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Lessons in Organizational Ethics from the Columbia Disaster:

Can a Culture be Lethal?

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''Houston We Have a Problem.'' A Message Never Sent or Received.

On February 1, 2003, the Space Shuttle *Columbia*, on its way to its landing site in Florida, blew apart in the skies of East Texas. Its seven-member crew perished. The $2 billion ship was lost; some destruction occurred on the ground, and considerable cost was incurred to recover debris scattered over several states. The disaster sounded an eerie echo from the past. Seventeen years earlier the shuttle *Challenger* exploded 73 seconds into flight due to an O-ring malfunction. All seven crewmembers were also lost. And, about 11 years before that, the cabin of *Apollo 1* burst into flames on its pad. Three crewmembers were killed.

Within a day, as NASA policy requires, an internal investigation team of six *ex officio* members was formed. Harold Gehman Jr., a retired admiral who was NATO supreme allied commander in Europe, was appointed to chair it. A veteran of several military investigations, including the bombing of the *U.S. Cole*, Gehman, in an initially unpopular move, broadened the inquiry to include the agency's organization, history and culture. Sean O'Keefe, NASA's administrator, was incensed that the investigation would reach beyond the confines of the shuttle project alone, and his relations with Gehman became strained and stiff. Based on his experience, however, Gehman persisted. An Accident Investigation Board (hereafter referred to as the Board) was appointed with six additional members who represented a broader set of relevant constituencies. In addition to the chair, the 13 member Board included three other military aviation experts, a former astronaut (Sally Ride), a top NASA official, a retired corporate executive, several senior civil accident investigators and two distinguished engineering professors. The Board's overarching questions were those inevitable ones: Why did the accident occur? Who (or what) is to blame? What is to be done?

It was a mammoth task. During less than seven months, the Board's staff of more than 120 worked with over 400 NASA engineers examining more that 30,000 documents, conducting over 200 formal interviews, hearing testimony from dozens of expert witnesses and receiving and reviewing thousands of inputs from the general public. On Tuesday, August 26, 2003, the 248-page report of the *Columbia* Accident Board (Board Report) was released.

The Board's report pointed the finger at NASA's culture and its history. ''The bitter bottom line,'' lamented *New York Times* correspondent David Sanger, ''... comes down to this: NASA never absorbed the lessons of the *Challenger* explosion in 1986, and four successive American presidents never

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decided where America's space program should head after the cold war—and what it would cost in dollars and risk to human life to get there.'' The Board's findings were scathing. NASA's current culture, they concluded, was largely to blame for the tragedy because it stifled dissenting views and bred complacency over persistent risks. The press seized on phrases such as ''NASA's culture of complacency,'' ''deeply flawed culture'' and ''a broken safety culture.''

In an interview with William Langewiesche for the November 2003 issue of *The Atlantic Monthly*, Gehman described the flaws he observed in NASA's culture. ''They claim that the culture in Houston is a 'badgeless society,' meaning it doesn't matter what you have on your badge—you're concerned about shuttle safety together. Well, that's all nice, but the truth is that it *does* matter what badge you're wearing. Look, if you really do have an organization that has free communication and open doors and all that kind of stuff, it takes a special kind of management to make it work. And we just don't see that management here. Oh, they *say* all the right things. 'We have open doors and e-mails, and anybody who sees a problem can raise his hand, blow a whistle, and stop the whole process.' But then when you look at how it really works, it's an incestuous, hierarchical system, with invisible rankings and a very strict informal chain of command. They all know that. So even though they've got all of the trappings of communication, you don't actually *find* communication. It's very complex. But if a person brings an issue up, what caste he's in makes all the difference. Now, again, NASA will deny this, but if you talk to people, if you really listen to people, all the time you hear 'Well, I was afraid to speak up.' Boy, it comes across loud and clear. You listen to the meetings: 'Anybody got anything to say?' There are thirty people in the room, and *slam*! There's nothing. We have plenty of witness statements saying 'If I had spoken up, it would have been at the cost of my job.' And if you're in the engineering department, you're a nobody.''

A CHUNK OF FOAM FROM THE BIPOD RAMP THE PROXIMATE CAUSE

Although the Board placed special emphasis on the Space Shuttle Program's history and culture, the identifiable causes of the disaster were deemed to be both physical and organizational. The infamous chunk of foam that dislodged from the craft's ''bipod ramp'' and struck a heat shield tile on the left wing was determined to be the immediate physical cause of the disaster. More precisely, the proximate cause of the accident was ''a breach in the Thermal Protection System on the leading edge of the left wing, caused by a piece of insulating foam which separated from the left bipod ramp section of the External Tank at 81.7 seconds after launch, and struck the wing in the vicinity of the lower half of Reinforced Carbon-Carbon panel number 8. During re-entry this breach in the Thermal Protection System allowed superheated air to penetrate through the leading edge insulation and progressively melt the aluminum structure of the left wing, resulting in a weakening of the structure until increasing aerodynamic forces caused loss of control, failure of the wing, and breakup of the Orbiter. This breakup occurred in a flight regime in which, given the current design of the Orbiter, there was no possibility for the crew to survive.''

HISTORY AND CULTURE AS DISTANT, BUT EFFECTIVE, CAUSES

The famous economist, Alfred Marshall, once argued that all problems of political economy should be analyzed using a systems approach. ''People must be warned off by every possible means from considering the action of any one cause,'' he wrote, ''without taking account of the others whose effects are commingled with it.'' The Board acted consistently with Marshall's advice when it expanded the scope of its quest to include NASA's history and culture in its investigation, and when it sought to identify the social

conditions that served as contributing root causes of the accident. This leaves us, however, with another prerequisite question. In what sense can history or culture be a cause?

A key notion is that NASA is a socio-technical system. Its technology is designed, produced and operated by people working in groups under the guidance of human-made policies. The agency's ''socio'' component has a nearly fifty-year history. From a systems perspective, past events as well as the values and beliefs of previous managers are all interactive partners in a system that collectively produced the disaster. As moral agents, managers bear some of the moral responsibility for the result—good or bad.

Historians have grappled with this notion of remote or distant causes as a serious methodical issue. Causal chains may be long—conceivably infinite—and devilishly complex, as readers of James Burke's *Connections* realize. Nevertheless, we all recognize that many of the things that happen today do not appear *de novo*. They are to some degree the culmination of effects put in place some time ago and perhaps far away.

In *What is History?* E.H. Carr, for example, poses the following scenario to illustrate some of the complexities involved. ''Jones, returning from a party at which he has consumed more than his usual ration of alcohol, in a car whose brakes turn out to have been defective, at a blind corner where visibility is notoriously poor, knocks down and kills Robinson, who was crossing the road to buy cigarettes at the shop on the corner.'' Among the parties that may be held causally responsible are the following: Jones for drinking, the tavern for selling alcoholic drinks to him, the mechanic who serviced Jones' car, the car manufacture, the city transportation department for poor design or failing to put up adequate signs, Robinson for failing to look carefully enough, Robinson for his addiction to tobacco, and the tobacco companies for selling their products to people like Robinson. Significantly, these possible co-producing events may have taken place quite a long time ago or at a distant location. Any of the agents involved may be also be held morally responsible if three conditions are satisfied: they (1) did indeed serve as a co-producer of Robinson's death, (2) they acted knowingly (or should have known what they were doing), and (3) they acted voluntarily and without coercion. A complete causal analysis, as attempted by the Board, must pinpoint these contributing sources up to some degree of relevance and determine their relative degree of effect.

Every individual causal element has a context. To ignore its context is often to miss the essence of a problem. This kind of tunnel vision results in ineffective solutions. ''When the determinations of the causal chain are limited to technical flaw and individual failure,'' the Board argues, ''typically the actions taken to prevent a similar event in the future are also limited: fix the technical problem and replace or retain the individual responsibilities. Putting these corrections in place leads to another mistake—the belief that the problem is solved. The Board did not want to make these errors.'' In complex systems few, if any, causes are independently sufficient, there are many additional contributory necessary causes, perhaps from far and wide sources.

The Board concluded that the dislodging of the foam was sufficient to cause the *Columbia* disaster but it did not stop its examination there. It then proceeded to inquire as to why the ship was launched in the first place with a potential vulnerability in its design. ''What was the context?'' the investigators asked. That is, what were the other general, necessary conditions that allowed the foam to separate, and, given that it separated, kept NASA from actively trying to understand what damage may have resulted from the loose foam's striking the shuttle's left wing. These are the more penetrating questions of cause. Finding answers requires an examination of the accident's fuller socio-technical context.

DELVING INTO THE NECESSARY CAUSES

An event's context may reach back quite far in time or space. For this reason causes are

often labeled in three categories: distant, intermediate, and immediate or proximate. Some powerful distant causes may propel a system on a path that almost assures a future outcome. The Board's report identifies several types of distant and intermediate causes that in their judgment played a significant role in causing the disaster. These include organizational decisions made by or affecting NASA during its forty-plus-year history—including the founding of NASA, the early decisions the agency made, decisions made by the administration and Congress that provided expectations and budgetary limitations, the people NASA recruited, its early success, and the way of working it developed from its beginning. All of these shaped NASA's culture. One pivotal event was President Nixon's January 5, 1972 announcement of the U.S.'s new philosophy for exploring space. ''This system will center on a space vehicle,'' he boasted, ''that can shuttle repeatedly from Earth to orbit and back. *It will revolutionize transportation into near space, by routinizing it*'' (italics added in the Board Report). This commitment to reusable vehicles and routine operations set the agency on a definite course. It influenced subsequent decision-making and reshaped the agency's culture. If there is a crucial contextual point at which NASA began to transition from a culture focused on excellence to a culture focused on bureaucracy and production it is this 1972 pronouncement.

One unintended consequence of Nixon's policy was to reduce NASA's emphasis on safety. The Board concluded that for the last decade or so the agency's culture had not been robust in its dedication to safety. As a result important signals were ignored and opportunities to take remedial action missed. In order to understand how the Board believed this change in culture evolved we need to consider a few ideas about the concept of culture.

WHAT IS CULTURE?

Drawing on anthropological and organizational theories, the Board treated culture as ''the values, norms, beliefs, and practices that govern how an institution functions.'' Culture is, accordingly, a crucial determinant of human behavior. Organizational psychologist Edgar Shein offers up one of the most useful definitions. Culture, for Shein, is a ''pattern of shared basic assumptions that a group learned as it solved problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems.'' This pattern of shared assumptions shapes the way people will behave. It forms the context for the decisions they make and the actions they take.

An important attribute of culture is that it is learned. An individual or a group acquires patterns of thought and behavior by processes of socialization and acculturation. Consequently, leaders play a major role in establishing an organization's culture. Founding leaders are especially influential. Emerson famously said, ''An institution is the lengthened shadow of one man.'' While this may oversimplify the point, an argument can be made that a few founders like Thomas Watson of IBM Corp., J. Erik Jonsson of Texas Instruments Inc., Ross Perot of Electronic Data Systems Corp. (EDS) and Jack Lowe Sr. of TDIndustries had enormous influence on the culture and ethics of their companies. The essential point, however, is that a leader or a group of leaders can and do affect an organization's culture. Culture is malleable, but not easily so. Mike and Slocum's study of changing the culture of Pizza Hut and Yum Brands illustrates the degree of creativity and perseverance that is required to reinvent a culture.

NASA'S INITIAL CULTURE

Wernher Von Braun, German rocketry wizard and aerospace legend, was largely responsible for shaping NASA's early culture. The agency's much respected original technical and management culture—its culture of excellence—was formed at the

Marshall Space Flight Center in Huntsville, Alabama beginning in 1958. Diane Vaughan states that it arose ''out of a military heritage that made discipline a core cultural element.'' The center grew out of the army's Redstone Arsenal (named for the battlefield missile developed there, the Redstone rocket). After World War II, the Defense Department established the Army Ballistic Missile Agency (ABMA) in Huntsville, which designed and tested rockets for military use. The ABMA was operated at the Redstone Arsenal, run by a rocket team of 120 German engineers who had escaped to the United States after the war. There, under the leadership of Von Braun they recreated their strong precision/verification German research culture.'' Von Braun was appointed the director of Marshall when it opened in 1960. Just as Admiral Hyman Rickover fostered a culture of excellence for the U.S. Navy's nuclear-powered submarines, Von Braun and his associates set the technical standards, demanded the superior knowledge and expertise, mandated the hands-on strategies, inculcated an awareness of risk and failure, and opened up communications. All of these formed Marshall's original technical culture.

Following the 1972 decision to make a reusable shuttle, however, NASA began transitioning toward a ''culture of production''—a managerial culture which tends to stress efficiency over safety and effective reproducibility over creative problem solving. Dan Goldin, the NASA administrator from 1992 to 2001, sought to raise this production culture to a high art form with his mantra ''Faster, better, cheaper.'' But the results were not always salutary, as former astronaut Sally Ride explains: ''It's very difficult to have all three simultaneously. Pick your favorite two. With human space flight, you'd better add the word 'safety' in there, too, because if upper management is going 'Faster, better, cheaper,' that percolates down, it puts the emphasis on meeting schedules and improving the way that you do things and on costs. And over the years, it provides the impression that budget and schedule are the most important things.'' The culture of production was reinforced with the George W. Bush administration's appointment of Sean O'Keefe as director. A former deputy at the Office of Management and Budget, he was assigned the task of tackling the difficult problems of NASA's cost overruns and its failure to meet delivery schedules. He is not imbued deeply with scientific or technological values.

Another attribute of an organization's culture is that a significant portion of it lies below the level of conscious awareness. It is tacit, not tangible. An organization's culture is difficult to describe adequately in words; but you can experience it, feel it. In their studies of crisis systems Ian Mitroff and his associates have employed an ''onion'' model of organizations to locate the role of culture. Its layers form concentric circles, each of which describes a deeper degree of tacitness. On the outer layer, the most tangible one, is technology. It is the easiest to observe and, accordingly, the easiest to understand and change. The Board recognized a technological failure with respect to the foam as the most readily observable cause of the accident, but it persistently sought to probe several levels deeper.

The next level of the onion is the organization's infrastructure. An infrastructure portrays the formal power structure, and includes the bureaucratic mechanisms used to assign job responsibilities, allocate resources and make decisions. NASA, as has already been noted, during its later years had developed a rather unyielding hierarchical structure characterized by levels that served as invisible barriers.

How people and technology interact lies one more level down. Deeper still is the organization's culture and below that, at the onion's core, is the organization's emotional structure. Emotional states like anxiety and fear of reprisal drive an organization's behavior.

Tracing the causes of an accident generally starts where the Board did, at the technology layer, and works inward. That is, the inquiry begins with the physical, observable manifestations of the problem and then

delves down until the emotional and social sources are uncovered. To engage in organization learning and to change an organization's behavior, however, one usually must start at the emotional layer and work outward. The dislodged foam from the *Columbia*, like the O-rings of *Challenger*, is an artifact at the technology level. It can be observed, studied and re-engineered. The foam was the physical cause. But to prevent other accidents like *Columbia* from happening, change must be geared first to address the emotional and cultural layers. So, the Board wisely based its recommendations on its analysis of the culture, history and emotional state of the agency.

A CULTURE IS BASED ON DEEPLY HELD ASSUMPTIONS

There are several additional characteristics of an organization's culture that are related to its tacitness. First, although it is possible to create a culture out of whole cloth for a new organization, a culture once formed is tenacious and difficult to change. This is because a culture serves the deep psychological functions of reducing human anxiety and providing members with identity. In the face of external threats or internal failures, a culture tends to go into survival mode and to engage in rationalization and denial. These are among the reasons that an organization's culture exhibits an active resistance to change. An established culture has a tendency to fight to preserve itself and its members and remain the same.

NASA officials initially rejected the foam strike as the proximate cause of the accident and, thereafter, as a matter of faith held steadfastly to that belief, even in the face of accumulating evidence and the pleas of engineers. Indeed, the assumption was held so firmly by some, that requests to find more evidence by acquiring satellite or telescopic imagery were denied. That the foam had separated off on previous flights with no negative consequences nurtured a firmly held core belief which, if denied, would unravel a chain of other deeply held assumptions and expose flaws in the agency's previous decision making. Gehman understood this cultural process well. ''It has been scorched into my mind that bureaucracies will do anything to defend themselves,'' he explains. ''It's not evil—it's just a natural reaction of bureaucracies, and since NASA is a bureaucracy, I expect the same out of them. As we go through the investigation, I've been looking for signs where the system is trying to defend itself.'' Gehman's experience told him that when an organization holds a position with so much emotion and certainty it should be probed deeply. ''Now when I hear NASA telling me things like '*Gotta* be true!' or 'We *know* this to be true!' all my alarm bells go off.'' It was the Board's persistence in continuing to test the hypothesis that the foam strike was the immediate cause that finally led to the truth, despite active resistance on the part of NASA.

RESISTANCE TO CHANGE

During the last thirty years, the agency has experienced one crucial shift in its culture. The Von Braun culture established beginning in 1958 was rigorous in engineering precision and detail oriented. It put safety first. Over time, however, those emphases receded as the agency became more managerially and production oriented. Efficiency subsequently became the agency's core value. NASA's emergent culture of production proved to be very hardy and resistive. As a result, the space shuttle program, despite the wake-up calls of *Apollo* and *Challenger* and other mishaps, successfully fought to maintain its new culture of production. Moreover, following its reorganization after the failings of 1986, NASA's culture fought even harder to return to its efficiency-based value system. Partial evidence of this is found in the Board's report that cited eight ''missed opportunities'' when NASA engineers could have possibly averted the *Columbia* tragedy. The report concludes that NASA's flawed culture kept its employees from reading

these signals and responding adequately to them. The NASA culture of the 1960s and early 70s would have responded to these signals; its culture of production of the 1980s and 90s did not.

A CULTURE EXPRESSES ITS UNDERLYING ETHICS

A culture stems from fundamental ethical values and subsequently structures its members' patterns of thought and perception. The distinctions people make about the reality they face, the values they place on them, and the language they use to describe them are all first created by a culture as it evolves. Subsequently, the new language and work norms are learned by others as ''the way things are done around here.'' As a consequence, an organization's culture influences the range of choices that managers will view as rational or appropriate in any given situation. It provides them with a worldview that confines and directs their thinking and behavior. When norms of safety, respect, honesty, fairness and the like are integral parts of a culture, its people make ethical decisions. A climate of trust evolves. Cultures that lack these ethical norms (e.g., Enron Corp., WorldCom Inc., Tyco International) can make terribly harmful choices; and, often its members do not realize it. For most members the assumptions of a culture are taken for granted. Consequently, leaders must make clear to all involved that their organization's culture and its ethics are inextricably linked. It appears that by stressing cost cutting and meeting delivery dates so stringently NASA's leaders, perhaps inadvertently, encouraged less than forthright behavior on the part of some members of the organization.

A CULTURE AND ITS MEMBERS ARE NOT NECESSARILY THE SAME

A culture is different from the managers who are its members. Good, morally upright managers may participate in a complacent, flawed or broken culture. For example, General Motors Corp.'s Corvair automobile maimed or killed numerous innocent people during the 1960s and cost the company millions of dollars in legal expenses and out-of-court settlements. At GM, a culture that put costs, profit goals, and production deadlines above consumer safety largely ignored evidence of stability problems with the automobile until Ralph Nader published his exposé *Unsafe at Any Speed*. Nevertheless, most of the executives who made these decisions were considered to be men of high moral values, dedicated to their company and to their families, civic leaders and typically churchgoers. They would not deliberately send Corvair drivers to their death.

This phenomenon appears to be the case with NASA. Thousands of individual workers there would have never condoned sending a craft into space with known flaws that compromised any astronaut's safety. They were distraught to learn that they had been a party to it. Yet, the overwhelming force of the organization's culture and decision-making structure at the time effectively overrode their instinctive moral concerns. Or perhaps it served to salve their consciences. These NASA stalwarts believed that the agency could do no wrong. Why? One reason is that the agency's culture had become infested with hubris.

HUBRIS AND A FLAWED CULTURE AT NASA

The Von Braunean dedication to flawless performance was replaced by an emphasis on efficiency during President Nixon's term in office. At about the same time, NASA also implemented a hierarchical decision structure that separated decision making into levels and accorded substantial power to decision makers at the top level. Many managers operating in this new arrangement lulled themselves into believing that NASA's early successes were due to the agency's—and perhaps *their*—invulnerability. Moreover, fewer

of NASA's current employees understood or appreciated the crucial role that its original research culture had played in its previous accomplishments.

Although the Board concluded that some key seeds of the disaster were planted when NASA was founded, the agency's early missions had been sometimes successful, spectacularly so. So successful, in fact, that during its early days NASA deservedly acquired a ''Can Do!'' culture. It had developed a science and engineering based culture that was rich in a ''no stone unturned'' approach to problem solving and which took pride in its fierce dedication to safety. Part of this was due to the Von Braun orientation that so influenced the construction of the space craft and the protocols and procedures for conducting its missions. In the 1970s, however, budget cuts influenced the decision to adopt reusable craft for the shuttle. The agency's long string of previous successes still, however, led its managers to believe that they could do no wrong. This attitude of omnipotence is very dangerous when dealing with complex, unruly, ultimately unpredictable technology, and especially so when the fundamental norms of questioning and inquiry have been replaced by norms of silence, self-protection, and managerial efficiency. Attitudes of this sort cultivate organizational hubris.

Hubris refers to an exaggerated pride or self-confidence that turns into arrogance. It results from excessive admiration of oneself, a series of previous successes, uncritical acceptance of accolades and a belief that one is exempt from the rules. In the end, hubris is eventually rewarded with disaster and comeuppance. Evidence of hubris at NASA emerged in the Rogers Commission Report of 1986. ''The decision to launch the *Challenger* was flawed,'' Chapter 5 begins. Four findings are indicative of hubris. First, rising doubts within the engineering community about the performance of the Solid Rocket Booster joint seal (O-ring) were ignored. Second, launch constraints were waived at the expense of flight safety. The third finding was that the ''Commission is troubled by what appears to be a propensity of management at Marshall to contain potentially serious problems and to attempt to resolve them internally rather than communicate them forward. This tendency is altogether at odds with the need for Marshall to function as part of a system working forward toward successful flight missions, interfacing and communicating with the other parts of the system that work to the same end.'' And, finally, the Commission ''concluded that Thiokol Management reversed its position and recommended the launch of [*Challenger*], at the urging of Marshall and contrary to the views of its engineers in order to accommodate a major customer.'' ''In this situation'' the report states further, ''NASA appeared to be requiring a contractor to prove that it was not safe to launch, rather than proving it was safe.''

A crucial event during the period leading up to the decision to launch *Challenger* serves to capture the change in values orientation the agency had experienced. A teleconference was conducted between managers at the Kennedy Space Center, Marshall, and the contractor Morton Thiokol to solicit Thiokol's position on the launch. At the outset, engineers Roger Boisjoly and Arnie Thompson recommended against the launch based on their knowledge of the O-rings' poor performance at low temperatures. They were concerned that the temperature at the launch site the next morning was forecast to be less than 53 degrees, well below the temperatures at launch for previous flights most of which had also experienced some gas blow-by and O-ring erosion. In this system any single ''no'' vote meant no launch. But, George Hardy, Marshall's deputy director of science and engineering, responded that he was ''appalled'' at Thiokol's negative recommendation and the lack of hard evidence behind it. Upon hearing their top customer's opinion, the Thiokol party requested an off-line caucus. During the caucus several things happened. First, a senior vice president determined that this must be a ''management decision,'' thereby excluding Boisjoly and Thompson from participating in the final

decision. Nevertheless, one senior manager, Robert Lund, still voted against the launch based on the engineers' position. Finally, Lund was asked to ''*take off his engineering hat and put on his management hat*.'' Lund then voted with the rest, the teleconference was resumed, and the company announced that it had reconsidered. Thiokol now recommended launch. In the exchange of ''hats'' the managerial culture had clearly overridden the engineering culture, production besting excellence. Or, as Boisjoly later lamented, a decision was made away from ''goodness.'' In the process important, but organizationally disruptive, knowledge about the O-rings had been suppressed, relegated to the cubicles of the engineers. Executives who exhibit hubris trend to fall into the trap of listening only to people whose opinions are compatible with their own. It is apparent that some NASA executives felt pressure to launch *Challenger*—President Reagan planned to feature astronaut Christa McAuliffe and the Teacher in Space Project in his upcoming State of the Union address—and they simply did not want to listen to contrary opinions.

''With *Columbia*,'' Ride says, ''there was a history of foam coming off the external tank during launch. Each time, it was identified as a problem. But there was never a real significant engineering effort to understand why this was happening, what the potential implications were, and what needed to be done to stop it. There was no catastrophic damage the first time, the second time or even the third time. It got to be accepted as almost, 'in the family.' '' Consequently, knowledge and concern did not flow to points in the organization where it was needed.

This denial of an impending problem with the foam continued into *Columbia*'s flight. The day after the craft was launched, the foam strike was observed on film and a group of engineers were tasked with accessing the possible damage. The story of engineer Rodney Rocha, discussed more fully below, reveals that this group, too, found themselves having to prove that a major calamity would very likely occur in order to get an audience with upper management. They failed. In the old NASA culture, executives would have been eager to listen. In the culture of production, they had to be convinced. Hubris had set in as the result of too many previous successes (near misses didn't count). Senior NASA officials had been congratulated too many times and unfortunately they believed the accolades. They did not want to ''rock the boat.''

MINDFULNESS: CREATING A CULTURE THAT OVERCOMES HUBRIS AND CARELESSNESS

What models can NASA now use to rebuild its culture? High-reliability organizations (HROs), such as nuclear power plants, aircraft carriers, and air traffic controllers, have found solutions to some central problems created by the kinds of organizational hubris and carelessness that have beset the agency. HROs are extraordinarily effective at turning faint signs of impending problems into strong responses—before things get out of hand. HROs need to organize themselves in such a way that they are better able to notice the unexpected in the making and halt its development. Some people call this heightened organizational awareness ''mindfulness.'' The essential points are that these organizations are continuously looking for the unexpected, interpreting it in cultural and historical context, identifying the potential problems it raises, and initiating solutions. They do all of this at the least provocation—any sign of difficulty is taken seriously—and with a sense of urgency.

HROs are designed to manage risk and to deal effectively with hazards and crises. Not everything at NASA today, of course, is wrong. The great achievement of NASA during the second half of the twentieth century has been that the organization has been able to identify and defend against the enormous number of different risks associated with space flight. The agency has a history of implementing detailed protocols, checks and checklists to identify and correct incipient problems before they occur, and has, in

fact, delayed launching many times if some criterion was not satisfied. But, successful risk abatement requires *eternal vigilance*. No foreseeable harmful event should ever occur. There are many unforeseeable events that make space travel an inherently risky undertaking. For example, micrometeorite or bird strikes may occur unpredictably. The astronauts are aware of these uncertainties and willingly accept this level of risk. Any foreseeable risk they are exposed to beyond this level, however, is *unacceptable*.

During the last several decades, unfortunately, NASA has lowered its standards for coping with risk. Managers ''fiddled'' with the standards and lowered the threshold of what was ''acceptable.'' The agency routinely used the concept of ''acceptable risk'' in its technical analyses. The noted physicist and member of the President's Commission investigating *Challenger*, Richard Feynman, was abhorred to discover the terms ''acceptable risk'' and ''acceptable erosion'' in NASA's documents. But it is not the fact of natural, unforeseeable risk that is egregious. Rather, it is sliding down the slippery slope of lowering the standards that is ultimately immoral. ''It is a flight review, and so you decide what risks to accept,'' as Feynman explains NASA's decision process before every flight. ''I read all of these (pre-flight) reviews, and they agonize whether they can go, even though that had some (O-ring erosion) . . . And they decide yes. Then (the Shuttle) flies and nothing happens. Then it is suggested, therefore, that risk is no longer so high. For the next flight we can lower our standards a little bit because we got away with it last time. . . . It is a kind of Russian roulette. You got away with it, and it was a risk.'' This is exactly the kind of thinking NASA used with respect to the foam strikes.

The Board investigating the *Columbia* disaster reached a similar conclusion: ''The Shuttle Program was inappropriately *using previous success as a justification* for accepting increased risk; the Shuttle Program's *ability to manage risk was being eroded* 'by the desire to reduce costs' '' it stated quoting an independent assessment completed in 1999.

A specific incident illustrates. Foam strikes had occurred on all previous flights. ''Once the *Columbia* foam strike was discovered, the Mission Management Team chairperson asked for the rationale the previous flight's readiness review team had used to [justify] launch in spite of the [foam strike that have occurred on the flight before that]. In her e-mail, she admitted that the analysis used to continue flying was in a word, 'lousy.' This admission—that the rationale to fly was rubber stamped—is, to say the least, unsettling.'' The Board concludes, ''The Shuttle Program's complex structure erected barriers to effective communication and its safety culture no longer asks enough hard questions about risk . . .. In this context, the Board believes the mistakes that were made on [*Columbia*] are not isolated failures, but are indicative of systemic flaws that existed prior to the accident.''

Importantly, HROs do not have a ''shoot the messenger'' mentality, but rather encourage their members to raise problems quickly and readily. A strong sign of the deterioration of the culture of excellence at NASA transpired during the flight of *Columbia*. It concerned Rodney Rocha, one of the agency's highly respected engineers who was known for his precision and integrity. As James Glanz and John Schwartz reported in *The New York Times* on September 26, 2003:

> It was Tuesday, January 21, five days after the foam had broken loose during liftoff, and some 30 engineers from the National Aeronautics and Space Administration and its aerospace contractors were having the first formal meeting to assess potential damage when it struck the wing.
>
> Virtually every one of the participants—those in the room and some linked by teleconference—agreed that the space agency should immediately get images of the impact area, perhaps by requesting them from American spy satellites or powerful telescopes on the ground.

> They elected one of their number, a soft-spoken NASA engineer, Rodney Rocha, to convey the idea to the shuttle mission managers.
>
> Mr. Rocha said he tried at least half a dozen times to get the space agency to make the requests. There were two similar efforts by other engineers. All were turned aside. Mr. Rocha (pronounced ROE-cha) said a manager told him that he refused to be a 'Chicken Little.'
>
> The Columbia's flight director, Le Roy Cain, wrote a curt e-mail message that concluded, 'I consider it [the foam strike] to be a dead issue.'

A *Times* editorial the following day observed that this denial of impending danger led a frustrated Mr. Rocha ''to complain that NASA was acting more like 'an ostrich with its head in the sand.' Faced with such resistance, Mr. Rocha lost steam. He shrank from sending an e-mail note accusing shuttle managers of borderline irresponsibility and accepted the Boeing analysis (later shown to be fatally flawed) that the foam strike posed no risk to the shuttle.''

Clear two-way, open communications are key in HROs. Risk is mitigated by ensuring that pivotal decision-makers constantly receive the information—especially harsh and contrary information—they need to envision the ''big picture'' and to assess risk on an ongoing basis. In HROs, information about emerging risks and uncertainties is communicated very quickly to relevant decision-makers in as clear a form as possible. These parties, in turn, ''can put together warning signals from various areas of the organization, thus forming a picture of a risky or hazardous situation in its early stages of development.'' Clearly NASA was not able—or willing—to do this with respect to the flight of *Columbia*.

The core principles of mindfulness in highly reliable organizations may be summarized as follows:

1. Preoccupation with failure—constant awareness of the fact that something can go wrong and a willingness to track down any anomaly. This attitude is the very opposite of hubris. It is more like self-confidence with humility.
2. Deep understanding and appreciation of the complexity of the world the organization faces, and, consequently, a strong reluctance to simplify interpretations of observations. HROs do not simplify their tasks. What worked well yesterday will not necessarily work well today. No simple formulas suffice.
3. Focus on and sensitivity to operations and day-to-day business practices. At Dallas-based TDIndustries, for example, this concern is elevated to a ''passion for operations'' or ''sweating the small stuff.'' Mindfulness means worrying about what little bumps might lie ahead so one can anticipate what might go wrong, knowing that he or she can stumble on small things. By realizing they are in a complex world, being concerned with avoiding failure and focusing on operations people in a mindful culture keep alert. And facing complex, unruly technology, they must be forever humble. A little positive paranoia is justified. One famous practitioner of ''sweating the small stuff'' is former Intel chief executive officer (CEO) Andrew Grove. ''I believe in the value of paranoia,'' he says for shock value. ''I worry about products getting screwed up, and I worry about products getting introduced prematurely. I worry about factories not performing well, and I worry about having too many factories. I worry about hiring the right people, and I worry about morale slacking off. And, of course, I worry about competitors.'' NASA's culture under Von Braun sweated the small stuff. He and his associates worried about the details. The highest levels of management were involved in the design and manufacture of the craft and the execution of missions. But the NASA of the 1980s and 90s had established rather ridged levels of management that were difficult to penetrate. Senior executives did not worry about operational details

like O-rings and foam, they were loath to sweat the ''small stuff,'' that, in the end, turned out not to be so trivial at all.

4. Commitment to resilience and to responding quickly to contain any incipient problem. With respect to the O-rings NASA officials ignored persistent problems, with respect to the foam they failed to respond to Rocha's pleas. They simply did not want to respond to the problem.

5. Respect for and deference to relevant expertise, especially local expertise, wherever it resides. This requires listening to all pertinent points of view and letting the best, most knowledgeable person handle the situation regardless of rank or status. This is what a ''badgeless culture'' means. Here the present NASA culture of production deviated significantly from the culture of HROs. Roger Boisjoly, Arnie Thompson, Rodney Rocha and others' pleas and cautions went unheeded; their excellence was ignored.

As powerful as these 5 HRO precepts are, they have primarily been applied to technological issues. Mitroff asks, ''Would the Captain of a nuclear aircraft carrier address the statements 'Accusation of sexual harassment!' or 'Questionable accounting entry!' with the same alacrity as 'Foul on deck?' '' These may require a little more moral courage on the parts of both the accuser and the leader.

Reflecting on some of the lessons learned about organizational culture from the *Columbia* disaster, ethicist Rushworth Kidder concludes: ''Get the culture right, and the need for moral courage recedes as a daily requirement for doing business. If NASA is successful in developing a new culture, it won't need the courageous whistle-blowers it should have had in recent years.''

THREE ETHICAL PRINCIPLES FOR BUILDING TRUST

HROs build their culture around a value system based on three foundational ethical principles.

1. Knowledge and expertise is valued highly and encouraged to flow to the points in the organization where it is needed at the time it is needed. Contrary or annoying news is embraced. Decision-makers require adequate, wide-ranging information. In many situations, satisfying this principle requires that an organization switch back and forth—gracefully—between a hierarchical command-and-control structure and a flatter expert-centric structure. During its first decade and a half, NASA was effectively able to make these switches. In more recent years, however, its lines of authority—clearly labeled as Levels I, II, III and IV—have become more rigid and the expertise of employees has been effectively sealed off.

2. As many operations as feasible must be made open and transparent. Silence, confidentiality, cover-up, over protection of rights, and efforts to protect a reputation instead of telling the full truth are eliminated and only resorted to under exceptional security conditions. Potential and actual conflicts of interest are identified, reported and eliminated. NASA has lacked effective, open communications for some time. A 1999 independent assessment team chided that ''NASA *should continue to remove communication barriers and foster an inclusive environment where open communication is the norm*.'' It stressed the need to develop a culture in which ''*the importance of communication and a culture of trust and openness permeate all facets of the organization*.'' The report went on to recommend that ''*multiple processes to get the messages across the organizational structure*'' should be explored and fostered. It advised the agency to actively seek guidance in identifying and removing barriers to communications (emphases in originals).

3. Countervailing powers are encouraged, and independent oversight and audit of all operations is established, so that vested interests are exposed and controlled. Valuable information is not suppressed. In their wisdom, the United States' founding fathers recognized that unbridled power

was corrupting. The same ideas apply to creating effective organizations that are capable of dealing with today's uncertain technologies and changing realities. As early as 1990, a General Accounting Office (GAO) report found that ''NASA *did not have an independent and effective safety organization*,'' because they ''obtained most of their funds from activities whose safety-related performance they were responsible for overseeing.'' Based on these findings, the Board recommended that NASA ''establish an independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a disciplined, systematic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System.'' This authority ''should be funded directly from NASA Headquarters and should have no connection to or responsibility for schedule or program cost.'' That 1990 recommendation went largely unheeded.

One method for encouraging independent reporting is for an organization to set up a ''hot line'' or other third-party reporting mechanism that circumvents traditional lines of authority while maintaining anonymity. Many organizations have installed an ethics office or ombudsman that includes this as a central part of its mission.

SUMMARY

The *Columbia* disaster reminds us that at the heart of any organization are human emotions enshrouded in a culture. Its culture is the product of a history that may extend quite far back in time. Nevertheless, the history and resulting culture of an organization are integral parts of the context in which it makes decisions and acts. They are co-producers—causes—of events. Ethical cultures produce ethical events; less ethical ones do not. One reason for this is that successful cultures become susceptible to hubris and carelessness. One antidote for organizational hubris is the highly reliable organization (HRO) model, based on the concept of mindfulness. These organizations are constantly aware of the possibility of failure, appreciate the complexity of the world they face, concentrate on day-to-day operations and the little things, respond quickly to incipient problems, and accord deep respect to the expertise of their members. They value knowledge and expertise highly, communicate openly and transparently, and avoid concentrations of power or corruption by setting up independent units with countervailing powers.

With respect to *Columbia*, and *Challenger* and *Apollo* before it, NASA's culture proved to be lethal. It did not adhere to precepts like those upon which HROs are based. Because the agency failed to follow ethical principles such as deep respect for knowledge, openness in communications, and independence in operations, the *Columbia* disintegrated as it sought re-entry over the skies of Texas. From this tragedy, however, we can distill a few important lessons for the future.

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