1 The Challenger Disaster: Moral Responsibility and the Working Engineer

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Distinguished faculty of MIT, students, ladies and gentlemen. I am very honored to be invited to speak to you today [January 7, 1987]. I will present a background summary of important events from January 1985 through the evening before the Challenger launch then continue with the post-disaster chronology of my working relationship with Morton Thiokol management.

The significance of January 1985 as the starting point results from the observations made during the post flight hardware inspection of Flight 51C. During this inspection I found evidence that hot combustion gases had compromised the primary seals on two field joints. My concern heightened as a result of the large amount of blackened grease I observed between the two seals. Subsequent to reporting the findings to my superiors, I was asked to proceed to the Marshall Space Flight Center (MSFC) in Huntsville, Alabama to brief them with a preliminary viewgraph presentation which included my observations and an explanation of the scenarios that cause the seal erosion and hot gas blow-by.

Morton Thiokol was then asked to prepare a detailed presentation as part of the Flight Readiness Review (FRR) for Flight 51E which was scheduled for launch in April 1985. This presentation was given in February at three successively higher-level review boards with refinements in contents made at each level. I presented my belief that the lower than usual launch temperature was responsible for such a large witness of hot gas blow-by, but NASA management insisted that this position be softened for the final review board. The final flight readiness assessment chart read as follows:

Conclusions:

STS-51C consistent with erosion data base

Low temperature enhanced probability of blow-by—
STS-51C experienced worst case temperature change in Florida history
STS-51E could exhibit same behavior
Condition is acceptable
STS-51E field joints are acceptable for flight

These conclusions were accepted and the flight was certified ready for launch.

Later, I met with Arnie Thompson to discuss the blow-by scenario and the affect of cold temperature on O-ring resiliency which is the ability of the seal to restore itself to a round shape when the squeeze on the seal is removed. Arnie proposed that subscale lab tests be conducted which would provide us with assessment data. The resiliency testing was performed in March and showed that low temperature was a problem. The results indicated that the seals would lift off their sealing surfaces for several seconds at 75 degrees farenheit and in excess of 10 minutes at 50 degrees farenheit. This data was discussed with Morton Thiokol engineering management but was thought to be too sensitive by them to release.

Another post flight inspection occurred in June 1985 at Morton Thiokol in Utah. This time a nozzle joint from Flight 51B, which flew on April 29, 1985, was found to have a primary seal eroded in three places over a 1.3 inch length up to a maximum depth of 0.120 inches and the secondary seal in the same joint was eroded 0.032 inches. It was postulated that this primary seal had never sealed during the full two minutes of flight.

My former concerns now escalated because if this same scenario happened in a field joint, the secondary seal could also be compromised especially during a low temperature launch. A Flight Readiness Review presentation was prepared for Flight 51F which was scheduled for launch on July 29, 1985. The presentation was given to NASA at MSFC on July 1, 1985 with an additional presentation on the overall status of the booster seal given the next day. The preliminary results of the O-ring resiliency testing in March were presented for the first time during this meeting. All O-ring test samples were 0.280 inch diameter and compressed to 0.040 inches with a decompression distance of 0.030 inches at a 2 inch per minute rate as compared with a flight rate of approximately 3.2 inches per minute. The results showed that the seals did not lose contact at 100 degrees farenheit; lost contact for 2.4 seconds at 75 degrees and lost contact in excess of 10 minutes at 50 degrees. Test results also indicated that a 0.295 inch diameter seal lost contact for 2 to 3 seconds at 50 degrees which meant that the 0.295 inch diameter seal performance at 50 degrees was similar to the performance of a 0.28 inch diameter seal at 75 degrees. Everyone on the program for the first time was now aware of the influence of low temperature on the joint seals.

My concern increased once again due to lack of attention being given to this problem. My notebook entry on August 15, 1985 reads as follows: "An attempt to form the team (referring to the Solid Rocket Motor seal erosion team) was made on 19 July 1985. This attempt virtually failed and resulted in my writing memo 2870:FY86:073. This memo finally got some response and a team was formed officially. The first meeting was held on August 15, 1985 at 2:30 pm." The memo referred to is the one I

read to the Presidential Commission on February 25, 1986, which was written to the vice president of engineering at Morton Thiokol on July 31, 1985. The memo ended by saying, "It is my honest and very real fear that if we do not take immediate action to dedicate a team to solve the problem, with the field joint having the number one priority, then we stand in jeopardy of losing a flight along with all the launch pad and facilities."

During this July period, NASA headquarters in Washington D.C. asked Morton Thiokol to prepare a presentation on the problems with all the booster seals. The presentation was prepared by MSFC on August 19, 1985 with Morton Thiokol personnel in attendance.

Morton Thiokol was then asked by MSFC in September to send a representative to the SAE conference in October to discuss the seals and solicit help from the experts. I prepared and presented a six page overview of the joints and the seal configuration to approximately 130 technical experts on October 7, 1985. However, I was given strict instructions, which came from NASA, not to express the critical urgency of fixing the joint but to only emphasize the joint improvement aspect during my presentation. After my presentation I asked for help in the form of design improvement suggestions but no one said a word so Bob Ebeling and I spent the remainder of the convention time meeting with seal vendors whom we had previously contacted for help.

The Seal Task Team was frustrated from the beginning from lack of management support to provide the resources necessary for us to accomplish our task. Accordingly, I wrote a series of very damning activity reports in which I left no room for error about how I felt concerning the lack of management support. Unfortunately, I never received any comments back and never knew if they had been incorporated into reports up through the management structure.

The evening meeting of January 27, 1986 was the concluding event preceding the launch disaster. The major activity that day focused upon the predicted 18 degrees farenheit overnight temperature and meeting with engineering management to persuade them not to launch. The day concluded with the hurried preparation of fourteen viewgraphs which detailed our concerns about launching at such a low temperature. The teleconference with KSC (Kennedy Space Center) and MSFC started with a history of O-ring damage in field joints. Data was presented showing a major concern with seal resiliency and the change to the sealing timing function and the criticality of this on the ability to seal. I was asked several times during my portion of the presentation to quantify my concerns but I said I could not since the only data I had was what I had presented and that I had been trying to get more data since last October. At this comment, the general manager of Morton Thiokol gave me a scolding look as if to say, "Why are you telling that to them?" The presentation ended with the recommendation not to launch below 53 degrees which was not well received by NASA. The Vice President of Space Booster Programs, Joe Kilminster, was then asked by NASA for his launch decision. He said he did not recommend launching based upon the engineering position just presented. Then Larry Mulloy of NASA who was at KSC asked George Hardy of NASA who was at MSFC for his launch decision. George responded that he was appalled at Thiokol's recommendation but said he would not launch over the contractor's objection. Then Larry Mulloy spent some time giving his interpretation of the data with his conclusion that the data presented was inconclusive.

Just as he finished his conclusion, Joe Kilminster asked for a five minute off-line caucus to re-evaluate the data and as soon as the mute button was pushed our general manager, Jerry Mason, said in a soft voice "We have to make a management decision." I became furious when I heard this because I knew that an attempt would be made by management to reverse our recommendation not to launch.

Some discussion had started between the managers when Arnie Thompson moved from his position down the table to a position in front of the managers and once again tried to explain our position by sketching the joint and discussing the problem with the seals at low temperature. Arnie stopped when he saw the unfriendly look in Mason's eyes and also realized that no one was listening to him. I then grabbed the photographic evidence showing the hot gas blow-by and placed it on the table and, somewhat angered, admonished them to look and not ignore what the photos were telling us, namely, that low temperature indeed caused more hot gas blow-by in the joints. I too received the same cold stares as Arnie with looks as if to say "Go away and don't bother us with the facts." At that moment I felt totally helpless and that further argument was fruitless so I, too, stopped pressing my case.

What followed made me both sad and angry. The managers were struggling to make a pro-launch list of supporting data but unfortunately for them the data actually supported a decision not to launch. During the closed manager's discussion, Jerry Mason asked in a low voice if he was the only one who wanted to fly. The discussion continued, then Mason turned to Bob Lund, the vice-president of engineering, and told him to take off his engineering hat and put on his management hat. The decision to launch resulted from the yes vote of only the four senior executives since the rest of us were excluded from both the final decision and the vote poll. The telecon resumed and Joe Kilminster read the launch support rationale from a handwritten list and recommended that the launch proceed. NASA promptly accepted the recommendation to launch without any probing discussion and asked Joe to send a signed copy of the chart.

The change in decision so upset me that I do not remember Stanley Reinhartz of NASA asking if anyone had anything else to say over the telecon. The telecon was then disconnected so I immediately left the room feeling badly defeated. I wrote the following entry in my notebook after returning to my office. "I sincerely hope that this launch does not result in a catastrophe. I personally do not agree with some of the statements made in Joe Kilminster's written summary stating that SRM-25 is okay to fly."

As it turned out I didn't agree with any of his statements after I had a chance to review a copy of the chart. A review of the chart will produce the following conclusions from anyone having normal powers of reason. The chart lists nine separate statements, seven of which are actually reasons against launch, while one is actually a neutral statement of engineering fact. The remaining statement concerning a factor of safety of three on soil erosion is not even applicable to the discussion which had ensued for over an hour. Therefore, Morton Thiokol senior management reversed a sound technical decision without one shred of supporting data and without any re-evaluation of the data they had promised when they requested the caucus.

The next morning I paused outside Arnie Thompson's office and told him and the manager of applied mechanics, who was my boss, that I hoped the launch was safe, but

I also hoped that when we inspected the booster joints we would find all the seals burned almost through the joint, then maybe we could get someone with authority to stand up and stop the flights until we fixed the joints.

It was approximately five minutes prior to launch as I was walking past the room used to view launches when Bob Ebeling stepped out to encourage me to enter and watch the launch. At first I refused but he finally persuaded me to watch the launch. The room was filled so I seated myself on the floor closest to the screen and leaned against Bob's legs as he was seated in a chair. The boosters ignited and as the vehicle cleared the tower, Bob whispered to me that we had just dodged a bullet. At approximately T + 60 seconds Bob told me that he had just completed a prayer of thanks to the Lord for a successful launch. Just 13 seconds later we both saw the horror of destruction as the vehicle exploded. We all sat in stunned silence for a short time then I got up and left the room and went directly to my office where I remained the rest of the day. Two of my seal task-team colleagues inquired at my office to see if I was okay but I was unable to speak to them and hold back my emotions so I just nodded yes to them and they left after a short silent stay.

Within a day of the launch one of my colleagues, after reviewing the video tape, told me that he thought he saw a plume of flame coming from one of the boosters as it exited the explosion. My first thought was that one of the joints had failed and I postulated several scenarios to fit the observed failure. A failure investigation team was formed at Morton Thiokol on January 31, 1986, which included Arnie Thompson and me. The team was immediately sent to MSFC in Huntsville, Alabama.

The following is a description of my post-disaster experiences with Morton Thiokol management. The first indication that there was a division between me and management came when I was informed on February 13th that a Presidential Commission hearing would be held the next day. I was waiting at the Huntsville Airport when the company jet landed and Bob Lund asked each person who was at the telecon if he wanted to testify. When he came to me he simply stated that he didn't need to ask me because he knew that I wanted to testify. I replied that he was absolutely correct in his assumption. Apparently Morton Thiokol management had plenty of notice concerning this meeting since they had the publications group prepare a formal set of viewgraphs for their version of the events leading to the launch decision, but they didn't inform me so I could make similar preparations. Meanwhile, I had approximately two hours total by myself and was struggling to organize a set of notes to aid me during my testimony. After the testimony there were obvious tense feelings between Morton Thiokol management and those who testified, namely, myself, Al McDonald and Arnie Thompson.

Approximately five days later at MSFC, two Commission members requested a closed interview session with Arnie Thompson, Joe Kilminster and me. During this meeting, I handed a packet of memos and activity reports to a Commission member and this upset our company attorney. I sensed quite clearly from this time on that I had not endeared myself with management since my memos would clarify the true circumstances leading to the disaster and would also counteract both NASA and Morton Thiokol management attempts to discredit our testimony up to this point. My senses proved quite accurate because Joe Kilminster had a heated discussion with Arnie and me in the presence of our company attorney after our meeting with the two Presi-

dential Commission members. Joe strenuously objected to Arnie and me constantly correcting his technical version of what the data meant. Joe said we were welcome to express our opinions but that he also was entitled to express his. We agreed with him but said that we would continue to correct his version if his input was technically incorrect as it had been up to this point. We also expressed very clearly that we didn't give a hoot for his interpretation of the data. He became angry with us but we didn't let him intimidate us.

I suspect I fell into further disfavor with Morton Thiokol management after my February 25th testimony which was a public hearing open to the whole country. Again, management had prepared beautiful color graphic viewgraphs, while I struggled with my notes. However, this time management did not get the opportunity to speak from their viewgraphs but only to hand the written material to the Commission and answer their questions. During my testimony I rebutted our general manager's testimony concerning our supposed non-unanimous engineering position. My rebuttal was based on the fact that I remembered only Arnie and me as the principals involved in the continuing discussion during the whole telecon. Brian Russell and Bob Ebeling were the only other ones that spoke and they only said a few sentences. No one else said anything, either pro or con, so I therefore consider all those people as non-entities and it matters not what they may say after the fact since they did not have the conviction or the courage to speak during the telecon. Mason and others in management apparently talked to some of these people after the disaster who said that they supported the management decision to fly, and so Mason decided that he had received sufficient knowledge for him to state in testimony that the engineering position was not unanimous. I submit that this is an example of management's deceit and half truth at its best.

After the testimony on the 25th of February, we all gathered at our Washington, D.C., resident office where feelings were very tense once again. The feelings were so tense that someone in management suggested that the company jet take us back to Huntsville as soon as we gathered our belongings from the motel. Eventually cooler heads prevailed and we stayed overnight and took a commercial flight the next morning. Al McDonald then asked if he and I could stay and listen to NASA's testimony since they had heard ours and because Chairman Rogers had said that we would have the opportunity to rebut or clarify any testimony given. We were told in no uncertain terms that we would be leaving Washington and going back to work the next morning. Subsequent to this decision we found out that both Joe Kilminster and Jerry Mason stayed to hear NASA's testimony. Later that same evening management decided to send me back to Utah and keep Arnie at MSFC until the failure investigation was completed.

I was happy to return home because I was not pleased with the direction of the failure investigation. I had observed NASA management diligently attempting to find a condition other than low temperature which caused the disaster. This was being accomplished with the full knowledge and, I assume, approval of Morton Thiokol management who were extremely supportive of every NASA move.

In Utah I began to sense the first signs of isolation, but I didn't fully recognize the situation while it was happening to me. I continued to argue for full truthful disclosure while factions of Morton Thiokol and NASA management were fully content to tell

only half truths about the history of the development and production of the solid rocket boosters.

Sometime in April I realized that from mid-March on I was being used only for public relations purposes so the company could say if asked, yes, Roger Boisjoly still works here and in fact he is the new seal coordinator for the re-design effort. Actually, I was being carefully isolated from NASA and the re-design effort with great subtlety by management while they were telling me of my great importance in contributing to the re-design. I was being asked to furnish technical design information for the new design which was sometimes changed without my knowledge and was being presented by someone else with no copies of the final version of the presentation given to me for feedback. I was in effect actually isolated from the main re-design effort. Previous to my testimony, I always prepared and presented my own material and often my supervision gave me total freedom because of the confidence that they had in my ability. During this same time period, Al McDonald was re-assigned and no longer had any people reporting to him.

Conditions kept deteriorating for us who had testified until we were called once again to testify before the Presidential Commission in closed session on May 2, 1986. On the evening of May 1st we met with the president of aerospace operations for Morton Thiokol, Ed Garrison, at our Washington, D.C., resident office. Mr. Garrison opened the meeting with a few general remarks about the upcoming session with the Commission the following day. He then addressed me and chastised me for airing the company's dirty laundry via my memos which I had given to the Commission. He also stated that Morton Thiokol had suffered enough as a result of public disclosure, but that we should continue to tell the truth, but we should consider the best way to state it before speaking. I quickly took exception to his remarks about me and said that I had simply tried to restore the truth in all the testimony and that I did not consider my actions as airing dirty laundry. Just then Bob Ebeling spoke up with support for my remarks but Garrison told him to stop and to quit telling him how to run the company.

We went into the session with the Commission the next day with conditions as tense as they had ever been and Chairman Rogers asked Al and I about our current job assignments. We answered him and he was visibly upset because we were being punished for our honesty in our testimony. The commission decided to release the closed session testimony and Morton Thiokol received tremendous criticism from the Congress, the Presidential Commission and the news media.

A few days later Al and I were invited back to Washington by the Presidential Commission to review and comment on the final SRM accident analysis team report which was submitted to them by MSFC. The Commission had somehow found out that neither Al or I had seen the final report version. I submitted 12 pages of comments on the report and then Al and I gave verbal testimony about the report to a group of four Commission members. I testified that the report findings were biased towards an attempt to downplay the affect of low temperature on the joint failure by trying to first focus blame on such things as assembly problems and other areas. The Commission agreed with my comments and thanked us for our willingness to review and comment on the report on such short notice.

Those of us who had been testifying now sensed a major division developing within the company as some of our colleagues perceived that our testimony was

damaging the company, but we didn't agree with this assessment and decided to correct it by requesting a meeting with the three top executives who could do something about the company's internal strife.

A private meeting was held on May 16th with the CEO, the president of aerospace operations and the vice-president now heading the shuttle program. The meeting produced a very candid discussion from our side, but it was essentially one-sided with management telling us nothing. The CEO even made it sound like we were on probation and if we worked hard and proved ourselves during the re-design, then everything would be forgiven. His attitude was certainly consistent with his criticism of Al and me in his previous statements to *The Wall Street Journal*. I believe it was at this meeting that the CEO made the statement that the company was doing just fine until Al and I testified about our job re-assignments on May 2nd. He said that those statements caused the company more harm than all the previous releases up to that time.

Al McDonald and I were supposedly restored to our former positions after the company was scolded by some very angry U.S. Senators, but it was actually only a superficial restoration which the company skillfully reported by inference as a promotion for Al McDonald who was now heading the re-design effort while my interface with NASA was restored. Apparently, the press release was taken as Gospel by the news media because they all reported that Al was given a promotion and I was given my former job. Actually Al got his old job back without a promotion while some people who remained silent got promotions and the same people who wouldn't face up to the original bad joint design were directing the joint re-design effort. Simply put, the joint is being re-designed by top management with direction down to the working level engineer who is trying to engineer the details to make it work.

I have been ignored, chastised before my colleagues and criticized for not getting approval of my design proposals prior to presenting them to NASA in informal telecons. The best example is management's refusal to support the best design as the primary re-design candidate. The best design in my opinion, and others agreed, was submitted by Gray Tool Company of Houston, Texas, but it was simply carried as a back-up design in case the company's primary design fails to meet the testing requirements. I was the only one who responded to the Gray Tool design proposal and I fought hard to secure them a chance to present their design to our management, but the decision had already been made on the primary design, so Gray Tool has only a back-up position.

Al McDonald, Arnie Thompson, and I along with Morton Thiokol management were asked to testify at the House of Representatives Committee on Science and Technology hearing on June 17 and 18, 1986. The preparation and testimony for these hearings was almost more than I could withstand but fortunately I was on medication which allowed me to get through each day. Unfortunately, the medication also slowed me down, and I didn't realize it until I saw myself on video tape. My testimony on February 25th versus my testimony before the House Committee in June is from two different people. I now realize why one of Morton Thiokol's managers complimented me on my testimony after the first day of House hearings. Friends who have seen both video tapes have expressed similar comments.

Within a month after the House Committee testimony, I could no longer endure

the hostile environment so I have been on extended sick leave since July 21, 1986. This is why my current detailed knowledge about the joint re-design is sketchy at best. I cannot comment further on any re-design effort, but I surely can state with certainty that all of you who are young aspiring engineers must prepare to leave this university with the knowledge and conviction that you have a professional and moral responsibility to yourselves and your fellow man to defend the truth and expose any questionable practice that may lead to an unsafe product. This is accomplished by diligent application of your learned skills and by continuing to seek after knowledge in your chosen field of employment so you can rise to the top of your field.

Don't just sit passively in meetings when you know in your heart that you can make a constructive contribution and also be prepared to share your design ideas and to compliment others for their ideas, especially when their idea is better and may even replace yours. This is the best way to cultivate colleague respect and friendship which always results in a positive long-term benefit for you, the company and its product line.

I wish the shuttle disaster had never happened, and since I cannot turn the clock back, I hope that if anything good can result from this tragedy, then I desire that all universities like this great one will recognize the importance of teaching ethical behavior by using actual case histories like this one so you are aware of what to expect when you commence your careers.

I have been asked by some if I would testify again if I knew in advance of the potential consequences to me and my career. My answer is always an immediate yes. I couldn't live with any self respect if I tailored my actions based upon potential personal consequences as a result of my honorable actions. As a result of this and other exposures to real case histories, I hope that your answer will also be yes if and when you are confronted with a similar decision.

I thank you again for inviting me to share my experience with you.