Hazard Assessment

Is a Major Accident About to Occur in Your Operations?

Lessons to learn from the space shuttle Columbia *explosion*

By Fred A. Manuele

THE REPORT ISSUED IN AUGUST 2003 by the Columbia Accident Investigation Board (CAIB) is revealing about how a lot of little things can add up to a big thing. This report provides SH&E practitioners a basis for reflection on the potential for the occurrence of major accidents in their operations. This article is presented in three parts. Part 1 reviews the origins of causal factors for accidents that result in serious consequences. Part 2 presents excerpts from Volume 1 of CAIB's report. Part 3 presents a discussion guide which can be used to determine whether latent hazardous conditions and practices that could be the causal factors for a major accident have accumulated in a given setting. This guide provides the basis for a cultural, organizational and technical self-evaluation. It is for use by SH&E practitioners and, more particularly, for the executives influenced by those practitioners to undertake a review of major accident potential.

Fred A. Manuele, P.E., CSP, *is president of Hazards Limited, which he formed after retiring from Marsh & McLennan, where he was managing director and manager of M&M Protection Consultants. Manuele is an ASSE Fellow, an inductee of the Safety and Health Hall of Fame International and a recipient of National Safety Council's Distinguished Service to Safety Award. He is also a former board member of ASSE, Board of Certified Safety Professionals and National Safety Council, a former member of ASSE's Editorial Review Board, and a current member of NSC's Press Editorial Advisory Board and the Advisory Committee for The Institute for Safety Through Design. Manuele is a professional member of ASSE's Northeastern Illinois Chapter.*

Part 1: Causal Factors

Major accidents—meaning low-probability incidents with severe consequences—typically result from an accumulation of what Reason refers to as latent conditions. Such latent technical conditions and operating practices are built into a system and shape an organization's culture. In *Managing the Risks of Organizational Accidents*, Reason discusses the long-term impact of a continuum of less-than-adequate safety decision making—which is a central theme in CAIB's report:

> Latent conditions, such as poor design, gaps in supervision, undetected manufacturing defects or maintenance failures, unworkable procedures, clumsy automation, shortfalls in training, less than adequate tools and equipment, may be present for many years before they combine with local circumstances and active failures to penetrate the system's layers of defenses. They arise from strategic and other top-level decisions made by governments, regulators, manufacturers, designers and organizational managers. The impact of these decisions spreads throughout the organization, shaping a distinctive corporate culture and creating error-producing factors within the individual workplaces (10).

In this paragraph, Reason cites many of the cultural and organizational shortcomings that resulted in less-than-adequate safety decision-making at NASA, which CAIB considered significant. In *The*

Psychology of Everyday Things, Norman writes similarly about how major accidents occur:

> Explaining away errors is a common problem in commercial accidents. Most major accidents follow a series of breakdowns and errors, problem after problem, each making the next more likely. Seldom does a major accident occur without numerous failures: equipment malfunctions, unusual events, a series of apparently unrelated breakdowns and errors that culminate in major disaster; yet no single step has appeared to be serious. In many cases, the people noted the problem but explained it away, finding a logical explanation for the otherwise deviant observation (128).

What Norman says about "numerous failures" being typical when major accidents occur matches this author's experience, having reviewed many accident reports pertaining to severe injuries and fatalities. While reading the excerpts from CAIB's report later this article, two key quotes should be kept in mind:

> The impact of [top-level] decisions spreads throughout the organization, shaping a distinctive corporate culture and creating error-producing factors within individual workplaces (Reason 10).

> In many cases, the people noted the problem but explained it away, finding a logical explanation for the otherwise deviant observation (Norman 128).

SH&E professionals should review CAIB's entire investigation report, which is available at www.nasa.gov/columbia/home/CAIB_Vol1.html. While it is upsetting, readers are reminded that similar latent technical conditions and operating practices could exist in their operations.

The reality is that the following scenario is often repeated. A location does well for several years as measured by its safety statistics. Then, a major accident occurs and everyone is shocked that such an incident could happen in their operations. After all, wasn't the safety record commendable?

Unfortunately, what follows a major accident is well-described in CAIB's report.

> Many accident investigations do not go far enough. They identify the technical cause of the accident, and then connect it to a variant of "operator error"—the line worker who forgot to insert a bolt, the engineer who miscalculated the stress or the manager who made the wrong decision. But this is seldom the entire issue. When the determinations of the causal chain are limited to the technical flaw and individual failure, typically the actions taken to prevent a similar event in the future are also limited: Fix the technical problem and replace or retrain the individual responsible. 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. (CAIB 97).

SH&E practitioners who still profess that most work-related accidents are principally caused by unsafe acts of workers should seriously consider the report excerpts that follow. Perhaps their incident investigation procedures do not go far enough and should be extended to identify the real root-cause factors, as CAIB did.

PHOTO COURTESY NASA.

Furthermore, it is believed that the highlights of this report form a base from which operations managers and SH&E practitioners can assess whether there have been shortcomings in decision making in the past with respect to safety in the operations they influence. Such an assessment could determine whether these shortcomings have resulted in an accumulation of latent conditions and operating practices that may have serious injury potential. It will also result in an assessment of the organization's safety culture.

The verbatim excerpts from the 248-page Volume 1 describe cultural deficiencies that may exist in any operation. They also reinforce several premises:

- Causal factors for accidents that result in severe injuries are multiple and complex, and relate to several levels of responsibility.
- Accident investigations often blame a failure only on the last step in a complex process, when a more comprehensive understanding of that process could reveal that earlier steps might be equally or even more culpable.
- Accidents that result in severe injuries may not be random events; rather, their causal factors may derive from an accumulation over time of deficiencies in an organization's safety culture.
- An organization's culture with respect to safety decision making determines the incident experience obtained.

These highlights form a base from which stakeholders can assess whether there have been shortcomings in safety decision making.

Part 2: CAIB Report Excerpts

The Board Statement

Our aim has been to improve shuttle safety by multiple means, not just by correcting the specific faults that cost the nation this orbiter and this crew. With that intent, the board conducted not only an investigation of what happened to *Columbia*, but also to determine the conditions that allowed the accident to occur—a safety evaluation of the entire space shuttle program.

It is our view that complex systems almost always fail in complex ways, and we believe it would be wrong to reduce the complexities and weaknesses associated with these systems to some simple explanation.

In this board's opinion, unless the technical, organizational and cultural recommendations made in this report are implemented, little will have been accomplished to lessen the chance that another accident will follow (CAIB 6).

The Executive Summary

The board recognized early on that the accident was probably not an anomalous, random event, but rather likely rooted to some degree in NASA's history and the human space flight program's culture. Accordingly, the board broadened its mandate at the outset to include an investigation of a wide range of historical and organizational issues, including political and budgetary considerations, compromises and changing priorities over the life of the space shuttle program. The board's conviction regarding the importance of these factors strengthened as the investigation progressed, with the result that this report, in its findings, conclusions and recommendations, places as much weight on these causal factors as on the more easily understood and corrected physical cause of the accident (CAIB 9).

[Note: The executive summary remarks extensively on the physical and organizational causal factors for the accident. In-depth comments about the causal factors are found later in the report.]

The Report Synopsis

We consider it unlikely that the accident was a random event; rather it was likely related in some degree to NASA's budgets, history and program culture, as well as to the politics, compromises [and] changing priorities of the democratic process. We are convinced that the management practices overseeing the space shuttle program were as much a cause of the accident as the foam that struck the left wing (CAIB 11).

CAIB Report Part One: The Accident

Chapter 1: The Evolution of the Space Shuttle Program

It is the view of the Columbia Accident Investigation Board that the *Columbia* accident is not a random event, but rather a product of the space shuttle program's history and current management processes. Fully understanding how it happened requires an exploration of that history and management. This chapter charts how the shuttle emerged from a series of political compromises that produced unreasonable expectations—even myths—about its performance, how the *Challenger* accident shattered those myths several years after NASA began acting upon them as fact, and how, in retrospect, the shuttle's technically ambitious design resulted in an inherently vulnerable vehicle, the safe operation of which exceeded NASA's organizational capabilities as they existed at the time of the *Columbia* accident.

To understand the cause of the *Columbia* accident is to understand how a program promising reliability and cost efficiency resulted instead in a developmental vehicle that never achieved the fully operational status NASA and the nation accorded it (CAIB 21).

The *Challenger* Accident

When the Rogers Commission discovered that, on the eve of the launch, NASA and a contractor had vigorously debated the wisdom of operating the shuttle in the cold temperatures predicted for the next day, and that more senior NASA managers were unaware of this debate, the commission shifted the focus of its investigation to "NASA management practices, center-headquarters relationships and the chain of command for launch commit decisions." As the investigation continued, it revealed a NASA culture that had gradually begun to accept escalating risk, and a NASA safety program that was largely silent and ineffective (CAIB 25).

Chapter 3: Accident Analysis

The Physical Cause

The physical cause of the loss of *Columbia* and its crew was a breach in the thermal protection system on the leading edge of the left wing. The breach was initiated by a piece of insulating foam that separated from the left bipod ramp of the external tank and struck the wing in the vicinity of the lower half of reinforced carbon-carbon panel 8 at 81.9 seconds after launch. During re-entry, this breach . . . allowed superheated air to penetrate 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 (CAIB 49).

STS-107 Left Bipod Foam Ramp Loss

Foam loss has occurred on more than 80 percent of the 79 missions for which imagery is available, and foam was lost from the left bipod ramp on nearly 10 percent of missions where the left bipod ramp was visible following external tank separation (CAIB 53).

The precise reasons why the left bipod foam ramp was lost from the external tank during STS-107 [the *Columbia* mission] may never be known. The specific initiating event may likewise remain a mystery. However, it is evident that a combination of variable and pre-existing factors, such as insufficient testing and analysis in the early design stages, resulted in a highly variable and complex foam material, defects induced by an imperfect and variable application, and the results of that imperfect process, as well as severe load, thermal, pressure, vibration, acoustic, and structural launch and ascent conditions (CAIB 53, 55).

The Orbiter "Ran Into" the Foam

"How could a lightweight piece of foam travel so fast and hit the wing at 545 miles an hour?" Just prior to separating from the external tank, the foam was traveling with the shuttle stack at about 1,568 mph (2,300 feet per second). Visual evidence shows that the foam debris impacted the wing approximately 0.161 seconds after separating from the external tank. In that time, the velocity of the foam debris slowed from 1,568 mph to about 1,022 mph (1,500 feet per second). Therefore, the orbiter hit the foam with a relative velocity of about 545 mph (800 feet per second). In essence, the foam debris slowed down and the orbiter did not, so the orbiter ran into the foam. The foam slowed down rapidly because such low-density objects have low ballistic coefficients, which means that their speed rapidly decreases when they lose their means of propulsion (CAIB 60).

Orbiter Sensors

Nearly all of *Columbia*'s sensors were specified to have only a 10-year shelf life, and in some cases an even shorter service life. At 22 years old, the majority of the orbiter experiment instrumentation had been in service twice as long as its specified service life and, in fact, many sensors were already failing. Engineers planned to stop collecting and analyzing data once most of the sensors had failed, so failed sensors and wiring were not repaired. For instance, of the 181 sensors in *Columbia*'s wings, 55 had already failed or were producing questionable readings before STS-107 was launched (CAIB 65).

Findings

[During re-entry] abnormal heating events preceded abnormal aerodynamic events by several minutes. By the time data indicating problems was telemetered to Mission Control Center, the orbiter had already suffered damage from which it could not recover (CAIB 73).

CAIB Report Part Two: Why the Accident Occurred

In our view, the NASA organizational culture had as much to do with this accident as the foam. Organizational culture refers to the basic values, norms, beliefs and practices that characterize the functioning of an institution. At the most basic level, organizational culture defines the assumptions that employees make as they carry out their work. It is a powerful force that can persist through reorganizations and the change of key personnel. It can be a positive or a negative force.

At NASA's urging, the nation committed to building an amazing, if compromised, vehicle called the space shuttle. When the agency did this, it 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 (CAIB 97).

Chapter 5: From Challenger *to* Columbia

The board is convinced that the factors that led to the *Columbia* accident go well beyond the physical mechanisms [previously] discussed. The causal roots of the accident can also be traced, in part, to the turbulent post-Cold War policy environment in which NASA functioned during most of the years between the destruction of *Challenger* and the loss of *Columbia*.

The agency could not obtain budget increases through the 1990s. Rather than adjust its ambitions to this new state of affairs, NASA continued to push an ambitious agenda of space science and exploration, including a costly space station program.

The space shuttle program has been transformed since the late 1980s implementation of post-*Challenger* management changes in ways that raise questions . . . about NASA's ability to safely operate the space shuttle. While it would be inaccurate to say that NASA managed the space shuttle program at the time of the *Columbia* accident in the same manner it did prior to *Challenger,* there are unfortunate similarities between the agency's performance and safety practices in both periods (CAIB 99).

Space Shuttle Program Budget Patterns

In Fiscal Year 1993, the outgoing Bush administration requested $4.128 billion for the space shuttle program; five years later, the Clinton administration request was for $2.977 billion, a 27-percent reduction. By Fiscal Year 2003, the budget request had increased to $3.208 billion, still a 22-percent reduction from a decade earlier. With inflation taken into account, over the past decade, there has been a reduction of approximately 40 percent in the purchasing power of the program's budget, compared to a reduction of 13 percent in the NASA budget overall (CAIB 104).

Conclusion

[T]his is hardly an environment in which those responsible for safe operation of the shuttle can function without being influenced by external pressures. It is to the credit of space shuttle managers and the shuttle workforce that the vehicle was able to achieve its program objectives for as long as it did. An examination of the shuttle program's history from *Challenger* to *Columbia* raises the question: Did the space shuttle program budgets constrained by the White House and Congress threaten safe shuttle operations? There is no straightforward answer. At the time of the launch of STS-107, NASA retained too many negative (and also many positive) aspects of its traditional culture: "flawed decision making, self deception, introversion and a diminished curiosity about the world outside the perfect place." These characteristics were reflected in NASA's less-than-stellar performance before and during the STS-107 mission (CAIB 118).

Chapter 6: Decision Making at NASA

A History of Foam Anomalies

The shedding of external tank foam—the physical cause of the *Columbia* accident—had a long history. Damage caused by debris has occurred on every space shuttle flight, and most missions have had insulating foam shed during ascent. This raises an obvious question: Why did NASA continue flying the shuttle with a known problem that violated design requirements? It would seem that the longer the shuttle program allowed debris to continue striking the orbiters, the more opportunity existed to detect the serious threat it posed. But this is not what happened (CAIB 121).

Original Design Requirements

Early in the space shuttle program, foam loss was considered a dangerous problem. Design engineers were extremely concerned about potential damage to the orbiter and its fragile thermal protection system, parts of which are so vulnerable to impacts that lightly pressing a thumbnail into them leaves a mark (CAIB 121).

Findings

Foam-shedding, which had initially raised serious safety concerns, evolved into "in-family" or "no-safety-of-flight" events or were deemed an "accepted risk" (CAIB 130).

NASA failed to adequately perform trend analysis on foam losses. This greatly hampered the agency's ability to make informed decisions about foam losses (CAIB 131).

Discovery & Initial Analysis of Debris Strike

In the course of examining film and video images of *Columbia*'s ascent, the Intercenter Photo Working Group identified, on the day after launch, a large debris strike to the leading edge of *Columbia*'s left wing. Alarmed at seeing so severe a hit so late in ascent, and at not having a clear view of damage the strike might have caused, Intercenter Photo Working Group members alerted senior program managers by phone and sent a digitized clip of the strike to hundreds of NASA personnel via e-mail. These actions initiated a contingency plan that brought together an interdisciplinary group of experts from NASA, Boeing and the United Space Alliance to analyze the strike. So concerned were Intercenter Photo Working Group personnel that on the day they discovered the debris strike, they tapped their chair . . . to see through a request to image the left wing with Dept. of Defense assets in anticipation of analysts needing these images to better determine potential damage. By the board's count, this would be the first of three requests to secure imagery of *Columbia* on-orbit during the 16-day mission (CAIB 166).

[Note: Thirty-two pages in Volume 1 are devoted to decision making pertaining to analysis of the initial foam strike. Under the caption "Missed Opportunities," the report discusses eight situations whereby management personnel might have decided to arrange for the requested imagery. Comparable comments are also made in Chapter 2 concerning the absence of positive responses to requests of the Intercenter Photo Working Group and the Debris Assessment Team for the Dept. of Defense to photograph the orbiter's underside.]

Shuttle Program Management's Low Level of Concern

The opinions of shuttle program managers and debris and photo analysts on the potential severity of the debris strike diverged early in the mission and continued to diverge as the mission progressed, making it increasingly difficult for the Debris Assessment Team to have [its] concerns heard by those in a decision-making capacity. In the face of mission managers' low level of concern and desire to get on with the mission, Debris Assessment Team members had to prove unequivocally that a safety-of-flight issue existed before shuttle program management would move to obtain images of the left wing. The engineers found themselves in the unusual position of having to prove that the situation was unsafe—a reversal of the usual requirement to prove that a situation is safe (CAIB 169).

A Lack of Clear Communication

Communication did not flow effectively up to or down from program managers. As it became clear during the mission that managers were not as concerned as others about the danger of the foam strike, the ability of engineers to challenge those beliefs greatly diminished. Managers' tendency to accept opinions that agree with their own dams the flow of effective communications.

After the accident, program managers stated privately and publicly that if engineers had a safety concern, they were obligated to communicate their concerns to management. Managers did not seem to understand that as leaders they had a corresponding and perhaps greater obligation to create viable routes for the engineering community to express their views and receive information. This barrier to communications not only blocked the flow of information to managers, but it also prevented the downstream flow of information from managers to engineers, leaving Debris Assessment Team members no basis for understanding the reasoning behind Mission Management Team decisions (CAIB 169).

The Failure of Safety's Role

Safety personnel were present but passive and did not serve as a channel for the voicing of concerns or dissenting views. Safety representatives attended meetings of the Debris Assessment Team, Mission Evaluation Room and Mission Management Team, but were merely party to the analysis process and conclusions instead of an independent source of questions and challenges. Safety contractors in the Mission Evaluation Room were only marginally aware of the debris strike analysis (CAIB 170).

Summary

Management decisions made during *Columbia*'s final flight reflect missed opportunities, blocked or ineffective communications channels, flawed analysis and ineffective leadership. Perhaps most striking is the fact that management—including shuttle program, mission management team, Mission Evaluation Room, and flight director and Mission Control—displayed no interest in understanding a problem and its implications. Because managers failed to avail themselves of the wide range of expertise and opinion necessary to achieve the best answer to the debris strike question . . . some space shuttle program managers failed to fulfill the implicit contract to do whatever is possible to ensure the safety of the crew (CAIB 170).

Chapter 7: The Accident's Organizational Causes

Organizational Cause Statement

The organizational causes of this accident are rooted in the space shuttle program's history and culture, including the original compromises that were required to gain approval for the shuttle program, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterizations of the shuttle as operational rather than developmental and lack of an agreed national vision. Cultural traits and organizational practices detrimental to safety and reliability were allowed to develop, including:

- reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements/specifications);
- organizational barriers which prevented effective communication of critical safety information and stifled professional differences of opinion;
- lack of integrated management across program elements;
- the evolution of an informal chain of command and decision-making processes that operated outside the organization's rules (CAIB 177).

Understanding Causes

In the board's view, NASA's organizational culture and structure had as much to do with this accident as the external tank foam.

Given that today's risks in human space flight are as high and the safety margins as razor-thin as they have ever been, there is little room for overconfidence. Yet the attitudes and decision making of shuttle program managers and engineers during the events leading up to this accident were clearly overconfident and often bureaucratic in nature. They deferred to layered and cumbersome regulations rather than the fundamentals of safety.

As the board investigated the *Columbia* accident, it expected to find a vigorous safety organization, process and culture at NASA, bearing little resemblance to what the Rogers Commission identified. NASA's initial briefings to the board on its safety programs espoused a risk-averse philosophy that empowered any employee to stop an operation at the mere glimmer of a problem. Unfortunately, NASA's views of its safety culture in those briefings did not reflect reality (CAIB 177).

The silence of program-level safety processes undermined oversight; when they did not speak up, safety personnel could not fulfill their stated mission to provide "checks and balances." A pattern of acceptance prevailed throughout the organization that tolerated foam problems without sufficient engineering justification for doing so (CAIB 178).

Chapter 8: History As Cause:
Columbia & Challenger
Echoes of *Challenger*

The constraints under which the agency has operated throughout the shuttle program have contributed to both shuttle accidents. Although NASA leaders have played an important role, these constraints were not entirely of NASA's own making. The White House and Congress must recognize the role of their decisions in this accident and take responsibility for safety in the future (CAIB 195-196).

Failures of Foresight: Two Decision Histories & the Normalization of Deviance

NASA documents show how official classifications of risk were downgraded over time. Program managers designated the foam problem and the O-ring erosion as "acceptable risks" in flight readiness reviews (CAIB 196).

System Effects: The Effect of History & Politics on Risky Work

The board found that dangerous aspects of NASA's 1986 culture, identified by the Rogers Commission, remained unchanged (CAIB 198).

Pre-*Challenger* budget shortages resulted in safety personnel cutbacks. Without clout or independence, the safety personnel who remained were ineffective. In the case of *Columbia*, the board found the same problems were reproduced and for an identical reason: When pressed for cost reduction, NASA attacked its own safety system. The faulty assumption that supported this strategy prior to *Columbia* was that a reduction in safety staff would not result in a reduction of safety because contractors would assume greater safety responsibility. Post-*Challenger* NASA still had no systematic procedure for identifying and monitoring trends (CAIB 198-199).

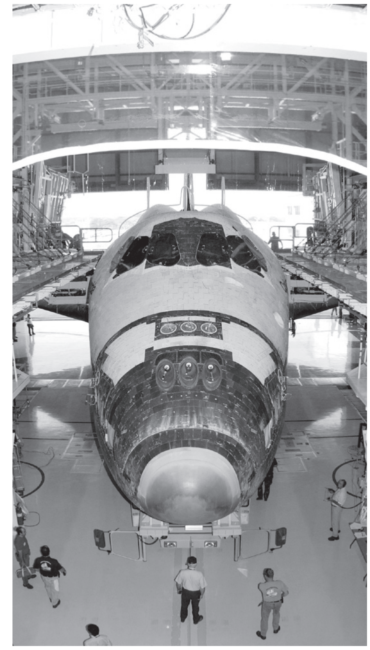

PHOTO COURTESY NASA.

Top executives must take responsibility for risk, failure and safety by remaining alert to the effects their decisions have on the system.

Organization, Culture & Unintended Consequences

At the same time that NASA leaders were emphasizing the importance of safety, their personnel cutbacks sent other signals. Streamlining and downsizing, which scarcely go unnoticed by employees, convey a message that efficiency is an important goal. The shuttle/space station partnership affected both programs. Working evenings and weekends just to meet the International Space Station Node 2 deadline sent a signal to employees that schedule is important. When paired with the "faster, better, cheaper" NASA motto of the 1990s and cuts that dramatically decreased safety personnel, efficiency becomes a strong signal and safety a weak one. This kind of doublespeak by top administrators affects people's decisions and actions without them even realizing it (CAIB 199).

History as a Cause: Two Accidents

The organizational structure and hierarchy blocked effective communication of technical problems. Signals were overlooked, people were silenced, and useful information and dissenting views on technical issues did not surface at higher levels. What was communicated to parts of the organization was that O-ring erosion and foam debris were not problems (CAIB 201).

NASA's safety system lacked resources, independence, personnel and authority to successfully apply alternative perspectives to developing problems. Overlapping roles and responsibilities across multiple safety offices also undermined the possibility of a reliable system of checks and balances (CAIB 202).

Changing NASA's Organizational System

Leaders create culture. It is their responsibility to change it. Top administrators must take responsibility for risk, failure and safety by remaining alert to the effects their decisions have on the system. Leaders are responsible for establishing the conditions that lead to their subordinates' successes or failures. 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 (203).

Part 3: Discussion Guide

An SH&E professional will need both considerable tact and diplomacy to convince management to review the history of safety decision making in order to determine whether, over time, latent technical conditions and operating practices have accumulated which could be the causal factors for a major accident. To generate interest in such a review, the author recommends that SH&E professionals send this article up through the organizational chain.

To facilitate such a review, it would be valuable to develop an outline of subjects to be discussed. An initial outline follows. It pertains specifically and only to the content of the CAIB report and, therefore, is not complete. However, it can serve as a framework for developing a discussion outline suitable to a particular operation.

1) How does management view its safety culture? How does management's view compare with the perception of employees? Does senior management's view of the safety culture reflect reality?

2) Does a gap exist between what management says and what management does?

3) Has the staff reporting directly to the senior manager been held accountable, in reality, for a high level of safety decision making?

4) Does the organization's culture gradually accept escalating risk?

5) Does the organizational structure enhance safety decision making?

6) Do organizational barriers prevent effective communication on safety, up and down?

7) Have streamlining and downsizing conveyed a message that efficiency and being on schedule are paramount, and that safety considerations can be overlooked? Does this result in "doublespeak" by management?

8) Are technical and operational safety standards at a sufficiently high level?

9) Has it been the practice to accept performance at a lesser level than that prescribed in technical and operational standards?

10) Have known safety problems, over time, been relegated to a less-than-adequate status and, thereby, become "accepted risk"?

11) Have safety-related hardware and software become obsolete?

12) Are certain operations continued with the knowledge they are unduly hazardous?

13) Have budget constraints had a negative effect on safety decision making?

14) Has inadequate maintenance resulted in an accumulation of hazardous situations that have gone unattended? For example, is detection equipment adequate, maintained and operable; are basic repairs to structures and equipment awaiting action?

15) For the opportunity to apply early interventions, has adequate attention been paid to near-hit incidents that could, under other circumstances, result in a major accident?

16) Are SH&E personnel encouraged to be tactfully aggressive when expressing their views on hazards and risks, even though their views may differ from those held by others?

17) Has it been acceptable that accident investigation stops at the first identifiable causal factor (referred to in the *Columbia* report as "the immediate technical flaw or individual failure")? Or, are accidents investigated in depth to identify the real root-cause factors so that appropriate safety interventions can be applied?

18) Has the firm relied too heavily on outside contractors (outsourcing) to do what they cannot do effectively with respect to safety?

19) Are purchasing and contracting procedures in place at a level to ensure that hazards are not introduced to the workplace?

Responses to these questions would be evaluative. What resources might an SH&E practitioner use to determine the related best practices? These publications (all available through ASSE) are a starting point:

- *Accident Investigation Techniques: Basic Theories, Analytical Methods and Applications* by Jeffrey S. Oakley.
- *Analyzing Safety System Effectiveness, Third Edition*, by Dan Petersen.
- *Innovations in Safety Management: Addressing Career Knowledge Needs*, by Fred A. Manuele.
- *Managing for World Class Safety*, by J.M. Stewart.
- *On The Practice of Safety, Third Edition*, by Fred A. Manuele.
- *Safety Engineering, Third Edition*, by Richard T. Boehm.

Safety management systems do not often include provisions for identifying and minimizing the potential for major accidents. It seems that there is opportunity here for the enterprising. ■

References

Columbia Accident Investigation Board (CAIB). "Columbia Accident Investigation Board Report, Vol. 1." Washington, DC: NASA, Aug. 2003. <http://www.nasa.gov/columbia/home/CAIB_Vol1.html>.

Norman, D.A. *The Psychology of Everyday Things.* New York: Basic Books, 1988.

Reason, J. *Managing the Risks of Organizational Accidents.* Burlington, VT: Ashgate Publishing Co., 1997.

Your Feedback

Did you find this article interesting and useful? Circle the corresponding number on the reader service card.

RSC#	*Feedback*
31	**Yes**
32	**Somewhat**
33	**No**