Section V

NASA Cultures

INTRODUCTION

One of the main conclusions of the Columbia Accident Investigation Board (CAIB) was that "the organizational causes of this accident are rooted in the Space Shuttle Program's history and culture" and that over many years at NASA, "cultural traits and organizational practices detrimental to safety and reliability were allowed to develop . . . ."[1] The idea of organizational culture is therefore a critical issue, though, as La Porte points out in this section, it is a "slippery concept" with a "high degree of operational ambiguity, its use subject to stiff criticism." Although organizational culture may in fact mean many things, all three authors in this section find the concept useful, for lack of a better term, to refer to what La Porte characterizes in the NASA context as "the norms, shared perceptions, work ways, and informal traditions that arise within the operating and overseeing groups closely involved with the systems of hazard." Slippery as it may be as a concept, organizational culture is important to understanding real-world questions, such as those that Vaughan (a sociologist by profession and a staff member of the CAIB) enumerates in her article: How do organizations gradually slide into negative patterns? Why do negative patterns persist? Why do organizations fail to learn from mistakes and accidents? Although human and technical failures are important, she finds their root causes in organizational systems. In order to reduce accidents, therefore, organizational systems and their cultures must be studied and understood.

The first two papers in this section concentrate on organizational culture as it relates to accidents in human spaceflight, here restricted to those in NASA's space program. Vaughan focuses on the Space Shuttle *Challenger* and *Columbia* accidents in 1986 and 2003, respectively, while Brown adds the ground-based Apollo 204 (also known as Apollo 1) fire in 1967. Altogether, 17 astronauts were killed in these accidents, triggering massive criticism, investigations, official reports, and personal and organizational soul-searching. Vaughan finds that, due to overly ambitious goals in an organization strapped for resources, NASA's Apollo-era technical culture was turned into a "culture of production" by the time of the *Challenger* accident, a culture that persisted through *Columbia* and was characterized by "cultural mandates for business-like efficiency, production pressures, allegiance to hierarchy, and rule-following." The result was what she calls "the normalization of deviance"—in other words, over time, that which was deviant or anomalous incrementally became redefined as normal, most notably Solid Rocket Booster (SRB) O-ring behavior in cold weather for *Challenger* and foam hits from the External

1. Columbia Accident Investigation Board, *Report* (Washington, DC: NASA and GPO, August 2003), chap. 8. Chapter 8 was largely written by Diane Vaughan.

Tank (ET) to the wing of the Shuttle in the case of *Columbia*. Lack of communication, which she terms "structural secrecy," within layers of NASA administration compounded the problem.

Vaughan believes that the thesis of "history as cause" in the CAIB report demonstrates how the history of decisions made by politicians and by NASA engineers and managers combined twice to produce disaster. She warns that economic strain and schedule pressure still exist at NASA and that in such circumstances, system effects, including accidents, tend to reproduce. It is important to note that it is not possible to prevent all accidents, but, she concludes, the *Challenger* and *Columbia* accidents, with their long incubation periods, were preventable. In her view, reducing the probability of accidents means changing NASA's culture as well as externally imposed expectations and limitations, a difficult and ongoing process, one in which social scientists must play a role in a systematic way.

Brown, a historian of technology in the Science, Technology and Society program at MIT, takes another approach by analyzing the "disjunctures" in the three fatal NASA accidents. In the case of Apollo 204, the disjuncture is between the engineers designing and managing the spacecraft and the technicians manufacturing it. For the two Shuttle accidents, the disjuncture is between managers controlling the Shuttle program and engineers maintaining and analyzing the spacecraft. By way of explaining these disjunctures, he analyzes the three accident reports and relates their styles and conclusions to the engineering practices of NASA and its contractors. Whereas the Apollo 204 report concluded that poor engineering practice was the sole cause of the fire, the Challenger Commission, by contrast, emphasized secondary causes in addition to the technical O-ring failure, including the decision to launch, schedule pressure, and a weak safety system. As emphasized in Vaughan's paper, the *Columbia* report went even further, pointing (partly at her urging) to equal importance for technical and social causes.

Reading the three accident reports to gain historical insights, Brown finds that they suggest a growing separation between management and engineering over the period under review. They reveal an asymmetry assumed by the accident investigators, in the sense that the technical/engineering causes are to be understood as "context-free and ahistorical activity," while management causes are to be understood in a complex historical and cultural framework. Brown therefore asks two questions: what historical processes caused this separation between management and engineering? And what changes in engineering over the quarter century covered by the accident reports might be important for placing engineering in its own historical and cultural context? In answer to the latter, he enumerates three changes: widespread use of computers, changes in engineering education, and the move away from systems engineering as an organizing philosophy. During the period 1967 to 2003, modeling, testing, and simulation had changed from hand calibration to computer-based calculations, resulting in loss of transparency. For example, Boeing engineers who used a computer model known as "Crater" to predict the effects of foam impacts on the Shuttle were unaware of its limitations precisely because the process had been computerized; this ignorance greatly affected their ability to make engineering judgments. Over the same period, engineering education, which was moving toward science and away from design, rendered engineering more abstract and less connected to reality. The *Challenger* and *Columbia* reports criticized the lack of engineering design expertise in some of the contractors involved. Finally, whereas systems engineering was the guiding philosophy of the space program at the time of the Apollo 204 fire, Total Quality Management and the "faster, better, cheaper" approach replaced system engineering during the 1990s for senior management, while engineers still used the tools of system management.

La Porte takes a broader view, tackling the issues of high-reliability systems that must operate across decades or generations, as NASA must do in planning and implementing its vision to take humans to the Moon and Mars. Drawing on a variety of empirical studies in the social and management sciences, including nuclear power plant operation and waste disposal, he undertakes this analysis of highly reliable operations that take place over decades, and he assumes high levels of public trust over that time. Such long-term operations also involve issues of institutional constancy. He finds, among other things, that high-reliability organizations (HROs) must have technical competence, stringent quality-assurance measures, flexibility and redundancy in operations, decentralized decision-making, and an unusual willingness to reward the discovery and reporting of error without assigning blame. Maintaining an organizational culture of reliability exhibiting these characteristics is difficult, but important. Nor can HROs become overly obsessed with safety; they must strive equally for high levels of production and safety. If the Shuttle never launches, NASA fails its mission in equal measure as it does when it has accidents. La Porte also emphasizes the importance of external "watchers," including congressional committees and investigating boards, to sustaining high-reliability organizations, a factor also evident in Vaughan's and Brown's analyses of the accident reports.

La Porte notes that, for obvious reasons, maintaining these characteristics over long-term, even trans-generational, efforts is the least-understood process in terms of empirical studies. In an attempt to shed light on this problem, he examines the idea of "institutional constancy" and concludes that in order for such long-term efforts to be successful, an agency such as NASA must demonstrate to the public and to Congress that it can be trusted to keep its word long into the future, and it must "show the capacity to enact programs that are faithful to the original spirit of its commitments." La Porte discusses the characteristics associated with institutional constancy, summarized in his table 13.2. He, too, calls for further empirical and analytical study, especially to delineate requirements for long-term institutional constancy and trustworthiness.

Implicitly or explicitly, these papers also deal with the question of risk. The Challenger Commission found that its managers and engineers understood risk in very different ways, with the engineers seeing it as quantifiable and the managers as flexible and manageable. The Columbia Accident Investigation Board noted similar differences in the perception of risk. La Porte broaches the question of risk averseness and the public's risk-averse demand for very reliable operations of intrinsically hazardous systems. He suggests research on the conditions under which the public would be willing to accept more risk, given that such operations can never be risk-free. NASA's "Risk and Exploration" symposium, held in late 2004 in the midst of the Hubble Space Telescope controversy and with the Shuttle still grounded, came to a similar conclusion: the public needs to be made aware that accidents are not completely preventable.[2]

Nevertheless, the three views in this section, by a sociologist, a historian, and a political scientist, shed important light on NASA cultures and, if one accepts their arguments, on ways to reduce accidents in what inevitably remains a high-risk endeavor. How to balance risk and exploration is the key question.

2. Steven J. Dick and Keith Cowing, *Risk and Exploration: Earth, Sea and Sky* (Washington, DC: NASA SP-2005-4701, 2005).

Chapter 11

Changing NASA: The Challenges of Organizational System Failures

Diane Vaughan

In both the *Columbia* and *Challenger* accidents, NASA made a gradual slide into disaster. The history of decisions about the risk of Solid Rocket Booster O-ring erosion that led to *Challenger* and the foam debris that resulted in *Columbia* is littered with early warning signs that were misinterpreted. For years preceding both accidents, technical experts defined risk away by repeatedly normalizing technical anomalies that deviated from expected performance. The significance of a long incubation period leading up to an accident is that it provides greater opportunity to intervene and to turn things around, avoiding the harmful outcome. But that did not happen. The Columbia Accident Investigation Board's report concluded that NASA's second Shuttle accident resulted from an organizational system failure, pointing out that the systemic causes of *Challenger* had not been fixed.[1] In fact, both disasters were triggered by NASA's organizational system: a complex constellation of factors including NASA's political/economic environment, organization structure, and layered cultures that affected how people making technical decisions assessed risk. These three aspects of NASA's organizational system interacted, explaining the origins of both accidents.

The amazing similarity and persistence of these systemic flaws over the 17 years separating the two accidents raise several questions: How do organizations gradually slide into negative patterns? Why do negative patterns persist? Why do organizations fail to learn from mistakes and accidents? In this chapter, I examine NASA's experience to consider the challenges of changing NASA's organizational system and to gain some new insight into these questions. My data for this analysis are my *Challenger* research, experience as a researcher and writer on the staff of the Columbia Accident Investigation Board, conversations and meetings with NASA personnel at Headquarters and a NASA "Forty Top Leaders Conference" soon after the CAIB report release, and, finally, a content analysis of the two official accident investigation

1. Columbia Accident Investigation Board, *Report* (Washington, DC: NASA and GPO, August 2003).

reports.[2] Summarizing from my testimony before the CAIB, I begin with a brief comparison of the social causes of *Challenger* and *Columbia* to show the systemic causes of both, how the two accidents were similar and different, and how and why NASA twice made an incremental descent into disaster.[3] I then review the conclusions of the Presidential Commission investigating the *Challenger* accident and their recommendations for change, the changes NASA made, and why those changes failed to prevent the identical mistake from recurring in *Columbia*.[4] Next, I contrast the Commission's findings with those of the CAIB report and discuss the CAIB's recommendations for changing NASA, the direction NASA is taking in making changes, and the challenges the space agency faces in preventing yet a third Shuttle accident.

Robert Jervis, in *System Effects*, considers how social systems work and why so often they produce unintended consequences.[5] He stresses the importance of dense interconnections and how units and relations with others are strongly influenced by interactions at other places and at earlier periods of time. Thus, disturbing a system produces chains of consequences that extend over time and have multiple effects that cannot be anticipated. I will argue in this chapter for the importance of analyzing and understanding the dynamics of organizational system failures and of connecting strategies for change with the systemic causes of problems. The "usual remedy" in the aftermath of a technological accident is to correct the causes of a technical failure and alter human factors that were responsible so that they, too, can be fixed. However, the root causes of both human and technical failure can be found in organizational systems. Thus, remedies targeting only the technology and individual error are insufficient. Neither complacency, negligence, ignorance, poor training, fatigue, nor carelessness of individuals explains why, in the face of increasing in-flight damage, NASA made flawed decisions, continuing to fly. The lessons to be learned from NASA's experience are, first, in order to reduce the potential for gradual slides and repeating negative patterns, NASA and other organizations dealing with risky technologies must go beyond the search for technical causes and individual error and search the full range of social causes located in the organizational system. Second, designing and implementing solutions that are matched to those causes is a crucial but challenging step in preventing a recurrence.

2. Diane Vaughan, *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA* (Chicago: University of Chicago Press, 1996); Diane Vaughan, "History as Cause: *Columbia* and *Challenger*," chap. 8 in Columbia Accident Investigation Board, *Report*; Presidential Commission on the Space Shuttle *Challenger* Accident, *Report to the President by the Presidential Commission on the Space Shuttle Challenger Accident*, 5 vols. (Washington, DC: GPO, 1986).

3. Vaughan, "History as Cause," pp. 185–204.

4. Presidential Commission on the Space Shuttle *Challenger* Accident, *Report to the President*.

5. Robert Jervis, *System Effects: Complexity in Political and Social Life* (Princeton: Princeton University Press, 1997).

NASA'S SLIPPERY SLOPE: O-RINGS, FOAM DEBRIS, AND NORMALIZING DEVIANCE

In a press conference a few days after the *Columbia* tragedy, NASA's Space Shuttle Program Manager, Ron Dittemore, held up a large piece of foam approximately the size of the one that fatally struck *Columbia* and discounted it as a probable cause of the accident, saying, "We were comfortable with it." Prior to the *Challenger* accident in 1986, that phrase might have been said about O-ring erosion by the person then occupying Dittemore's position. The O-ring erosion that caused the loss of *Challenger* and the foam debris problem that took *Columbia* out of the sky both had a long history. Neither anomaly was permitted by design specifications, yet NASA managers and engineers accepted the first occurrence, then accepted repeated occurrences, concluding after examining each incident that these deviations from predicted performance were normal and acceptable. In the years preceding NASA's two

This photograph of the Space Shuttle *Challenger* accident on 28 January 1986 was taken by a 70-millimeter tracking camera at site 15, south of Pad 39B, at 11:39:16.061 EST. One of the Solid Rocket Boosters can be seen at the top of the view. *(Image no. STS-51L 10181; Kennedy Space Center alternative photo no. is 108-KSC-86PC-147)* accidents, managers and engineers had normalized recurring technical anomalies—anomalies that, according to design specifications, were not allowed. How—and why—was the normalization of technical deviations possible?

We must avoid the luxuries of retrospection, when all the flawed decisions of the past are clear and can be directly linked to the harmful outcomes, and instead see the events preceding each accident as did the personnel making risk assessments, as the problems unfolded. As managers and engineers were making decisions, continuing to launch under the circumstances they had made sense to them. The immediate social context of decision-making was an important factor. Although NASA treated the Shuttle as if it were an operational vehicle, it was experimental: alterations of design and unpredictable flight conditions led to anomalies on many parts on every mission. Because having anomalies was normal, neither O-ring erosion nor foam debris was the signal of danger it seemed in retrospect. In both cases, engineering decisions were made incrementally, anomaly by anomaly. Accepting the first deviation set a precedent on which future decisions were based. After inspection and analysis, engineers calculated a safety margin that placed initial damage within a safety margin showing that the design could tolerate even more.

In addition, the pattern of information had an impact on how managers and engineers were defining and redefining risk. As the anomalies began to occur, engineers saw signals of danger that were mixed—an anomalous incident would be followed by a mission with none or a reduced level of damage, so they believed they had fixed the problem and understood the parameters of cause and effect. Or signals were weak—incidents that were outside what had become defined as the acceptable parameters were not alarming because their circumstances were so unprecedented that they were viewed as unlikely to repeat. And finally, signals became routine, occurring so frequently that the repeating pattern became a sign that the machine was operating as predicted. The result was the production of a cultural belief that the problems were not a threat to flight safety, a belief repeatedly reinforced by mission success. Both erosion and foam debris were downgraded in official systems categorizing risk over time, institutionalizing the definition of these problems as low-level problems.

Although these patterns are identical in the two accidents, two differences are noteworthy. First, for O-ring erosion, the first incident of erosion occurred on the second Shuttle flight, which was the beginning of problem normalization; for foam debris, the normalization of the technical deviation began *even before the first Shuttle was launched.* Damage to the thermal-protection system—the thousands of tiles on the orbiter to guard against the heat of reentry—was expected due to the forces at launch and during flight, such that replacement of damaged tiles was defined from the design stage as a maintenance problem that had to be budgeted. Thus, when foam debris damage was observed on the orbiter tiles after the first Shuttle flight in 1981, it was defined as a maintenance problem, not a flight hazard. This early definition of the foam problem as routine and normal perhaps explains a second difference. Before the *Challenger* disaster, engineering concerns about proceeding with more frequent and serious erosion were marked by a paper trail of memos. The foam debris problem history also had escalations in occurrence but showed no such paper trail, no worried engineers.

These decisions did not occur in a vacuum. To understand how these two technical anomalies continued to be normalized, we need to grasp the important role that NASA's political and budgetary environment played and how the history of the Space Shuttle program affected the local situation. Decisions made by leaders in the White House and Congress left the space agency constantly strapped for resources to meet its own sometimes overly ambitious goals. The Agency's institutional history was one of competition and scarcity, which created a "trickle-down effect."[6] Thus, the original, pure technical culture of NASA's Apollo era was reshaped into a *culture of production* that existed at the time of *Challenger* and persisted over 50 launches later, for *Columbia*. NASA's original technical culture was reshaped by new cultural mandates for business-like efficiency, production pressures, allegiance to hierarchy, and rule-following.

This culture of production reinforced the decisions to proceed. Meeting deadlines and schedule was important to NASA's scientific launch imperatives and also for securing annual congressional funding. Flight always was halted to permanently correct other problems that were a clear threat to take the Shuttle out of the sky (a cracked fuel duct to the Space Shuttle main engine, for example), but the schedule and resources could not give way for a thorough hazard analysis of ambiguous, low-lying problems that the vehicle seemed to be tolerating. Indeed, the successes of the program led to a belief that NASA's Shuttle was an operational, not an experimental, system, thus affirming that it was safe to fly. Finally, the fact that managers and engineers obeyed the cultural mandates of hierarchy and protocol reinforced the belief that the anomalies were not a threat to flight safety because NASA personnel were convinced, having followed all the rules, that they had done everything possible to assure mission safety.

Both problems had gone on for years. Why had no one recognized what was happening and intervened, halting NASA's two transitions into disaster? The final piece of the organizational system contributing to both accidents was *structural secrecy*. By this I refer to how organization structure concealed the seriousness of the problems from people with responsibility for technical oversight who might have turned the situation around prior to both

6. Diane Vaughan, "The Trickle-Down Effect: Policy Decisions, Risky Work, and the *Challenger* Accident," *California Management Review* 39 (winter 1997): 1–23.

accidents. Organization structure affected not only the flow of information, a chronic problem in all organizations, but also how that information was interpreted. Neither NASA's several safety organizations nor the four-tiered Flight Readiness Review (FRR), a formal, adversarial, open-to-all structure designed to vet all engineering risk assessments prior to launch, called a halt to flying with these anomalies. Top administrators and regulators alike were dependent upon project groups for engineering information and analysis. As managers and engineers reinterpreted warning signs as weak, mixed, and routine signals, normalizing deviance, that diagnosis was what got passed up the hierarchy. Instead of reversing the pattern of flying with erosion and foam debris, Flight Readiness Review ratified it.

The structure of safety regulation also affected understandings about risk. NASA's internal safety system—both times—a) had suffered safety personnel cuts and de-skilling as more oversight responsibility was shifted to contractors in an economy move and b) was dependent upon the parent organization for authority and funding, so it had no ability to independently run tests that might challenge existing assessments. NASA's external safety panel had the advantage of independence but was handicapped by inspection at infrequent intervals. Unless NASA engineers defined something as a serious problem, it was not brought to the attention of safety personnel. As a result of structural secrecy, the cultural belief that it was safe to fly with these two anomalies prevailed throughout the Agency in the years prior to each of NASA's tragedies.

TWO ACCIDENTS: THE REPRODUCTION OF SYSTEM EFFECTS

I have shown how the organizational system worked in the years preceding both accidents to normalize the technical anomalies: the immediate context of decision-making—patterns of information; the context of multiple problems; mixed, weak, and routine signals—the culture of production, and structural secrecy all interacted in complex ways to neutralize and normalize risk and keep NASA proceeding with missions. To show how NASA's organizational system affected the crucial decisions made immediately before both accidents, I now revisit the unprecedented circumstances that created yet new signals of potential danger: an emergency teleconference held on the eve of the 1986 *Challenger* launch, when worried engineers recommended not launching in unprecedented cold temperatures predicted for the next day, and the events at NASA after the 2003 *Columbia* foam debris strike, when engineers again expressed concerns for flight safety. I selectively use examples of these incidents to show similarities and differences, recognizing that doing so greatly simplifies enormously complicated interactions.[7] An initial difference

7. For details, see Vaughan, *Challenger Launch Decision*, chap. 8; and CAIB, *Report*, chap. 6.

that mattered was the window of opportunity for decision and number of people involved. The *Challenger* teleconference was held prelaunch, involved 34 people in three locations, consuming several hours of one day, the proceedings unknown to others at NASA. *Columbia*'s discussion was postlaunch, with a window of 16 days before reentry, and videos of the foam debris strike were widely circulated, involving people throughout the Agency. They can be called crisis situations only in retrospect because at the time these events were unfolding, many participants did not define it as a crisis situation, which was, in fact, one of the problems.

In both scenarios, people facing unprecedented situations came to the table with a cultural belief in the risk acceptability of O-ring erosion and foam debris based on years of engineering analysis and flight experience. Thus, both the history of decision-making and the history of political and budgetary decisions by elites had system effects. As these selected examples show, the mandates of the culture of production for efficiency, schedule, hierarchy, and protocol infiltrated the proceedings. Also, structural secrecy acted as before, feeding into the tragic outcomes.

- Schedule pressure showed when *Challenger*'s Solid Rocket Booster Project Manager and *Columbia*'s Mission Management Team (MMT) Head, responsible for both schedule and safety, were confronted with engineering concerns. Both managers repeated that preexisting definition of risk, sending to others a message about the desired result. Schedule pressure on managers' thinking also showed when engineers proposed a temperature criterion for *Challenger* that would jeopardize the launch schedule for all launches, and for *Columbia* when obtaining satellite imagery would require the orbiter to change its flight orientation, thus prolonging the mission and likely jeopardizing the timing of an important future launch. Believing the safety of the mission was not a factor, both managers focused on future flights, making decisions that minimized the risk of delay.

- In both cases, hierarchy and protocol dominated; deference to engineering expertise was missing. In the *Challenger* teleconference, unprecedented and therefore open to innovation, participants automatically conformed to formal, prelaunch, hierarchical Flight Readiness Review procedures, placing engineers in a secondary role. The postlaunch *Columbia* Mission Management Team operation, intentionally decentralized to amass information quickly, also operated in a hierarchical, centralized manner that reduced engineering input. Further, engineering attempts to get satellite imagery were blocked for not having followed appropriate protocol. In both cases, norms requiring quantitative data were pushed, rendering engineering concerns insufficient; they were asked to prove that it was unsafe to fly, a reverse of the normal situation, which was to prove it was safe to fly. Engineers animated by concern took the issue to a certain level, then, discouraged and intimidated by management response, fell silent. A difference for *Columbia*: the rule on rule-following was inoperative for management, whose definition of risk was influenced by an "informal chain of command"—one influential person's opinion, not hard data.

- Organization structure created structural secrecy, as people structurally peripheral to the technical issue, either by location or expertise or rank, had information but did not feel empowered to speak up. Thus, critical input was lost to the decision-making. The weakened safety system was silent. No safety representative was told of the *Challenger* teleconference. Present at the *Columbia* MMT meeting but weak in authority, safety personnel interjected no cautions or adversarial challenges; information dependence and organizational dependence gave them no recourse but to follow the management lead.

This overview shows these accidents as the unanticipated consequences of system effects, the causes located in the dynamic connection between three layers of NASA's organizational system:

1) Interaction and the Normalization of Deviance: A history of decision-making in which, incrementally, meanings developed in which the unacceptable became acceptable. The first decisions became a basis for subsequent ones in which technical anomalies—signals of danger—were normalized, creating a cultural belief in the safety of foam and O-ring anomalies.

2) The Culture of Production: History was important in a second way. Historic external political and budgetary decisions had system effects, trickling down through the organization, converting NASA's original, pure technical culture into a culture of production that merged bureaucratic, technical, and cost/schedule/efficiency mandates that, in turn, reinforced decisions to continue flying with flaws.

3) Structural Secrecy: These same external forces affected NASA's organization structure and the structure of the safety system, which in turn affected the interpretation of the problem, so that the seriousness of these two anomalies was, in effect, unknown to those in a position to intervene. Instead, before the crisis events immediately preceding

the accidents, a consensus about these anomalies existed, including among agents of social control—top administrators and safety personnel—who failed to intervene to reverse the trend.

With these systemic social causes in mind, I now turn to the problem of repeating negative patterns and learning from mistake by considering the "Findings" and "Recommendations" of the report of the Presidential Commission on the Space Shuttle *Challenger* Accident, NASA's changes in response, and why the changes NASA implemented failed to prevent a second tragedy.[8]

THE PRESIDENTIAL COMMISSION: CONNECTING CAUSES AND STRATEGIES FOR CONTROL

Published in June 1986, the Presidential Commission's report followed the traditional accident investigation format of prioritizing the technical causes of the accident and identifying human factors as "contributing causes," meaning that they were of lesser, not equal, importance. NASA's organizational system was not attributed causal significance. However, the report was pathbreaking in the amount of its coverage of human factors, going well beyond the usual focus on individual incompetence, poor training, negligence, mistake, and physical or mental impairment.

Chapters 5 and 6 examine decisions about the O-ring problems, adhering to the traditional human factors/individual failure model. Chapter 5, "The Contributing Cause of the Accident," examines the controversial eve-of-the-launch teleconference. A "flawed decision making process" is cited as the primary causal agent. Managerial failures dominate the empirical "Findings": the teleconference was not managed so that the outcome reflected the opposition of many contractor engineers and some of NASA's engineers; managers in charge had a tendency to solve problems internally, not forwarding them to all hierarchical levels; the contractor reversed its first recommendation for delay "at the urging of Marshall [Space Flight Center] . . . to accommodate a major customer."[9]

Chapter 6, "An Accident Rooted in History," chronicled the history of O-ring decision-making in the years preceding the teleconference. Again, the empirical Findings located cause in individual failures.[10] Inadequate testing was done; neither the contractor nor NASA understood why the O-ring anomalies were happening; escalated risk-taking was endemic, apparently "because they got away with it the last time"; in a thorough review at Headquarters in 1985, information "was sufficiently detailed to require corrective action prior

8. Presidential Commission on the Space Shuttle *Challenger* Accident, *Report to the President*.
9. Ibid., p. 104.
10. Ibid., p. 148.

to the next flight"; managers and engineers failed to carefully analyze flight history, so data were not available on the eve of *Challenger's* launch to properly evaluate the risks.[11] The system failure cited was in the anomaly tracking system, which permitted flight to continue despite erosion, with no record of waivers or launch constraints, and paid attention only to anomalies "outside the data base."

Both chapters described decision-making, focusing on interaction, but did not explain why decisions were made as they were. Chapter 7, "The Silent Safety Program," turned to organizational matters, initially addressing them in the traditional accident investigation frame. The Commission noted the failures: "lack of problem reporting requirements, inadequate trend analysis, misrepresentation of criticality and lack of involvement in critical discussions."[12] For example, they found so many problems listed on NASA's Critical Items List that the number reduced the seriousness of each. Acknowledging that top administrators were unaware of the seriousness of the O-ring problems, the Commission labeled the problem a "communication failure," thus deflecting attention from organization structure as a cause of the problems. In evaluating NASA's several safety offices and panels, however, the Commission made a break with the human factors approach by addressing the structure of regulatory relations. The Commission found that in-house safety programs were dependent upon the parent organization for funding, personnel, and authority. This dependence showed when NASA reduced the safety workforce even as the flight rate increased. In another economy move, NASA had increased reliance upon contractors, relegating many NASA technical experts to safety oversight of contractor activities, becoming dependent on contractors rather than retaining safety control in-house.

In chapter 8, "Pressures on the System," the Commission took an unprecedented step by examining schedule pressure and its effects on the NASA organization. However, this pressure, according to the report, was NASA-initiated, with no reference to external demands or restrictions on the Agency that might have contributed to it. The fault rested with NASA's own leaders. "NASA began a planned acceleration of the Space Shuttle launch schedule .... In establishing the schedule, NASA had not provided adequate resources for its attainment. As a result, the capabilities of the system were strained . . . ."[13] The system being analyzed is the flight production system: all the processes that must be engaged and completed in order to launch a mission. The report states that NASA declared the Shuttle "operational" after the fourth experimental flight even though the Agency was not prepared to meet the demands of an

11. Ibid., p. 148.
12. Ibid., p. 152.
13. Ibid., p. 164.

operational schedule. This belief in operational capability, according to the Commission, was reinforced by NASA's history of 24 launches without a failure prior to *Challenger* and to NASA's legendary "can-do" attitude, in which the space agency always rose to the challenge, draining resources away from safety-essential functions to do it.[14]

Next consider the fit between the Commission's "Findings," above, and their "Recommendations" for change, summarized as follows.[15] Many of the changes, if properly implemented, would reduce structural secrecy. The Commission mandated a review of Shuttle Management Structure because Project Managers felt more accountable to their Center administration than the Shuttle Program Director, thus vital information bypassed Headquarters. The Commission targeted "poor communications" by mandating that NASA eliminate the tendency of managers not to report upward, "whether by changes of personnel, organization, indoctrination or all three"; develop rules regarding launch constraints; and record Flight Readiness Reviews and Mission Management Team Meetings. Astronauts were to be brought into management to instill a keen awareness of risk and safety.[16]

Centralizing safety oversight, a new Shuttle Safety Panel would report to the Shuttle Program Manager. It would attend to Shuttle operations, rules and requirements associated with launch decisions, flight readiness, and risk management. Also, an independent Office of Safety, Reliability and Quality Assurance would be established, headed by an Associate NASA Administrator, with direct authority over all safety bodies throughout the Agency, and reporting to the NASA Administrator. With designated funding to give it independence, SR&QA would direct reporting and documentation of problems and trends affecting flight safety. Last, but by no means least, to deal with schedule pressures, the Commission recommended that NASA establish a flight rate that was consistent with its resources.

These were the official lessons to be learned from *Challenger*. The Commission's "Findings" and "Recommendations," in contrast to those later forthcoming from the CAIB, were few and very general, leaving NASA considerable leeway in how to implement them. How did the space agency respond? At the interaction level, NASA addressed the flawed decision-making by following traditional paths of changing policies, procedures, and processes that would increase the probability that signals of danger would be recognized. NASA used the opportunity to make changes to "scrub the system totally." The Agency rebaselined the Failure Modes Effects Analysis. All problems tracked by the Critical Items List were reviewed, engineering

14. Ibid., pp. 171–177.
15. Ibid., pp. 198–201.
16. Ibid., p. 200.

fixes implemented when possible, and the list reduced. NASA established Data Systems and Trend Analysis, recording all anomalies so that problems could be tracked over time. Rules were changed for Flight Readiness Review so that engineers, formerly included only in the lower-level reviews, could participate in the entire process. Astronauts were extensively incorporated into management, including participation in the final prelaunch Flight Readiness Review and signing the authorization for the final mission "go."

At the organizational level, NASA made several structural changes, centralizing control of operations and safety.[17] NASA shifted control for the Space Shuttle program from Johnson Space Center in Houston to NASA Headquarters in an attempt to replicate the management structure at the time of Apollo, thus striving to restore communication to a former level of excellence. NASA also initiated the recommended Headquarters Office of Safety, Reliability and Quality Assurance (renamed as Safety and Mission Assurance), but instead of the direct authority over all safety operations, as the Commission recommended, each of the Centers had its own safety organization, reporting to the Center Director.[18] Finally, NASA repeatedly acknowledged in press conferences that the Space Shuttle was and always would be treated as an experimental, not operational, vehicle and vowed that henceforth, safety would take priority over schedule in launch decisions. One step taken to achieve this outcome was to have an astronaut attending Flight Readiness Reviews and participating in decisions about Shuttle readiness for flight; another was an effort to bring resources and goals into alignment.

Each of these changes addressed causes identified in the report, so why did the negative pattern repeat, producing the *Columbia* accident? First, the Commission did not identify all the social causes of the accident. From our post-*Columbia* position of hindsight, we can see that the Commission did not target NASA's institutional environment as a cause. The powerful actors whose actions precipitated "Pressures on the System" by their policy and budgetary decisions do not become part of the contributing-cause scenario. NASA is obliged to bring resources and goals into alignment, although resources are determined externally. NASA took the blame for safety cuts, which were attributed to NASA's own "perception that less safety, reliability and quality assurance activity would be required during 'routine' Shuttle operations."[19] The external budgetary actions that forced NASA leaders to impose such efficiencies were not mentioned. Most of the Commission's recommended changes aimed at the organization itself, in particular, changing interactions

17. CAIB, *Report*, p. 101.

18. Ibid.

19. Presidential Commission on the Space Shuttle *Challenger* Accident, *Report to the President*, p. 160.

structure. The Commission did not name culture as a culprit, although production pressure is the subject of an entire chapter. Also, NASA's historic "can-do" attitude (a cultural attribute) is not made part of the "Findings" and "Recommendations." Thus, NASA was not sensitized to possible flaws in the culture or that action needed to be taken. The Commission did deal with the problem of structural secrecy; however, in keeping with the human factors approach, the report ultimately places responsibility for "communication failures" not with organization structure, but with the individual middle managers responsible for key decisions and inadequate rules and procedures. The obstacles to communication caused by hierarchy and consequent power that managers wielded over engineers, stifling their input in crucial decisions, are not mentioned. These obstacles originate in organization structure but become part of the culture.

Second, consider NASA's response to these "Recommendations" and the challenges they faced. Although NASA's own leaders played a role in determining goals and how to achieve them, the institutional environment was not in their control. NASA remained essentially powerless as a government agency dependent upon political winds and budgetary decisions made elsewhere. Thus, NASA had little recourse but to try to achieve its ambitious goals—necessary politically to keep the Agency a national budgetary priority—with limited resources. The intra-organizational changes that NASA did control were reviewed in the CAIB report.[20] It found that many of NASA's initial changes were good. However, a critical one—the structural changes to centralize safety—was not enacted as the Commission had outlined. NASA's new Headquarters Office of Safety, Reliability and Quality Assurance did not have direct authority, as the Commission mandated; further, the various Center safety offices in its domain remained dependent because their funds came from the activities that they were overseeing.[21]

The CAIB also found that other changes—positive changes—were undone by subsequent events stemming from political and budgetary decisions made by the White House and Congress. The new, externally imposed goal of the International Space Station (ISS) forced the Agency to mind the schedule and perpetuated an operational mode. As a consequence, the culture of production was unchanged; the organization structure became more complex. This structural complexity created poor systems integration; communication paths were not clear. Also, the initial surge in post-*Challenger* funding was followed by cuts, such that the new NASA Administrator, Daniel Golden, introduced new efficiencies and smaller programs with the slogan "faster, better, cheaper." As a result of the squeeze, the initial increase in NASA safety

20. CAIB, *Report.*
21. Ibid., pp. 101, 178–179.

personnel was followed by a repeat of pre-accident economy moves that again cut safety staff and placed even more responsibility for safety with contractors. The accumulation of successful missions (defined as flights returned without accident) also reproduced the belief in an operational system, thus legitimating these cuts: Fewer resources needed to be dedicated to safety. The loss of people and subsequent transfer of safety responsibilities to contractors resulted in a deterioration of post-*Challenger* trend analyses and other NASA safety oversight capabilities.

NASA took the report's mandate to make changes as an opportunity to make others it deemed necessary, so the number of changes actually made is impossible to know and assess, much less report in a chapter of this length. The extent to which additional changes might have become part of the problem rather than contributing to the solution is also unknown. Be aware, however, that we are assessing these changes from the position of post-*Columbia* hindsight, tending to identify all the negatives associated with the harmful outcome.[22] The positive effects, the mistakes avoided by post-*Challenger* changes,

The 13-member Columbia Accident Investigation Board poses for a group photo taken in the CAIB boardroom. The official STS-107 insignia hangs on the wall in the center of the boardroom. From left to right, seated, are Board members G. Scott Hubbard, Dr. James N. Hallock, Dr. Sally Ride, Chairman Admiral Hal Gehman (ret.), Steven Wallace, Dr. John Logsdon, and Dr. Sheila Widnall. Standing, from left to right, are Dr. Douglas D. Osheroff, Major General John Barry, Rear Admiral Stephen Turcotte, Brigadier General Duane Deal, Major General Kenneth W. Hess, and Roger E. Tetrault. *(CAIB photo by Rick Stiles, 2003)*

22. William H. Starbuck, "Executives' Perceptual Filters: What They Notice and How They Make Sense," in *The Executive Effect*, ed. Donald C. Hambrick (Greenwich, CT: JAI, 1988).

tend to be lost in the wake of *Columbia*. However, we do know that increasing system complexity increases the probability of mistake, and some changes did produced unanticipated consequences. One example was NASA's inability to monitor reductions in personnel during a relocation of Boeing, a major contractor, which turned out to negatively affect the technical analysis Boeing prepared for NASA decision-making about the foam problem.[23] Finally, NASA believed that the very fact that many changes had been made had so changed the Agency that it was completely different from the NASA that produced the *Challenger* accident. Prior to the CAIB report release, despite the harsh revelations about organizational flaws echoing *Challenger* that the CAIB investigation frequently released to the press, many at NASA believed no parallels existed between *Columbia* and *Challenger*.[24]

THE CAIB: CONNECTING CAUSES WITH STRATEGIES FOR CONTROL

Published in August 2003, the Columbia Accident Investigation Board report presented an "expanded causal model" that was a complete break with accident investigation tradition. Turning from the usual accident investigation focus on technical causes and human factors, the CAIB fully embraced an organizational systems approach and was replete with social science concepts. Further, it made the social causes equal in importance to the technical causes, in contrast to the Commission's relegation of nontechnical causes to "contributing causes." Part 1 of the CAIB report, "The Accident," addressed the technical causes; part 2, "Why the Accident Occurred," examined the social causes; part 3 discussed the future of spaceflight and recommendations for change.

In the executive summary, the CAIB report articulated both a "technical cause statement" and an "organizational cause statement." On the latter, the Board stated that it "places as much weight on these causal factors as on the more easily understood and corrected physical cause of the accident."[25] With the exception of the "informal chain of command" operating "outside the organization's rules," this organizational cause statement applied equally to *Challenger*:

> The organizational causes of this accident are rooted in the Space Shuttle Program's history and culture, including the

23. CAIB, *Report*.

24. Michael Cabbage and William Harwood, *CommCheck . . . The Final Flight of Shuttle Columbia* (New York: Free Press, 2004), p. 203.

25. CAIB, *Report*, p. 9.

> original compromises that were required to gain approval for the Shuttle, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization of the Shuttle as operational rather than developmental, and lack of an agreed national vision for human space flight. Cultural traits and organizational practices detrimental to safety 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); organizational barriers that 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.[26]

The part 2 chapters described system effects. In contrast to the Commission's report, the CAIB explained NASA actions as caused by social factors. Chapter 5, "From *Columbia* to *Challenger*," began part 2 with an analysis of NASA's institutional environment. Tracking historic decisions by leaders in NASA's political and budgetary environment and the effect of policy decisions on the Agency after the first accident, it showed how NASA's external environment caused internal problems by shaping organization culture: the persistence of NASA's legendary can-do attitude, excessive allegiance to bureaucratic proceduralism and hierarchy due to increased contracting out, and the squeeze produced by "an agency trying to do too much with too little" as funding dropped so that downsizing and sticking to the schedule became the means to all ends.[27] The political environment continued to produce pressures for the Shuttle to operate like an operational system, and NASA accommodated. Chapter 6, "Decision Making at NASA," chronicled the history of decision-making on the foam problem, showing how the weak, mixed, and routine signals behind the normalization of deviance prior to *Challenger* also precipitated NASA's second gradual slide into disaster. Chapter 6 presented evidence that schedule pressure directly impacted management decision-making about the *Columbia* foam debris hit. Also, it showed how NASA's bureaucratic culture, hierarchical structure, and power differences created missing signals, so that the depth of engineer concerns and logic of their request for imagery were not admitted to poststrike deliberations.

26. Ibid.
27. Ibid., pp. 101–120.

Chapter 7, "The Accident's Organizational Causes," stepped back from the reconstruction of the decision history to examine how the organizational context affected the decisions traced in chapter 6. The chapter set forth an analysis of NASA's organizational culture and structure. The focal point was the "broken safety culture" that resulted from a weakened safety structure that, in turn, caused decision-makers to "miss the signals the foam was sending."[28] Organization structure, not communication failure, was responsible for problems with conveying and interpreting information. Systems integration and strong independent NASA safety systems were absent. Incorporating the social science literature from organization theory, theories of risk, and accidents, this chapter surveyed alternative models of organizations that did risky work, posing some safety structures that NASA might consider as models for revamping the Agency. Then, in the conclusion, it connected these organizational factors with the trajectory of decision-making after the *Columbia* foam strike. Chapter 8, "History as Cause: *Columbia* and *Challenger*," compared the two accidents. By showing the repeating patterns, it established the second accident as an organizational system failure, making obvious the causal links within and between the three preceding chapters. It demonstrated that the causes of *Challenger* had not been fixed. By bringing forward the thesis of "history" as cause, it showed how both the history of decision-making by political elites and the history of decision-making by NASA engineers and managers had twice combined to produce a gradual slide into disaster.

Now consider the fit between the Board's expanded causal model and its "Findings" and its "Recommendations." Empirically, the CAIB found the same problems as did the Presidential Commission and in fact recognized that in the report: schedule pressure; dependent and understaffed safety agents; communication problems stemming from hierarchy, power differences, and structural arrangements; poor systems integration and a weakened safety system; overburdened problem-reporting mechanisms that muted signals of potential danger; a can-do attitude that translated into an unfounded belief in the safety system; a success-based belief in an operational system; and bureaucratic rule-following that took precedence over deference to the expertise of engineers.[29] The data interpretation and causal analysis differed, however, because the CAIB report integrated social science analysis and concepts throughout part 2: culture, institutional failure, organizational system, history as cause, structure, the normalization of deviance, and the causal linkages between the three empirical chapters. Thus, the CAIB targeted for change each of the three layers of NASA's organizational system. A second difference

28. Ibid., p. 164.
29. Ibid., p. 100.

was that the number of findings and recommendations was greater and each was more detailed and specific than those of the Commission. A few of those illustrative of the organization system approach to change follow.

Chapter 5, "From *Challenger* to *Columbia*," tracing historic decisions by leaders, included neither findings nor recommendations about NASA's external environment. However, in contrast to the Commission's report, the CAIB specifically implicated decision leaders by the data in chapter 5, and in the introduction to part 2, the CAIB report stated that the Agency

> accepted the bargain to operate and maintain the vehicle in the safest possible way. The Board is not convinced that NASA has completely lived up to the bargain, or that Congress and the Administration have provided the funding and support necessary for NASA to do so. This situation needs to be addressed—if the nation intends to keep conducting human space flight, it needs to live up to its part of the bargain.[30]

Policy and budgetary decisions by leaders again show up in the "Findings" and "Recommendations" in chapters 6 and 7. Chapter 6, "Decision Making at NASA," makes three Recommendations, primary among them the adoption of "a Shuttle flight schedule that is consistent with available resources."[31] Also, it advocated training the Mission Management Team, which did not operate in a decentralized mode or innovate, instead adhering to an ill-advised protocol in dealing with the foam strike. As Weick found with forest-fire fighters in a crisis, the failure "to drop their tools," which they were trained to always carry, resulted in death for most.[32] The CAIB recommendation was to train NASA managers to "drop their tools," responding innovatively rather than bureaucratically to uncertain flight conditions and to decentralize by interacting across levels of hierarchy and organizational boundaries.[33]

Chapter 7, "The Accident's Organizational Causes," asserts the important causal role of a broken safety culture and NASA's cultural "blind spot" that kept them from getting the signals the foam was sending. The "Recommendations" advocated changes in the structure of NASA's safety system: the broken safety culture was to be fixed by changing the safety structure. The Commission charged NASA to create an "independent Technical Engineering Authority" with complete authority over technical issues, its independence guaranteed by funding directly from NASA Headquarters, with no responsibility for sched-

30. CAIB, *Report*, p. 97.

31. Ibid., p. 139.

32. Karl E. Weick, "The Collapse of Sensemaking in Organizations: The Mann Gulch Disaster," *Administrative Science Quarterly* 38 (1993): 628–652.

33. CAIB, *Report*, p. 172.

ule or program cost.[34] After *Challenger,* cost, schedule, and safety were all the domain of a single office. Second, NASA Headquarters' Office of Safety and Mission Assurance would have direct authority and be independently resourced. Finally, to assure that problems on one part of the Shuttle (e.g., the foam debris from the External Tank) took into account ramifications for other parts (e.g., foam hitting the orbiter wing), the Space Shuttle Integration Office would be reorganized to include the orbiter, previously not included.

Chapter 8, "History as Cause," presented general principles for making changes, rather than concrete recommendations. These principles incorporate the three layers of NASA's organizational system and the relationship between them. First, decision-making patterns that normalize deviance should be altered by "strategies that increase the clarity, strength, and presence of signals that challenge assumptions about risk," which include empowering engineers, changing managerial practices, and strengthening the safety system.[35] Second, this chapter reiterates the accountability at higher levels, stating, "The White House and Congress must recognize the role of their decisions in this accident and take responsibility for safety in the future."[36] Later and more specifically, "Leaders create culture. It is their responsibility to change it . . . . The past decisions of national leaders—the White House, Congress, and NASA Headquarters—set the *Columbia* accident in motion by creating resource and schedule strains that compromised the principles of a high-risk technology organization."[37] Third, at the organizational level, culture and structure are both targets for change. Understanding culture should be an ongoing research-based project. Necessary changes to organization structure must be carefully considered because of the law of unintended consequences: change and increased complexity produce mistake; changing structure can change culture in unpredictable ways.

The report made it imperative that NASA respond to many of these recommendations prior to the Return to Flight Evaluation in 2005.[38] Although change is still under way at NASA, it is appropriate to examine the direction NASA is taking and the obstacles the Agency is encountering as it goes about implementing change.

Signals of Danger and the Normalization of Deviance

Because the Space Shuttle is and always will be an experimental vehicle, technical problems will proliferate. In such a setting, categorizing risk will

34. Ibid., p. 193.
35. Ibid., p. 203.
36. Ibid., p. 196.
37. Ibid., p. 203.
38. Prior to the resumption of Shuttle launches, progress on these changes was monitored and approved by a NASA-appointed board, the Covey-Stafford Board, and also by the U.S. Congress House Committee on Science, which has official oversight responsibilities for the space agency.

always be difficult, especially with low-lying, ambiguous problems, like foam debris and O-ring erosion, where the threat to flight safety is not readily apparent and mission success constitutes definitive evidence: calculations and lab experiments are approximations, but flight outcome is considered the final test of engineering predictions. The decision problem is not only how to categorize the many elements and variations in risk, but how to make salient early warning signs about low-lying problems that, by definition, will be seen against a backdrop of more serious problems.

The new NASA Engineering and Safety Center (NESC), created after the *Columbia* accident, is to be a safety resource for engineering decisions throughout the Agency. NESC will review recurring anomalies that engineering had determined do not affect flight safety to see if those decisions were correct.[39] Going back to the start of the Shuttle program, NESC will create a common database, looking for missed signals, reviewing problem dispositions, and taking further investigative and corrective action when deemed necessary. However, as we have seen from *Columbia* and *Challenger,* what happens at the level of everyday interaction, interpretation, and decision-making does not occur in a vacuum, but in an organizational system in which other factors affect problem definition, corrective actions, and problem dispositions.

The Culture of Production: NASA's Political/Economic Environment

NASA remains a politically vulnerable agency, dependent on the White House and Congress for its share of the budget and approval of its goals. After *Columbia*, the Bush administration supported the continuation of the Space Shuttle program and supplied the vision for NASA's future that the CAIB report concluded was missing: the space program would return to exploration of Mars. However, the funds to make the changes required for the Shuttle to return to flight and simultaneously accomplish this new goal were insufficient. Thus, NASA, following the CAIB prescription, attempted to align goals and resources by phasing out the Hubble telescope program and, eventually, planning to phase out the Shuttle itself. Further, during the standdown from launch while changes are implemented, the International Space Station is still operating and remains dependent upon the Shuttle to ferry astronaut crews, materials, and experiments back and forth in space. Thus, both economic strain and schedule pressure still persist at NASA. How the conflict between NASA's goals and the constraints upon achieving them will unfold is still unknown, but one lesson from *Challenger* is that system effects tend to reproduce. The Board mandated independence and resources for the safety system, but when

39. Frank Morring, Jr., "Anomaly Analysis: NASA's Engineering and Safety Center Checks Recurring Shuttle Glitches," *Aviation Week & Space Technology* (2 August 2004): 53.

goals, schedule, efficiency, and safety conflicted post-*Challenger*, NASA goals were reined in, but the safety system also was compromised.

The Organization: NASA Structure and Culture

In the months preceding the report release, the Board kept the public and NASA informed of some of the recommended changes so that NASA could get a head start on changes required for Return to Flight. With the press announcement that the CAIB would recommend a new safety center, and pressed to get the Shuttle flying again, NASA rushed ahead to begin designing a center despite having no details about what it should entail. When the report was published, NASA discovered that the planned NASA Engineering and Safety Center (NESC) it had designed and begun to implement was not the Independent Technical Authority that the Board recommended. Converting to the CAIB-recommended structure was resisted internally at NASA, in large part because the proposed structure a) did not fit with insiders' ideas about how things should work and where accountability should lie and b) was difficult to integrate into existing operations and structures. NESC is in operation, as described above, but NASA is now working on a separate organization, the Independent Technical Authority, as outlined by the CAIB.

Whereas CAIB recommendations for changing structure were specific, CAIB directions for changing culture were vague. The CAIB was clear about implicating NASA leaders, making them responsible for changing culture. What was the role of NASA leaders in cultural change, and how should that change be achieved? The report's one clear instruction for making internal change was for correcting the broken safety culture by changing the structure of the safety system. From my participation in meetings at NASA, it was clear that NASA leaders did not understand how to go about changing culture. To these leaders, who were trained in engineering and accustomed to human factors analysis, changing culture seemed "fuzzy." Many NASA personnel believed that the report's conclusion about Agencywide cultural failures wrongly indicted parts of NASA that were working well. More fundamentally, they had a problem translating the contents of the report to identify what changes were necessary and what actions they implied. Each of the three causal chapters contained explicit information about where necessary cultural changes were needed:

1) Chapter 5 shows actions by leaders in OMB, Congress, the White House, and NASA made cost and schedule a part of the organization culture, competing with safety and technical and scientific innovation as goals.

2) Chapter 6 shows how the technical anomaly became normalized, experience with the foam debris problem leading to a cultural belief that foam was not a threat to flight safety.

3) Chapter 7 points out a gap; administrators' belief in NASA's strong "safety culture" was contradicted by the way the organization actually operated in this accident. Layers of structure, hierarchy, protocol, power differences, and an informal chain of command in combination stifled engineering opinion and actions, impeding information gathering and exchange, showing a culture where deference to engineering technical expertise was missing. The belief that operations were safe led NASA to buy as much safety as they felt they needed; cutbacks were made in safety personnel accordingly.

So changes that targeted the cause of NASA's cultural problems had to be three-pronged. But how to do it? NASA's approach was this: On 16 December 2003, NASA Headquarters posted a Request for Proposals on its Web site for a cultural analysis to be followed by the implementation of activities that would eliminate cultural problems identified as detrimental to safety. Verifying the CAIB's conclusions about NASA's deadline-oriented culture, proposals first were due 6 January; then the deadline was extended by a meager 10 days. Ironically, the CAIB mandate to achieve cultural change itself produced the very production pressure about which the report had complained. Although the study was to last three years, NASA required data on cultural change in six months (just in time for the originally scheduled date of the Return to Flight Evaluation, later deferred several times), then annually.

The bidders were corporate contractors with whom NASA frequently worked. Details are not available at this writing, but the awardee conducted a "cultural analysis" survey to gather data on the extent and location of cultural problems in the Agency. The ability of a survey to tap into cultural problems is questionable because it asks insiders, who can be blinded to certain aspects of their culture. A better assessment results when insider information is complemented by outside observers who become temporary members, spending sufficient time there to be able to identify cultural patterns, examine records, and interview asking open-ended questions. A further problem is implied in the initial response rate of 40 percent, indicating that insider viewpoints tapped will not capture Agencywide cultural patterns. Further, this survey was to be followed by plans to train and retrain managers to listen and decentralize and to encourage engineers to speak up. Thus, the Agency response would be at the interactional level only, leaving other aspects of culture identified in the CAIB report—such as goals; schedule pressures; power distribution across the hierarchy and between administrators, managers, and engineers—unaddressed. The agency that had always been expected to do too much with too little was still struggling with that all-too-familiar situation.

CONCLUSION: LESSONS LEARNED

The dilemmas of slippery slopes, repeating negative patterns, and learning from mistake are not uniquely NASA's. We have evidence that slippery slopes are frequent patterns in manmade disasters.[40] We also know that slippery slopes with harmful outcomes occur in other kinds of organizations where producing and using risky technology is not the goal: think of the incursion of drug use into professional athletics, U.S. military abuse of prisoners in Iraq, and Enron—to name some sensational cases in which incrementalism, commitment, feedback, cultural persistence, and structural secrecy seem to have created an organizational "blind spot" that allowed actors to see their actions as acceptable and conforming, perpetuating a collective incremental descent into poor judgment. Knowing the conditions that cause organizations to make a gradual downward slide, whether the manmade disasters that result are technical, political, financial, public relations, moral, or other, does give us some insight into how it happens that may be helpful to other managers hoping to avoid these problems.

In contradiction to the apparent suddenness of their surprising and sometimes devastating public outcomes, mistakes can have a long incubation period. How do early warning signs of a wrong direction become normalized? A first decision, once taken and met by either success or no obvious failure (which also can be a success!), sets a precedent upon which future decisions are based. The first decision may be defined as entirely within the logic of daily operations because it conforms with ongoing activities, cultural norms, and goals. Or, if initially viewed as deviant, the positive outcome may neutralize perceptions of risk and harm; thus, what was originally defined as deviant becomes normal and acceptable as decisions that build upon the precedent accumulate. Patterns of information bury early warning signs amidst subsequent indicators that all is well. As decisions and their positive result become public to others in the organization, those making decisions become committed to their chosen line of action, so reversing direction—even in the face of contradictory information—becomes more difficult.

The accumulating actions assume a taken-for-granted quality, becoming cultural understandings, such that newcomers may take over from others without questioning the status quo; or, if objecting because they have fresh eyes that view the course of actions as deviant, they may acquiesce and participate upon learning the decision logic and that "this is the way we do it here." Cultural beliefs persist because people tend to make the problematic nonprob-

---

40. Barry M. Turner, *Man-made Disasters* (London: Wykeham, 1978); Scott A. Snook, *Friendly Fire: The Accidental Shootdown of U.S. Black Hawks over Northern Iraq* (Princeton: Princeton University Press, 2000).

lematic by defining a situation in a way that makes sense of it in cultural terms. NASA's gradual slides continued because 1) the decisions made conformed to the mandates of the dominating culture of production and 2) because organization structure impeded the ability of those with regulatory responsibilities—top administrators, safety representatives—to critically question and intervene.

Why do negative patterns repeat? Was it true, as the press concluded after *Columbia*, that the lessons of *Challenger* weren't learned? When we examined the lessons of *Challenger* identified in the "Findings" and "Recommendations" of the Commission's 1986 report, they located cause primarily in individual mistakes, misjudgments, flawed analysis, flawed decision-making, and communication failures. The findings about schedule pressures and safety structure were attributed also to flawed decision-making, not by middle managers but by NASA leaders. In response, the Commission recommended adjusting decision-making processes, creating structural change in safety systems, and bringing goals and resources into alignment. NASA acted on each of those recommendations; thus, we could say that the lessons were learned. The *Columbia* accident and the CAIB report that followed taught different lessons, however. They showed that an organizational system failure, not individual failure, was behind both accidents, causing the negative pattern to repeat. So, in retrospect, we must conclude that from *Challenger* NASA learned incomplete lessons. Thus, they did not connect their strategies for control with the full social causes of the first accident.

Events since *Columbia* teach an additional lesson: we see just how hard it is to learn and implement the lessons of an organization system failure, even when the CAIB Report pointed them out. Further, there are practical problems. NASA leaders had difficulty integrating new structures with existing parts of the operation; cultural change and how to go about it eluded them. Some of the CAIB recommendations for change were puzzling to NASA personnel because they had seen their system working well under most circumstances. Further, understanding how social circumstances affect individual actions is not easy to grasp, especially in an American ethos in which both success and failure are seen as the result of individual action.[41] Finally, negative patterns can repeat because making changes has system effects that can produce unintended consequences. Changing structure can increase complexity and, therefore, the probability of mistake; it can change culture in unpredictable ways.[42]

41. After a presentation in which I translated the cultural change implications of the CAIB report to a group of administrators at NASA Headquarters, giving examples of how to go about it, two administrators approached me. Drawing parallels between the personalities of a *Columbia* engineer and a *Challenger* engineer who both acted aggressively to avert an accident but, faced with management opposition, backed off, the administrators wanted to know why replacing these individuals was not the solution.

42. Charles B. Perrow, *Normal Accidents* (New York: Basic Books, 1994); Diane Vaughan, "The Dark Side of Organizations: Mistake, Misconduct, and Disaster," *Annual Review of Sociology* 25

continued on the next page

Even when the lessons are learned, negative patterns can still repeat. The process and mechanisms behind the normalization of deviance make incremental change hard to detect until it's too late. Change occurs gradually, the signs of a new and possibly harmful direction occurring one at a time, injected into daily routines that obfuscate the developing pattern. Moreover, external forces are often beyond a single organization's ability to control. Cultures of production, whether production of police statistics, war, profits, or timely Shuttle launches, are a product of larger historical, cultural, political, ideological, and economic institutions that produce them. Making organizational change that contradicts them is difficult to implement but, in the face of continuing and consistent institutional forces, even more difficult to sustain as time passes. The extent to which an organization can resist these conditions is likely to vary as its status and power vary. Although compared to some, NASA seems a powerful government agency, its share of the federal budget is small compared to other agencies. In the aftermath of both accidents, NASA changes were undermined by subsequent events, many of which they could not control. Political and budgetary decisions of elites created new goals, resulting in new structures, making the system more complex; by not giving sufficient support, they reproduced a culture dominated by schedule pressures, deadlines, resource scarcity, bureaucratic protocols, and power differences that made it difficult to create and sustain a different kind of NASA where negative patterns do not repeat. It may be argued that under the circumstances, NASA's Space Shuttle program has had a remarkable safety record.

But even when everything possible is done, we cannot have mistake-free organizations because system effects will produce unanticipated consequences. Because the Shuttle is unprecedented and flight conditions unpredictable, NASA will always have many postflight anomalies to deal with, and low-lying problems with hard-to-decipher, uncertain outcomes like O-ring erosion and foam debris will always be a challenge. Part of the remedy is to increase the power and effectiveness of the safety system, but the critical piece to this puzzle is changing the culture of production. For *Columbia*, as for *Challenger*, resources—both time and money—were not available for thorough hazard analysis to fully explore why these two technical problems were occurring and the implications of continuing to fly with flaws. The reason they were not thoroughly analyzed and fixed was that the level of risk assigned to these problems was low. The definition of risk precluded the dedication of time and money to problems that had no clear potential for high costs. Further, all contingencies can never be predicted; most people don't understand how social

---

continued from the previous page
(1999): 271–305; Diane Vaughan, "Organisational Rituals of Risk and Error," in *Organisational Encounters with Risk*, ed. Bridget M. Hutter and Michael K. Power (Cambridge: Cambridge University Press, 2005).

context affects individual action and so cannot create strategies of control that connect with the social causes of a problem; organizational changes that correct one problem may, in fact, have a dark side, creating unpredictable others; and external environments are difficult to control.

Jervis describes the unintended consequences and harmful outcomes that result from complex interactions in social systems.[43] When complex, interactive technical systems, like the Space Shuttle, are run by complex organizations, like NASA, the probability of accidents is increased. Thus, system effects force us to recognize that it is not possible to prevent all accidents. However, it is important to remember that both of NASA's accidents had a long incubation period, and thus *were preventable*. By addressing the social causes of gradual slides and repeating negative patterns, organizations *can reduce the probability* that mistakes and accidents will occur. To do so, connecting strategies for correcting organizational problems with their social causes is crucial. Social scientists can play a significant role. First, we have research showing the problem of the slippery slope is perhaps more frequent than we now imagine, but less is known about cases where this pattern, once begun, is reversed.[44] Building a research base about organizations that make effective cultural change and reverse downward slides is an important step. Further, by their writing, analysis, and consulting, social scientists can 1) teach organizations about the social sources of their problems, 2) advise on strategies that will address those social causes, and 3) explore the system effects of planned changes, helping to forestall unintended consequences.[45]

---

43. Robert Jervis, *System Effects: Complexity in Political and Social Life* (Princeton: Princeton University Press, 1997).

44. Turner, *Man-made Disasters*; David Miller, *The Icarus Paradox: How Exceptional Companies Bring About Their Own Downfall* (New York: Harper, 1990), but see Rosabeth Moss Kanter, *Confidence: How Winning Streaks and Losing Streaks Begin and End* (New York: Simon & Schuster, 2004).

45. See, e.g., Rosabeth Moss Kanter, *The Changemasters* (New York: Simon & Schuster, 1983), and *Confidence: How Winning Streaks and Losing Streaks Begin and End* (New York: Simon & Schuster, 2004); Karlene H. Roberts, "Managing High Reliability Organizations," *California Management Review* 32, no. 4 (1990): 101–114; Karl E. Weick, Kathleen Sutcliffe, and David Obstfeld, "Organizing for High Reliability," *Research in Organizational Behavior* 21 (1990): 81–123; Todd R. La Porte and Richard Consolini, "Working in Practice but not in Theory: Theoretical Challenges of High-Reliability Organizations," *Journal of Public Administration Research and Theory* 1 (1991): 19–47; Diane Vaughan, "The Trickle-Down Effect: Policy Decisions, Risky Work, and the *Challenger* Accident," *California Management Review* 39 (winter 1997): 1–23; Lee Clarke, *Mission Improbable: Using Fantasy Documents to Tame Disaster* (Chicago: University of Chicago Press: 1999); Anita L. Tucker and Amy C. Edmondson, "Why Hospitals Don't Learn from Failures: Organizational and Psychological Dynamics that Inhibit System Change," *California Management Review* 45 (winter 2003): 55–72; Karen Marais, Nicolas Dulac, and Nancy Leveson, "Beyond Normal Accidents and High Reliability Organizations: The Need for an Alternative Approach to Safety in Complex Systems," (unpublished manuscript, Massachusetts Institute of Technology, 2004); Amy C. Edmondson, Michael Roberto, and Richard Bohmer, *The Columbia's Last Flight* (multimedia business case, Harvard Business School, 2005).

Second, NASA's problem of the cultural blind spot shows that insiders are unable to identify the characteristics of their own workplace structure and culture that might be causing problems. This suggests that rather than waiting until after a gradual slide into disaster or repeat of a negative pattern to expose the dark side of culture and structure, organizations would benefit from ongoing cultural analysis by ethnographically trained sociologists and anthropologists giving regular feedback, annually replaced by others to avoid seduction by the cultural ethos and assure fresh insights. Bear in mind this additional obstacle: the other facet of NASA's cultural blind spot was that the Agency's success-based belief in its own goodness was so great that it developed a pattern of disregarding the advice of outside experts.[46] To the extent that the CAIB report's embrace of an organizational system approach becomes a model for other accident investigation reports, other organizations may become increasingly aware of the social origins of mistakes and of the need to stay in touch with how their own organizational system is working.

46. CAIB, *Report*, chap. 5.