Case Study *The* Challenger *and* Columbia *Shuttle Disasters*

THE *CHALLENGER* DISASTER[71]

On January 28, 1986, the space shuttle *Challenger* rose into the sky, its seven crew strapped into their padded seats while the 2,000-ton vehicle vibrated as it gained speed and altitude. The launch was going perfectly. Seventy seconds had passed since liftoff and the shuttle was already 50,000 feet above the earth. From Mission Control at Houston's Johnson Space Center, Spacecraft Communicator Richard Covey instructed "*Challenger,* go at throttle up."

"Roger, go at throttle up," replied Commander Dick Scobee on board *Challenger.*

> But in the next few seconds *Challenger* slammed through increasingly violent manoeuvres. [Pilot] Mike Smith voiced sudden apprehension. "Uh-oh." In Mission Control, the pulsing digits on the screen abruptly stopped. . . Mission Control spokesman Steve Nesbitt sat above the four console tiers. For a long moment he stared around the silent, softly lit room. The red ascent trajectory line was stationary on the display screen across the room. Finally he spoke: "Flight controllers here looking very carefully at the situation. Obviously a major malfunction."[72]

The presidential commission, headed by former Secretary of State William Rogers, that was set up to investigate the cause of the disaster had little trouble identifying the physical cause. One of the joints on a booster rocket failed to seal. The "culprits" were the synthetic rubber O-rings that were designed to keep the rockets' superhot gases from escaping from the joints between the booster's four main segments. Resulting flames then burned through the shuttle's external fuel tank. Liquid hydrogen and liquid oxygen then mixed and ignited, causing the explosion that destroyed the *Challenger.*

However, "the Rogers Commission" investigations also revealed a lot about the internal workings of NASA. It was a geographically dispersed matrix organization. Its HQ was in Washington, D.C., where its most senior managers, including its head, NASA administrator James Begg, were mainly involved in lobbying activity reflecting the dependence on federal funds (and its subsequent vulnerability to fluctuations in funding). Mission Control was located at the Johnson Space Center in Houston, Texas; all propulsion aspects (main engines, rocket boosters, fuel tanks) were the responsibility of the Marshall Space Center in Huntsville, Alabama; while the assembly and launch took place at the Kennedy Space Center, Cape Canaveral, Florida.

The centers existed in an uneasy alliance of cooperation and competition. The Marshall Center in particular was known for its independent stance based on its proud tradition going right back through the *Apollo* program to the early days of rocketry with Werner von Braun. One manifestation of this pride, reinforced by its autocratic leader William Lucas, was that loyalty to Marshall came before all. Any problems that were identified were to be kept strictly "in-house," which at Marshall meant within Marshall. Those who failed to abide by this expectation—perhaps by talking too freely to other parts of NASA—could expect to receive a very public admonishment. Marshall was also at the center of a "can-do" attitude within NASA, the idea that great objectives are achievable if only the will is there. Born of the *Apollo* success, this took form in Marshall as a strong pride in the achievement of objectives and strongly held views that if a flight was to be delayed for any reason, it would not ever be because of something caused by Marshall.

The Commission also concluded that NASA was working with an unrealistic schedule for flights. The formal schedule was for 12 in 1984, 14 in 1985, 17 in 1986, 17 in 1987, and 24 in 1988. In practice it had managed five in 1984 and eight in 1985. Congressional critics had begun to question the appropriateness of continuing the current (high) level of funding to the program when NASA was falling so far short in meeting its own goals. However, rather than revise its schedules, these were retained and increased pressure to meet the schedules was placed by senior NASA managers on employees and contractors.

Most of the design and construction work in the shuttle program was contracted out. One of the contractors was Morton Thiokol, a Brigham City, Utah–based company that had won the contract to produce the solid rocket boosters. At the time of the *Challenger* launch, Thiokol and NASA were in the middle of contract negotiations that would determine whether or not Thiokol would be awarded a renewal of the contract.

The Commission revealed that there had been doubts about the reliability of the O-rings for some time. Since 1982 they had been labeled a "criticality 1" item, a label reserved for components whose failure would have a catastrophic result. However, despite evidence of O-ring erosion on many flights and requests from O-ring experts both inside NASA and inside Thiokol that flights be suspended until the problem was resolved, no action was taken. There was no reliable backup to the O-rings; this violated a long-standing NASA principle, but each time a flight was scheduled, this principle was formally waived.

A cold front hit Cape Canaveral the day before the scheduled launch; temperatures as low as 18° F were forecast for that night. Engineers from Thiokol expressed their serious reservations about the wisdom of launching in such conditions because the unusually cold conditions at the launch site would affect the O-rings' ability to seal. As a result, a teleconference was called for that evening.

At the teleconference, Roger Boisjoly, Thiokol's O-ring expert, argued that temperature was a factor in the performance of the rings and Robert Lund, Thiokol's vice president for engineering, stated that unless the temperature reached at least 53°F he did not want the launch to proceed. This position led to a strong reaction from NASA in the form of Lawrence Mulloy, Marshall's chief of the solid rocket booster program, and George Hardy, Marshall's deputy director of science and engineering. Hardy said that he was "appalled" at the reasoning behind Thiokol's recommendation to delay the launch and Mulloy argued that Thiokol had not proven the link between temperature and erosion of the O-rings, adding, "My God, Thiokol, when do you want me to launch, next April?" A view expressed at the Commission was that the Thiokol engineers had been put in a position where, in order for a delay to be approved, they were being required to prove that the O-rings would fail, rather than to prove that they would be safe at the low temperatures before a go-ahead was approved.

A break was taken in the teleconference to allow the Thiokol management team to consider their position. The Thiokol engineers were still unanimously opposed to a launch. Jerald Mason, Thiokol's senior vice president, asked Robert Lund to "take off his engineering hat and put on his management hat." Polling just the senior Thiokol managers present, not any of the engineers, Mason managed to get agreement to launch. The teleconference was then reconvened, the Thiokol approval was conveyed, no NASA managers expressed any reservations, and so the OK to launch was given.

POST-*CHALLENGER* CHANGES IN NASA

The Commission's recommendations included that NASA restructure its management to tighten control, set up a group dedicated to finding and tracking hazards in regard to shuttle safety, and review its critical items as well as submitting its redesign of the booster joint to a National Academy of Sciences group for verification. The official line within NASA was that the necessary changes had been successfully implemented. A NASA news release on January 22, 1988, stated that

> In response to various reviews of NASA safety and quality programs conducted in the aftermath of the *Challenger* accident and associated recommendations for improvements, NASA has acted to elevate agency emphasis on safety and implement organizational changes to strengthen SRM&QA [Safety, Reliability, Management & Quality Assurance] programs. . . There has been a 30 percent increase in NASA personnel assigned to SRM&QA functions since January 1986.

THE *COLUMBIA* DISASTER[73]

On February 1, 2003, the space shuttle *Columbia*'s braking rockets were fired as the shuttle headed toward a landing at Kennedy Space Center. As it passed over the United States, observers spotted glowing pieces of debris falling from the shuttle. At 8:59:32 a.m. EST, commander Rick Husband replied to a call from Mission Control, but his acknowledgment ceased mid-transmission. About a minute later, *Columbia* broke up, killing its seven astronauts.

The *Columbia* Accident Investigation Board (CAIB or Board) was formed to identify what had happened. In its August 2003 final report, it identified the physical cause of the accident. A 1.67-pound slab of insulating foam fell off the external fuel tank 81.7 seconds after *Columbia* was launched (January 16), hit the left wing, and caused a breach in the tiles designed to protect the aluminum wing from the heat of reentry. On reentry, the breach allowed superheated gas into the wing, which, as a result, melted in critical areas.

But the Board also addressed the nonphysical factors that contributed to the disaster. Because of no improvement in the level of NASA funding, NASA Administrator Daniel Goldin pushed a "Faster, Better, Cheaper" program that impacted on the shuttle program.

> The premium placed on maintaining an operational schedule, combined with ever-decreasing resources, gradually led Shuttle managers and engineers to miss signals of potential danger. Foam strikes on the Orbiter's Thermal Protection System, no matter what the size of the debris, were "normalized" and accepted as not being a "safety-of-flight risk."[74]

The shuttle workforce was downsized and various shuttle program responsibilities (including safety oversight) had been outsourced. Success was being measured through cost reduction and the meeting of schedules and the shuttle was still being mischaracterized as operational rather than developmental technology.

The Board particularly identified NASA's organizational culture as being as much to blame as the physical causes. According to the Board:

> Though NASA underwent many management reforms in the wake of the *Challenger* accident, . . . the agency's powerful human space flight culture remained intact, as did many practices . . . such as inadequate concern over deviations from expected performance, a silent safety program, and schedule pressure.[75]

Further, the Board stated:

> Cultural traits and organization practices detrimental to safety and reliability were allowed to develop, including: reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements/specifications); organizational barriers which prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements, and the evolution of an informal chain of command and decision-making processes that operated outside the organization's rules.[76]

According to the Board: "NASA's blind spot is that it believes it has a strong safety culture [when in fact it] has become reactive, complacent, and dominated by unjustified optimism."[77] The Board found that while NASA managers said that staff were encouraged to identify safety issues and bring these to the attention of management, there was evidence to the contrary, including insufficient deference to engineers and other technical experts. Also, while NASA's safety policy specified oversight at headquarters combined with decentralized execution of safety programs at the program and project levels, the Board found that the reality was that NASA had not been willing to give the latter the independent status for this to actually work.

The external tank of the shuttle was designed with a layer of insulation tiles that were designed to stick to the tank, not to be shed. Similarly, the shuttle's heat shield was not designed to be damaged (the tiles are very fragile, so much so that the shuttle isn't allowed to fly in rain or stay outside when it hails).

However, the experience of previous launches was that foam sometimes did fall off and tiles sometimes were damaged. But this was occurring without any noticeable negative effect on the functioning of the shuttle. Of 112 flights prior to the fatal *Columbia* flight, foam had been shed 70 times and tiles had come back damaged every time. Over time, NASA managers got used to the idea that such damage would occur and convinced themselves there was no safety-of-flight issue. The Board reported that "program management made erroneous assumptions about the robustness of a system based on prior success rather than on dependable engineering data and rigorous testing."[78]

The report cites eight separate "missed opportunities" by NASA during the 16-day flight to respond to expressions of concern or offers that could have assisted. For example, engineer Rodney Rocha's e-mail four days into the mission asking Johnson Space Center if the crew had been directed to inspect *Columbia*'s left wing for damage had been left unanswered. Also, NASA had failed to accept the U.S. Defense Department's offer to obtain spy satellite imagery of the damaged shuttle.

The CAIB faulted NASA managers for assuming that there would be nothing that could be done if the foam strike had indeed caused serious damage to the TPS. After the accident, NASA engineers, working on the request of the CAIB, concluded that it might have been possible either to repair the wing using materials on board *Columbia* or to rescue the crew through a sped-up launch of the shuttle *Atlantis*.

The Board also criticized NASA managers for not taking steps to ensure that minority and dissenting voices were heard. It commented:

> all voices must be heard, which can be difficult when facing a hierarchy. An employees' location in the hierarchy can encourage silence. Organizations interested in safety must take steps to guarantee that all relevant information is presented to decision makers. This did not happen in the meetings during the *Columbia* mission. . . Program managers created huge barriers against dissenting opinions by stating preconceived conclusions based on subjective knowledge and experience, rather than on solid data.[79]

The NASA intercenter photo working group had recommended that the loss of foam be classified as an in-flight anomaly—a much more critical designation than it currently had—but this was not approved by the program requirements control board. The engineers were placed in the situation of having to prove that a safety-of-flight issue existed before the shuttle program management would take action to get images of the left wing. The Board found that this was just one example of a more general situation where those concerned with safety found themselves having to prove that a situation was unsafe, whereas it might be reasonably expected that the emphasis would be on proving that a high level of safety existed.

The Board also concluded that there was an unofficial hierarchy among NASA programs and directorates that hindered the flow of communications:

> Management decisions made during *Columbia*'s final flight reflect missed opportunities, blocked or ineffective communication channels, flawed analysis, and ineffective leadership. Perhaps most striking is the fact that management . . . displayed no interest in understanding a problem and its implications. Because managers failed to avail themselves of the wide range of expertise and opinion necessary to achieve the best answer to the debris strike question—"was this a safety-of-flight concern?"—some Space Shuttle Program managers failed to fulfill the implicit contract to do whatever is possible to ensure the safety of the crew. In fact, their management techniques unknowingly imposed barriers that kept at bay both engineering concerns and dissenting views, and ultimately helped create "blind spots" that prevented them from seeing the danger the foam strike posed.[80]

The Board concluded that the post-*Challenger* changes "were undone over time by management actions"[81] and that "the pre-*Challenger* layers of processes, boards and panels that had produced a false sense of confidence in the system and its level of safety returned in full force prior to *Columbia*."[82]

Questions

1. What aspects of NASA practice revealed in the aftermath of the *Columbia* disaster suggest that the changes sought in the aftermath of the *Challenger* disaster were not sustained?
2. This chapter provides a discussion of actions that can be taken to sustain change. Which of the following do you see as most applicable to addressing the situation described in this case?
   - Redesign roles.
   - Redesign reward system.
   - Link selection decisions to change objectives.
   - Act consistently with advocated actions.
   - Encourage "voluntary acts of initiative."
   - Measure progress.
   - Celebrate en route.
   - Fine-tune.
3. This chapter provides some words of caution in terms of what to be alert to in regard to sustaining change. Which of the following do you see as most applicable to addressing the situation described in this case?
   - Expect some unanticipated outcomes.
   - Be alert to measurement limitations.
   - Don't "declare victory" too soon.
   - Beware escalation of commitment.
   - Recognize "productive failures."