence that a no-launch decision would threaten the survival of Morton Thiokol, or even that it would in any fundamental way jeopardize Thiokol's financial wellbeing. In any case, engineering considerations should have had priority.

Second, criterion (2) of the PMD was not satisfied, because the decision to launch violated engineers' propensity to modify or change course only in small increments. The temperature was more than 20 degrees below any previous launch. This was an enormous change, which should have given an engineer good reason to object to the launch.

Third, criterion (1) of the PED was fulfilled. Even though the quantitative data were limited and certainly did not give conclusive evidence that there would be a disaster, the data did seem to point in that direction, so that the desire for quantitative measures was not wholly frustrated. Engineers, furthermore, are alert to the fact that composites, such as the ones the O-rings are made of, are temperature-sensitive and that one could reasonably expect substantially lower temperatures to produce substantially greater blowby problems.

Fourth, criterion (2) of the PED was met, because human life was at stake, and engineers are trained to be unusually cautious when there are serious issues of health and safety. This should be particularly important when those at risk do not give informed consent to special dangers. This was the case with the astronauts who did not have any knowledge of the problem with the O-rings.

The importance of the safety issue was further highlighted because the practice of requiring the burden of proof to be borne by anyone advocating a launch decision rather than a no-launch decision was violated. In testimony before the Rogers Commission, Robert Lund recounts this all-important shift in the locus of the burden of proof:

Chairman Rogers: How do you explain the fact that you seemed to change your mind when you changed your hat?

Mr. Lund: I guess we have got to go back a little further in the conversations than that. We have dealt with Marshall for a long time and have always been in the position of defending our position to make sure that we were ready to fly, and I guess I didn't realize until after that meeting and after several days that we had absolutely changed our position from what we had been before. But that evening I guess I had never had those kinds of things come from the people at Marshall that we had to prove to them that we weren't ready. . . . And so we got ourselves in the thought process that we were trying to find some way to prove to them it wouldn't work, and we were unable to do that. We couldn't prove absolutely that motor wouldn't work.

Chairman Rogers: In other words, you honestly believed that you had a duty to prove that it would not work?

Mr. Lund: Well that is kind of the mode we got ourselves into that evening. It seems like we have always been in the opposite mode. I should have detected that, but I did not, but the roles kind of switched.²⁹

This last-minute reversal of a long-standing policy, requiring the burden of proof to rest with anyone recommending a no-launch rather than a launch decision, was a serious threat to the integrity of the engineering obligation to protect human life.

Although hindsight no doubt benefits our judgment, it does seem that the decision whether or not to recommend launch was properly an engineering decision rather than a management decision, even though it may not have been a paradigm case of a proper engineering decision. There is insufficient reason to believe that the case diverged so much from the paradigm engineering decision that management considerations should have been allowed to override the engineering constraints. Engineers, not managers, should have had the final say on whether or not to launch. Or, if the person wore both an engineering hat and a management hat—as Robert Lund did—he should have had his engineering hat on when he made the decision. The distinction between paradigmatic engineering and management decisions and the attendant methodology developed here help to confirm this conclusion.

