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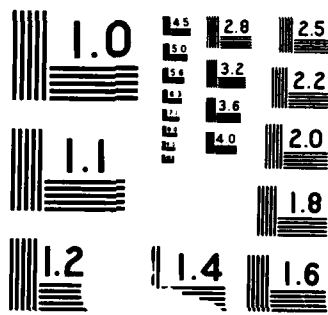
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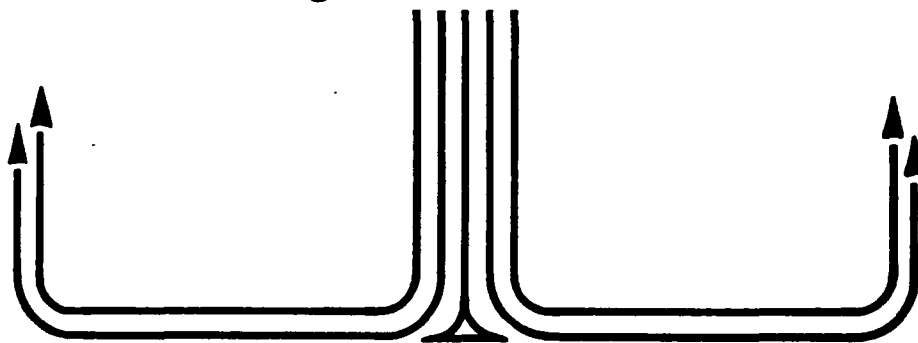
STUDENT REPORT

BOOK ANALYSIS: CHALLENGER: A MAJOR
MALFUNCTION

MAJOR THOMAS M. HALL

88-1135

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AUTHOR(S) MAJOR THOMAS M. HALL, USAF

FACULTY ADVISOR LT COL JOHN R. GRELLMAN, ACSC/EDC

SPONSOR MAJOR BRUCE A. THIEMAN, ACSC/EDW

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PREFACE

Like nearly everyone in the country, I felt the Challenger accident was both a personal loss and a national tragedy. At the time, I was a member of the B-1B Test Team at Edwards AFB, California, and I was struck by the similarities between the B-1B and the space shuttle programs. Both were large, complex, highly visible, high technology programs with top national priorities. Both programs were highly politicized, with design and production decisions coming only after intense national debates. It was clear that those of us in the B-1B community were under many of the same types of pressure as the people in the shuttle program. These pressures increased as the B-1B came under close scrutiny from the Congress, the General Accounting Office, and the media. This politically-charged atmosphere had the potential to compromise safety in many ways, such as exerting pressure to fly an important test by a given date, to certify new software or equipment as airworthy, or to release new capabilities to the field. It is to the credit of the people in the B-1B program that they were able to recognize and deal with these pressures before they took their toll on safety. The two B-1 accidents were not related to pressures in the system.

Of course, pressure is a part of any job in the modern world. But in the shuttle program, extraordinary pressures combined over several years to cause otherwise reasonable men to make the serious errors in judgment that led to the Challenger accident. If this report has any value beyond an academic exercise, it is to convey some of these causes to a military audience. We must learn how to prevent such accidents in the future. But the investigations into the Challenger accident raised even more profound questions: How can this nation make reasonable decisions about programs as complex, expensive, and controversial as the space shuttle? Should we even attempt such programs without a strong national consensus? These questions are beyond the scope of this report, but they are ones we must deal with in the future. Understanding what happened to Challenger is an important place to start.



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ABOUT THE AUTHOR

Major Thomas M. Hall is an Electronic Warfare Officer with flying experience in the B-1B, RC-135, and B-52G. Commissioned in 1974, he completed Undergraduate Navigator Training and Electronic Warfare Training in 1975, and was assigned to B-52Gs at Loring AFB, Maine. After a three year tour, he joined the 55th Strategic Reconnaissance Wing at Offutt AFB, Nebraska, and flew worldwide reconnaissance missions in the RC-135. His next assignment was to the Defense Intelligence Agency in the Pentagon as an Electronic Intelligence Analyst. Working in the National Military Intelligence Center, he provided intelligence estimates to the Joint Chiefs of Staff. His most recent assignment was with the B-1B Combined Test Force at Edwards AFB, California. As Chief of the B-1B Defensive Systems Branch, he was responsible for Operational Test and Evaluation of the B-1B's defensive avionics. He is currently attending the Air Command and Staff College at Maxwell AFB, Alabama.

Major Hall graduated from the United States Air Force Academy in 1974 with a Bachelor of Science Degree in American Studies. He earned his Master of Science Degree in Systems Management in 1978 from the University of Southern California. His awards include the Defense Meritorious Service Medal, the Meritorious Service Medal with two Oak Leaf Clusters, the Air Medal, and the Humanitarian Service Medal. He is a 1979 Distinguished Graduate from Squadron Officer School.

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EXECUTIVE SUMMARY



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REPORT NUMBER

88-1135

AUTHOR(S)

MAJOR THOMAS M. HALL

TITLE

BOOK ANALYSIS: CHALLENGER: A MAJOR MALFUNCTION

The explosion of the space shuttle Challenger was a national tragedy with profound implications for the Air Force. In addition to the tragic loss of life, the loss of the shuttle's launch capability was a tremendous blow to national security--critical payloads have been delayed by several years. The accident reshaped the space policy of the United States, and proved the need for expendable launch vehicles in addition to the shuttle. But just as importantly, the causes of the accident need to be clearly understood by anyone who works in the procurement or operation of complex weapons systems.

The subject of this analysis is Challenger: A Major Malfunction, by Malcolm McConnell, one of the first books written on the accident. McConnell told the history behind the accident, beginning with the design of the shuttle through the flawed decision to launch Challenger on its last flight. He explained how the design was compromised by cost considerations, how politics affected the management of the program, and how pressure to fly compromised safety. But McConnell's central theme was about the pressure on NASA that resulted from its commitment to a "cost-effective, reuseable space transportation system." In retrospect, he said, the promises of cost effectiveness were unreasonable, and trying to live up to them later proved increasingly difficult.

CONTINUED

The purpose of this analysis is to prove whether McConnell's basic themes were true. To test his credibility, I compared his facts and conclusions with other published reports on the accident, such as that of the Presidential Commission. With minor exceptions, McConnell closely followed the commission's report. Some of his claims about inside political influence in the award of shuttle contracts were impossible to verify, and his language was sometimes over-emotional, yet McConnell clearly proved most of his major arguments.

I recommend Challenger: A Major Malfunction and the report of the Presidential Commission to every Air Force reader. Anyone who has worked on a highly visible or costly program will be able to identify with the tremendous pressures and complex decisions faced by NASA. As McConnell showed, the Challenger accident could have been prevented if these pressures had not caused otherwise reasonable men to ignore the warning signs. Since the Air Force will always be involved in complex programs like the space shuttle, it must learn to cope with pressure to prevent a similar accident in the future.

Chapter One

INTRODUCTION

The explosion of the space shuttle Challenger on January 28, 1986, left an image that will be forever burned into the memories of Americans. The shuttle represented what was good about the United States, a belief that made the accident difficult to bear. In its aftermath, a host of inquiries examined every detail of the accident. One of the first books released on the subject, Challenger: A Major Malfunction, is the subject of my analysis.

The Challenger accident may have more significance to Air Force members than to most Americans. The loss of the launch vehicle was a blow to the Air Force space program. It is likely that the problems in shuttle procurement and operations, and the pressure faced by NASA, are similar to those faced by people throughout the Air Force. Therefore, an important aspect of this report is to give greater visibility to some of these issues.

This book analysis will prove whether the basic themes in Challenger: A Major Malfunction are true. I will begin with a brief synopsis of the book, followed by a general analysis of the author's credibility. Next, I will analyze the validity of the book's major themes. Finally, I will conclude with my overall assessment of the book.

Chapter Two

SYNOPSIS

Challenger: A Major Malfunction was released in early 1987, on the first anniversary of the accident. McConnell's goal was to "dissect a tragic policy failure, to reveal the political intrigue and compromise, the venality and hidden agendas that combined over almost twenty years to produce the disaster." (11:x) He agreed with the Presidential Commission assigned to investigate the accident, that this was "an accident rooted in history." (15:120) He used a chronological approach to cover recent events that led to the accident, with flashbacks to significant events in shuttle development. Three themes emerged: the design of the shuttle was compromised by politics and cost, politics played a major role in the management of the program, and pressure to fly compromised safety. This pressure was prevalent throughout the shuttle program, and was clearly the book's major theme. A brief look at each theme provides a good overview of the book.

McConnell's first theme was that the design of the space shuttle was a compromise, based on politics and cost. When the shuttle was conceived in the late 1960s and early 1970s, it did not have the overwhelming national mandate enjoyed by the Apollo program. Given the drain on the economy of the Vietnam War, increased emphasis on social and environmental programs, and a decline in enthusiasm over the space program, advocates felt that only a "reuseable" shuttle that could largely "pay its own way" had a chance of getting funded. Unlike the Apollo days, NASA was forced to make major design concessions due to budgetary constraints. What McConnell called the "myth" of the operational shuttle was born out of the need to convince skeptical decision makers that the shuttle would be "cost-effective," since customers would bear most of the costs. He pointed out the contradiction that, by opting for a design that had the least developmental costs, NASA was accepting greater operating costs. The implication of all this was that politics and cost, rather than safety, were the primary design considerations.

McConnell's second theme was that politics played a major role in the management of the shuttle program. Beginning with the source-selection process, McConnell showed how Rockwell and Morton Thiokol used "hardball" politics to win major shuttle contracts. For example, he stated that Rockwell's Vice President and Manager for the company's Space Shuttle Program, Dale Myers, managed to get a political appointment to NASA as the Associate Administrator for Manned Space Flight. In this position, Myers was second only to NASA's Administrator, James Fletcher, in the power to award contracts. When Rockwell secured the contract to build

the orbiter, Myers resigned and went back to work for Rockwell. McConnell attempted to make a similar point regarding the award of the solid rocket booster contract to Thiokol, believing that former employees of Thiokol were on the Source Evaluation Board for the boosters. However, he said that NASA refused to release the names of the board members, so the point was unproven. (11:x) McConnell said that this same type of politics throughout the history of the program caused NASA to neglect safety concerns. Another example was the selection of crewmembers. He detailed the impact of the flight of Congressman Bill Nelson, an important supporter of NASA, on the overall shuttle schedule. He said that such crew assignments "were often the result of political considerations transcending the individual skills" of the astronauts. (11:96) When a crewmember was reassigned, the experiment he was working on was moved as well. If this happened late in the mission planning process, as in the case of Congressman Nelson, it upset the complicated process of building the software and engineering data for the flight, and diverted resources from other problems. (11:99; 15:167) McConnell also claimed that the selection of a "Teacher in Space" was "politically charged." (11:100) He said NASA had planned to use a journalist as the first private citizen in space, but that the Reagan Administration, believing it needed to enhance its record on education for the 1984 Presidential campaign, decided to select a teacher instead. While this example did not have the same safety implications as the flight of Congressman Nelson, it was one of many McConnell offered to show the major role of politics in the shuttle program.

McConnell's central theme was that the pressure to fly also compromised safety. He cited many examples, such as NASA's early promises on the performance of the shuttle, which led to impossible goals and unreasonable schedules. He said the pressure came from the highest levels of NASA, such as Administrator James Beggs, who ordered his subordinates to "fly out the manifest." (11:62) Much of this pressure, McConnell said, was understandable. For example, the European launch vehicle Ariane was unexpected competition for the shuttle, and the Air Force wanted to build its own expendable launch vehicles. These competitive pressures became more severe as unforeseen developmental and logistic problems forced additional delays in the program. He further showed how pressure compromised the decision-making process, and led key decision makers to minimize the seriousness of the design flaw in the field joint of the solid rocket boosters. He showed how NASA officials, over-eager to avoid another schedule slip, made the decision to launch Challenger over the objections of Thiokol and Rockwell engineers.

In Challenger: A Major Malfunction, McConnell attempted to do more than show that mistakes were made in the shuttle program, but also to show that these mistakes were the result of politics, favoritism, and pressure. The book contained much of the same information revealed during the investigations following the Challenger accident, but it added historical and background information less commonly known. The book was interesting and generally believable; just how believable is the subject of the next two sections.

Chapter Three

CREDIBILITY OF THE AUTHOR

In this section I intend to establish the degree of credibility of author Malcolm McConnell. Credibility, crucial to the success of any book, can be determined by the answers to questions such as: What are the author's professional qualifications and experience? What documentation does he offer to back up his claims? Is his treatment of the material even-handed, or does he exaggerate? What do others think of his work? The answers provide a reference from which we can judge his message.

There is nothing in Malcolm McConnell's background to suggest he was biased or unqualified to write about the major issues of the Challenger accident. He served briefly in the Army prior to college, graduating from the University of Wisconsin, Madison, in 1962. After graduation, he was a member of the U.S. Foreign Service for several years. Later, he was a free-lance writer and Writer-in-Residence at several universities. At the time of the Challenger disaster, he had been covering the space shuttle for Reader's Digest for three years and had witnessed 11 shuttle launches. He was present at Cape Canaveral on the day of the accident and was a finalist in the competition to select a journalist to fly on the shuttle. (12:31) He was recently interviewed on Cable News Network for his knowledge of the Challenger accident. McConnell has written three novels and eight books of nonfiction. He is probably most familiar to Air Force readers for Into the Mouth of the Cat, the story of Air Force Medal of Honor winner Lance Sijan, published in 1985. In short, McConnell appeared to be well-qualified, with solid professional and academic credentials. I found nothing in his background to suggest bias. Rather, McConnell admitted to having been "spellbound" by the glamour of the space program. (11:32)

Given McConnell's academic credentials, it's hard to explain the absence of footnotes and a bibliography. One reason for their absence may be the author's style, which one reviewer referred to as "New Journalism." That is, in some passages McConnell attempted to re-create actual meetings or conversations. (6:75) Perhaps McConnell believed that footnotes interfered with this style, but their absence made the job of verification much harder. On the other hand, since so much has been published since the accident, much of McConnell's job was to organize it into readable form. Nearly all of the 29 sources I used for this report substantiated McConnell's positions. For example, much of the book closely mirrored the report of the Presidential Commission headed by William Rogers. If McConnell had departed from the Commission's findings, it would have called into question facts that are not so easily checked. In

sum, the absence of footnotes was a problem, but the force of McConnell's logic and his use of well-known facts provided a good deal of "internal" proof.

McConnell's credibility suffered whenever his tone departed from an even-handed scholarly style. The book's cover was a turn-off to the serious reader: "The true story of politics, greed, and the wrong stuff." It listed a series of what appeared to be "juicy" revelations to be found inside. Fortunately, the cover seemed to reflect the publisher's desire to sell books rather than McConnell's own style. But he occasionally used language that his facts did not support. For example, part of his purpose was to reveal "the venality and hidden agendas" of those who worked on the shuttle program. (11:x) But McConnell offered no proof of actual bribery or corruption, as the term "venality" implied. Rather, the wealth of evidence showed that "hardball" politics were involved in the shuttle procurement process. This was probably disturbing enough to readers who had an idealized view of NASA and the shuttle program. The occasional use of graphic imagery detracted from an otherwise even-handed presentation of the facts as McConnell saw them. Moreover, such exaggerations were unnecessary--the facts were compelling enough.

Finally, let's look at what others said about the book. The seven book reviews I found of Challenger: A Major Malfunction were divided on the issue of credibility. For example, Booklist said it was a "well-ordered marshalling of facts" (1:730), while the Library Journal said some "undocumented assertions. . . demand substantiation." (6:75) Book World said the book was "solidily researched, thoroughly documented" (10:4), and Choice pointed out the lack of bibliography or notes. (16:1469) While the overall conclusions of these reviews were largely favorable, their lack of consensus on McConnell's credibility suggests that we should not merely "take his word for it" regarding the major issues of the book. Therefore my analysis of the major themes is the central element of this report.

Chapter Four

ANALYSIS

Overview

Did McConnell prove his case? To answer that basic question, I'll look at representative facts and logic from his major themes. I'll first address how the design of the shuttle was compromised, as McConnell claims, largely by cost factors, and how cost became the primary concern over safety in the program. Next, I'll look briefly at McConnell's assertions of political influence on the shuttle contract awards, and the impact this may have had on safety. I'll devote the rest of my analysis to McConnell's central theme, that pressure on NASA compromised safety. I'll show how McConnell traced this pressure back to the design of the shuttle, how it continued to grow over the years, and how it led to a compromise of safety in the decision to launch Challenger. The focus of this analysis is the author, his assertions and proof, not the accident itself. However, the official investigations, such as that of the Presidential Commission, were useful tools in evaluating McConnell's claims.

Design Compromises

In the chapter "A Decade of Compromise," McConnell showed how the design of the shuttle was compromised, largely by political and budgetary considerations. The shuttle was proposed in 1969 by a Presidential Task Group headed by Vice President Spiro Agnew, as a vehicle to get men and equipment up to a permanently manned space station, which would become the departure point for a mission to Mars. But with cost estimates well above the \$24 billion spent on the Apollo program, the ambitious proposal met with immediate resistance. McConnell said that President Nixon, who was preoccupied by problems of the Vietnam War and political unrest, was "flabbergasted" by these estimates, and refused to give the proposal his full support. Faced with this opposition, NASA was forced to cancel the Mars mission, postpone the space station, and scale back the design of the shuttle. (11:32) McConnell accurately reported the opposition of many in the Democratically-controlled Congress, such as Senator Walter Mondale, who called the shuttle, "A senseless extravaganza." The shuttle was also opposed by many in the space community who favored using smaller, unmanned boosters for scientific work in space. (7:392) But with the space station "on hold," NASA had lost its primary justification for the shuttle. To keep the program alive, it adopted the idea of "cost effectiveness," which was popular at the time. (11:32) McConnell accurately reported this process. As Science News said in April 1972, "What happened to the space world of the 1960s was a political story. But what happened to the space shuttle of the 1970s will go down [in

history] as a classic in cost-effectiveness study." (5:221) President Nixon did not give his full support to the shuttle until early 1972, when he decided to make it a campaign issue. Robert Gillette, writing in Science magazine in January 1972, reflected McConnell's view that the shuttle was a "child of compromise."

The shuttle and its stamp of Presidential approval stand as a tribute to NASA's deft and persistent salesmanship, a talent marked by careful acquiescence to political and economic realities, and a willingness to bleed other programs to keep the shuttle alive. NASA planners conceived and reconceived its design and even its justification with an eye to maximizing its attractiveness while mollifying opposition to it in Congress. (7:393)

By early 1972, with the mandate of the Apollo program coming to an end, McConnell said that NASA was fighting for its bureaucratic life, a fact supported by the literature of the day. For example, Science News said that the shuttle would "save" NASA as it existed at the time, along with the jobs of 50,000 aerospace workers. (4:36) Clearly, McConnell proved that the design of the shuttle was a compromise, based largely on budgetary and political considerations. This became important when the budget displaced safety as the primary concern.

The real significance of the compromise in the design of the shuttle was that cost became the primary concern, ahead of safety or technical excellence. To make this case, McConnell detailed the evolution of the design compromise, showing how various shuttle capabilities, backups, and escape systems were eliminated due to cost considerations. One example was in the selection of Morton Thiokol to design and produce the shuttle's Solid Rocket Boosters. In November 1973, a NASA Source Evaluation Board selected the Thiokol proposal over that of United Technologies, Aerojet, and Lockheed. (11:53) The board's ratings of each proposal, based on a complex set of criteria, were very close. The Aerojet design was judged best on engineering merits alone, and was also considered the safest, since it had a one-piece booster case that had no field joints (the point of failure in the Challenger accident). But when cost and management were considered, Thiokol was judged best. McConnell pointed out that in the formal announcement of Thiokol's selection, NASA Administrator James Fletcher cited the Thiokol field joint as an example of engineering excellence, that "offered great operational economies." (11:59) Here, McConnell's findings closely paralleled the conclusions of the Presidential Commission, which said that, "Costs were the primary concern of NASA's selection board, particularly those incurred early in the program." (15:120) The consequences of putting cost ahead of safety and other concerns became clear after the Challenger accident. As the Presidential Commission found, "The genesis of the Challenger accident—the failure of the joint of the right Solid Rocket Motor—began with the decisions made in the design of the joint. . . ." (15:148) T. A. Heppenheimer, an associate fellow of the American Institute of Aeronautics and Astronautics, agreed, saying, "The word was 'design to cost,' as the nation's leaders forced the space program into a budgetary straitjacket. Therin lay the seeds of failure." (8:5A) But if cost, not safety, became the primary concern, it may not have been the only

factor in the decision.

Political Influence

McConnell also believed that the inside political connections of the shuttle's main contractors helped them win the major contract awards. For example, Morton Thiokol was based in Utah, home of Senator Frank Moss, who was chairman of the Senate Committee on Aeronautical and Space Sciences, which had oversight responsibility for NASA. In addition, NASA Administrator James Fletcher was from Utah, was a prominent figure in the Mormon Church, and had close ties to the Utah business and religious communities. McConnell attempted to illustrate the influence of this "Utah Connection" on the events that followed the Thiokol award. (11:54) Soon after the announcement, Lockheed filed a formal protest, and the General Accounting Office conducted its own investigation into the award. The GAO concluded that the Lockheed and Thiokol proposals were about equal on technical grounds, and that the probable cost advantages of the Thiokol design were not as great as NASA believed. McConnell concluded that NASA should have reopened the competition, as recommended by the GAO. (13:18) NASA did not do this, according to McConnell, for purely political reasons. However, there are some weaknesses in McConnell's case. In the first place, Fletcher denied that he was influenced by political loyalties to Utah. (17:116) Fletcher is supported by the fact that the GAO report, by McConnell's own admission, and the Presidential Commission, did not mention political influence. McConnell barely mentioned the fact that other contractors were also trying to use their own political influence over NASA. Finally, the issue lacked significance, since he failed to make the same connection between politics and safety that he did on the cost issue. However, we will see later how politics did contribute to the tremendous pressure placed on NASA.

McConnell concluded that the design, compromised by cost considerations and politics, was part of the "squalid legacy" of the shuttle program. (11:60) This was another case where his tone was not justified by his facts. He did not even attempt to prove that anyone's actions were illegal—nor were they "sordid" or "repulsive" as the word "squalid" suggested. What he did prove was that the shuttle was subject to the same fiscal and political realities as other government programs. This was probably all he had to do, given the larger-than-life view most Americans had of the shuttle. But politics and cost were only two of the forces that combined to put pressure on the shuttle program.

Pressure to Fly

McConnell's central theme was that the pressure on NASA to meet its shuttle schedule, the "pressure to fly," was the most significant factor that compromised safety. McConnell demonstrated that this pressure began with the design of the shuttle, continued to grow over the years, and led to a compromise of safety in the decision to launch Challenger on its final flight.

The pressure on NASA began with the debate over the shuttle design. What McConnell called the "myth" of the operational shuttle was born out

of this debate. McConnell reasoned that the promises and compromises NASA made on the shuttle were increasingly difficult to live up to later. Recall his reasoning on the design compromise: the shuttle was originally designed as an integral part of a three-part Mars mission/space station/shuttle proposal. When the first two parts were cancelled, the original justification for the shuttle went away. This meant that NASA had no manned space flights authorized beyond Apollo and Skylab, and was therefore fighting for its bureaucratic life. Given the previous discussion of the political and fiscal climate, NASA felt that it had to change its justification for the shuttle to one of cost-effectiveness. (11:36) The key to McConnell's argument is that NASA's promises of cost-effectiveness were unreasonable, or at best, inaccurate, and that they inevitably led to more pressure later.

In retrospect, it is easy to see that projections for the shuttle were wrong. A study by the Princeton research firm Mathematica, used by NASA to justify the shuttle, said that if the shuttle flew as few as 30 flights a year, it would actually pay for itself. (11:41) McConnell argued that NASA purposely slanted such studies to favor the shuttle. He was supported by T. A. Heppenheimer who said that tight budgets led to "success-oriented management" at NASA, which "amounted to institutionalized optimism." This, in turn, meant "reliance on the results of paper studies, prepared by other optimists, to guide the program." (8:5A) But given the political climate of the time, a truly objective appraisal of the shuttle might have been almost impossible. For example, in November 1972 the Universe Astronautic Foundation, a privately funded research company, compared the Mathematica study with a similar effort by the Rand Corporation, which had been widely quoted by opponents of the shuttle. The Foundation pointed to serious flaws and a need for more data in both reports. (9:32) Again, in retrospect, it is obvious that all three studies were way off in many critical assumptions, such as what flight rates could be achieved, the number of payloads to be launched, and the cost per flight. McConnell's argument that NASA may have purposely slanted the figures was irrelevant--honest or not, the figures were wrong. They provided the basis from which the shuttle's projected fly rate continually had to be revised downward, and from which the cost per flight continued to rise. Likewise, they were the basis for much of the pressure on NASA almost 10 years before the first shuttle flight. During this period before the shuttle became "operational," the pressure continued to grow.

McConnell maintained that by mid-1982, NASA was still making unreasonable claims about the shuttle's capability, leading to even further pressure. He quoted President Reagan in a speech on July 4, 1982, at Edwards AFB, after the shuttle Columbia had just landed from the last of four test flights. Reagan said that the shuttle was the nation's "primary space launch system," and its first priority was to become "fully operational and cost-effective in providing routine access to space." (11:28) Later, the Presidential Commission said that just this transition to an "operational era" created new pressures in NASA, because it then had to do many things routinely that it had never done before, when it flew vehicles designed only for a single launch. (15:170) And as McConnell showed, the promise of an operational shuttle was still far from reality. He said that late in 1982, NASA was forced to drastically cut back the

schedule from previous estimates. This revised schedule projected 12 flights in 1984, 14 in 1985, 17 each in 1986 and 1987, and 24 in 1988. The actual fly rate was far below these figures, even farther from those used in the early 1970s—there were just five flights in 1984, and eight in 1985. (11:29) As the Presidential Commission stated, "Long before the Challenger accident, it was becoming obvious that even the modified goal of two flights a month was overambitious." (15:164) NASA's failure to live up to its commitments had a snowball effect by providing further ammunition to the shuttle's critics. NASA Administrator James Beggs acknowledged the pressure in March 1985 when he said, "The next 18 months are very critical for the shuttle. If we are going to prove our mettle and demonstrate our capability, we have got to fly out that manifest. Otherwise, we will give all our friends and enemies an excuse to say 'you really can't depend on the shuttle.'" (3:110) In July that same year, Congress cut five percent from the NASA budget, putting even greater pressure on the shuttle to "pay its own way." (11:30) Clearly, McConnell proved that, with the President and NASA Administrator promoting the shuttle on the one hand and Congress and others criticizing it on the other, NASA was in the center of extreme pressure.

McConnell continued to detail how pressure mounted from other sources. For example, the Ariane, an expendable launch vehicle built by the European Space Agency, offered growing competition for the shuttle. The Ariane was far less expensive and better suited to launch certain types of commercial satellites, so businesses began to choose it over the shuttle. Perhaps even worse for NASA, the Air Force began the process of acquiring its own launch vehicles because it perceived the shuttle could not meet its national security requirements. (2:19) The National Oceanic and Atmospheric Administration ordered weather satellites that were not shuttle compatible and would have to be launched on refurbished Titan 2 ballistic missiles. (3:110) Finally, McConnell said that NASA was stung by severe criticism from the scientific community, such as an article by astronomer James Van Allen, which appeared in Scientific American in January 1986. (11:15) Van Allen argued that the budget drain caused by the shuttle had forced the cancellation of more valuable scientific missions, and that the work of the shuttle could be better accomplished by unmanned spacecraft. (20:32) A reading of Van Allen's article made it clear that McConnell had accurately relayed his source's tone and content. McConnell summarized the impact of all these pressures as follows:

All of this unforeseen competition and criticism put NASA in an extremely difficult if not impossible position. In order to keep the confidence of its commercial, civil-government, and military customers, NASA would have to fly the shuttle dependably on an increasingly ambitious launch schedule. But the very nature of this schedule created pressures and engendered conditions that threatened launch-schedule reliability, to say nothing of flight safety. (11:65)

The significance of McConnell's arguments was that the pressures combined to have a tremendous impact on safety. He closely followed the findings of the Presidential Commission, which devoted an entire chapter of its report to "Pressures on the System." (15:164) To illustrate how

these pressures were felt throughout NASA, I'll look at their impact on the work force and the decision makers. In his chapter, "The Human Toll," McConnell illustrated the effects of the modest 1985 fly rate on NASA's labor force. Workers were forced to put in increasingly longer hours, on consecutive days, for weeks at a time. (11:66) The resulting fatigue led to numerous safety violations, the most dramatic occurring on the attempted shuttle launch on January 6, 1986. Less than five minutes before lift off, a worker unknowingly drained off enough liquid oxygen propellant to have caused an inflight abort if the error had not been discovered. The Presidential Commission agreed that fatigue, brought on by overtime and shiftwork, were the major contributing factors in this accident. (15:171) McConnell went on to detail other effects of pressure on the "shuttle flow," the process of refurbishment of the shuttle prior to each mission. He demonstrated that maintenance, spare parts, inspection, quality control, and other functions all suffered. As the Presidential Commission stated, "The flight rate did not appear to be based on assessment of available resources and capabilities, and was not reduced to accommodate the capacity of the work force." (15:171)

These same pressures had an even greater effect on NASA management, and directly impacted the flawed decision to launch Challenger on its last flight. The pressures came to a head as senior NASA officials met on January 15, 1986, at the Level I Flight Readiness Review, to formally certify that Challenger was ready to fly. This review, at the highest level of NASA, was the last step in the long review process that McConnell described in his chapter called "Certification of Deceit." (11:18) In addition to all the pressure previously detailed, they faced additional problems resulting from several postponements of the Shuttle Columbia the previous month. Failure to get Challenger off on time would have a cascade effect on the rest of the 1986 schedule, and would force cancellation of the highly visible ASTRO mission, scheduled for the shuttle in March to observe Halley's comet. McConnell suggested that missions like ASTRO were important to appease critics in the scientific community, such as James Van Allen. Challenger's own payload consisted of a Tracking Data Relay Satellite (TDRS) which NASA badly needed to complete its global communications system, and another Halley's Comet observation package called Spartan. (11:17) McConnell contended that even the Spartan package forced a safety compromise, because it required that the Challenger be launched late in the day, when the shuttle's emergency landing fields would be in darkness. Again, McConnell established the enormous pressures at work, but he failed to prove that there was also deceit or fraud in the review process. His nearest example of deceit was that Challenger was certified ready to fly, in spite of the fact that it was still waiting on spare parts that had to be removed from the orbiter Columbia, which was still in orbit. Air Force fliers and maintenance crews are familiar with this type of routine "cannibalization" procedure on their airplanes. But on the shuttle, "cannibalization" was far more risky. Changing parts with the vehicle on the launch pad could lead to further problems, and since many maintenance tasks and inspections had to be performed sequentially, much work remained before the shuttle would finally be ready. This meant, according to McConnell, that an accurate status of Challenger was not known at the time it was certified ready to fly because so much work remained to be done. (11:25) When Columbia actually landed, two days later than planned, the launch

of Challenger also had to be slipped. The Presidential Commission agreed that "cannibalization" was a major problem, but addressed it as a logistics issue, not as one involving fraud or deceit. (15:174) Likewise, McConnell did not prove that there was deceit in the Challenger's certification process, but again, he did establish the enormous pressures that affected the flawed decision to launch.

Finally, McConnell showed that the pressure to fly compromised safety in the final decision by NASA to launch Challenger. McConnell accurately portrayed the flawed NASA decision-making process, which, the Presidential Commission concluded, was the contributing cause of the accident. (15:82) McConnell's book, and the Commission's Report, both tell how the previously documented flaw in the field joints of the shuttle's Solid Rocket Boosters went uncorrected for years, and how the fatal decision to launch was made during a teleconference between NASA and Morton Thiokol the night before. McConnell accurately reflected the irony of the decision—that it was made over so many objections, any one of which, in retrospect, should have caused NASA to cancel the launch. Why would supposedly reasonable men make such a mistake? In the first place, McConnell said, they did it because they had, in effect, made the mistake before and "gotten away with it." The history of O-ring failure in the Solid Rocket Booster field joints did not become public knowledge until after the accident. Yet numerous officials at NASA and Morton Thiokol knew of the problem. For example, Lawrence Mulloy, Project Manager of the Solid Rocket Boosters for NASA at the Marshall Space Flight Center, was not only aware of the problem but had placed a formal constraint on the shuttle launch five times. Each time he granted a waiver to this constraint. (11:121) McConnell quoted Richard Feynman, a member of the Presidential Commission, who summarized NASA's actions as:

"A kind of Russian roulette. . . . [The shuttle] flies [with O-ring erosion] and nothing happens. Then it is suggested, therefore, that the risk is no longer so high for the next flights. We can lower our standards a little bit because we got away with it last time. . . . You got away with it, but it shouldn't be done over and over again like that. (15:143)

Mulloy was one of the key decision makers present at the teleconference the night before the Challenger accident. This conference was held at the request of a Thiokol official who was concerned about the effects of the cold weather on the O-rings. The position of Thiokol's engineers was that Challenger should not be launched unless the temperature was considerably warmer, to which Mulloy responded, "My God, Thiokol, when do you want me to launch? Next April?" (11:196) Under this type of pressure from Mulloy and other NASA officials, Thiokol reversed its objections. Testifying before Congress, Mulloy denied that he intentionally put pressure on Thiokol's engineers to change their minds. (18:439) Yet in their own testimony, the engineers said they perceived they were being pressured, and were surprised that NASA, which in the past had always made them prove it was safe to launch, was now asking them to prove that it was unsafe to launch, a much more difficult problem. (18:376) Clearly, McConnell established that pressure compromised safety in the flawed decision to launch Challenger. He did

not prove a direct causal link between pressure and the accident, but that was not his purpose. Rather he showed through the great weight of evidence—only a small portion of which has been repeated here—how pressure compromised much of the entire program, not just the launch decision.

Chapter Five

CONCLUSION

Challenger: A Major Malfunction, is, with some exceptions, a credible analysis of the Challenger accident. McConnell clearly showed the compromises NASA had to make to get the shuttle built, as well as the heavy burdens it had to bear in the form of political and fiscal pressures. He demonstrated how these pressures caused NASA to shift its focus from safety concerns to cost. He correctly showed how pressure continued to mount as the shuttle was declared "operational," and how it affected the final decision to launch Challenger. In the end, he did not offer any of his own suggestions for a revised space policy, but his conclusions closely followed the findings of the Presidential Commission, which he called, "a wise blueprint for the future operation of the shuttle." (11:255) However, his weakest arguments were those not covered in the Commission's Report, such as the influence of politics on the award of shuttle contracts. Here his lack of footnotes made it hard to judge the accuracy of his claims. My major objection to the book was its tone. For example, McConnell used the word "deceit" to describe the Flight Readiness Review process, but he clearly, did not prove any deception by the NASA officials involved. (11:18) Rather, the weight of McConnell's own evidence suggested that the enormous pressure they were under caused them to make serious errors in judgment. Likewise, McConnell failed to prove the "venality" on the part of NASA, one of his stated purposes for writing the book. (11:x) This was one of the few instances where McConnell's judgment differed from the references I used. William Rogers, Chairman of the Presidential Commission, and Senator Ernest Hollings both said they believed there was "no venality" on the part of NASA. (19:66) I agree with the reviewer who said that McConnell was far more effective when he avoided emotionalism and stayed with the facts. (14:53)

Challenger: A Major Malfunction is interesting, however, and offers some important lessons to the Air Force, and despite its sometimes emotional tone, I recommend it. I also highly recommend the Report of the Presidential Commission, as one work complements the other. Air Force members, even if they have never worked in a space-related activity, will find themselves relating to the myriad of pressures and complex decisions faced by workers throughout NASA. There are similar pressures on most highly visible or costly acquisition programs. The saddest part of the Challenger accident was that these pressures caused otherwise reasonable men to ignore the warning signs. Since the Air Force will continue to be deeply involved in complex programs like the space shuttle, we must learn to cope with pressure if we are to prevent a similar accident. This is the main lesson for the Air Force. As William Rogers said, "The real problem is, how are we going to deal with it in the future?" (19:99)

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