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Do Shocks Change Organizations? The Case of NASA

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ABSTRACT

The 50-year history of the National Aeronautics and Space Administration's (NASA) spaceflight program is marked by spectacular accomplishments and devastating tragedy. NASA has suffered three major disasters, each of which destroyed a spacecraft and killed its crew. In the wake of each accident, investigators and analysts identified causes and recommended technical and organizational improvements that NASA should undertake. The NASA case presents an opportunity to examine the question: Do shocks change organizations? The article reviews three prominent theoretical models of organizational change. Then, using data derived from 5 years of participant observation, as well as government reports, academic investigations, and news articles, we present an analysis of whether the factors required for change identified in the literature were and are present at NASA. The results of this examination suggest that in the wake of these shocks, the agency undertook many technical and procedural changes, but that, as the literature predicts, there are also barriers embedded in the fabric of the agency that are likely to thwart change. We conclude by examining the prospects for understanding change in public, private, and nonprofit organizations of all sizes that experience shocks and offer propositions for future research.

The 50-year history of the National Aeronautics and Space Administration's (NASA) spaceflight program is marked by spectacular accomplishments. These triumphs of science, engineering, and technology have come at a high price, however. NASA has suffered three major disasters, each of which destroyed a spacecraft and killed its crew. Some would say the many benefits of NASA's work do not justify these costs. Others argue only great risks bring great rewards. Regardless, all concur that NASA can and should learn from its mistakes and make changes to mitigate the chance of further catastrophe. In the wake of each accident, investigators and analysts identified causes and recommended technical and organizational improvements that NASA should undertake. The NASA case presents an opportunity to examine the question: Do shocks change organizations?

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The article reviews three seminal models of organizational change to distill the theoretical preconditions for change. Then, using data derived from 5 years of participant observation, government reports, academic investigations, and news articles, we examine NASA's organization to determine whether the requirements for successful change were present before and after the *Columbia* accident. We conclude by examining the lessons learned for change in organizations more generally and offer propositions for future research.

This study makes several contributions. First, we examine the NASA phenomenon through a theoretical lens distinct from any used before in the public management literature—one that combines three theories. This yields a different perspective on the NASA case than prior studies that have focused on the causes of the accidents or NASA's ability to learn. At the same time, it allows key models of organizational change to be vetted against this case to help confirm and improve their utility. In addition, we join Vaughan as among the few scholars who have written about NASA as participant observers in NASA change efforts. Moreover, we include the perspective of three accidents, whereas other studies typically focus only on one (though Boin and Schulman's [2008] analysis is a notable exception). Last, although one study discovered that over 1 million articles that address organization change have been published across nine disciplines (Van de Ven and Poole 1995), there are relatively few articles on organization change in the public management literature (Fernandez and Rainey 2006). This is surprising since change is a central management concern. This article serves to fill that gap and helps to draw these literatures together in a way that is relevant to all organizations that experience shocks.

NASA IN THE LITERATURE

There is no shortage of analyses of NASA's organizational challenges in the literature. Perhaps most prominent is Vaughan's (1996) *The Challenger Launch Decision*, in which she analyzed in great detail the decision to launch the *Challenger* space shuttle above the objections of some NASA technical staff. This seminal work gave rise to the concept of the normalization of deviance, now familiar in the risk literature. Among her conclusions is that the *Challenger* disaster was "socially organized and systematically produced" as people in organizations incrementally translated deviance into acceptable behavior through the process of normalization (1996, 394). Vaughan closed by criticizing environmental forces that torqued NASA's culture and expressed some cynicism about the future of the organization.

Romzek and Dubnick (1987) examined the *Challenger* tragedy from an institutional perspective with a view toward describing the landscape of accountability mechanisms within which NASA operated. An important insight from their work is the great difficulty NASA had in balancing the numerous, conflicting expectations of a democratic political system. They showed that the technical challenges NASA faced over time were relatively stable compared to very dynamic institutional pressures. In particular, NASA's success in the "space race" caused these pressures to shift: As constituents came to view space flight as more routine and operational, expectations rose while political support and budgets fell. Finally, Romzek and Dubnick determined that the accident resulted from the mismatch between the technical problems NASA faced and the political and bureaucratic accountability mechanisms to which the agency felt beholden. They were prescient in their conclusion that the new legal and bureaucratic accountability mechanisms and numerous other reforms the *Challenger* accident forced upon NASA would enhance rather than thwart the likelihood of further failures.

J. L. Hall (2003) examined organizational failure at NASA, focusing on the *Columbia* and *Challenger* space shuttle accidents. Noting NASA's uniqueness on a number of measures, Hall asserts that NASA's institutionalized risk is invariably high. Mitigating this risk becomes more difficult as budgets are cut and the organization becomes more complex; additionally, the mission has gradually moved from specific to abstract. Hall points out that change processes at NASA are also complicated by path dependence (which limits reactions to stimuli) and by the routinization of "acceptable deviance"—which noted scientist Richard Feynman has likened to Russian roulette, saying "[the Shuttle] flies [with O-Ring erosion] and nothing happens. Then it is suggested, therefore, that the risk is no longer so high for the next flights. We can lower our standards a little bit because we got away with it last time" (Rogers Commission 1986, chap. 6). Finally, Hall notes that embedded bureaucracy inappropriate to NASA's work presents a significant obstacle to implementing necessary change. The *Columbia* disaster revealed that NASA had not absorbed key lessons from the *Challenger* accident, and thus, forewarnings leading up to the *Columbia* disaster were not given due attention. Management's refusal to adequately address engineers' concerns indicates a troubling ability of bureaucracy to thwart legitimate inquiry and a clear hierarchical problem. Problematic cultural features unique to NASA were specifically identified by Hall along with their potential for, and historical involvement in, disaster.

Boin and Shulman (2008) analyzed the Columbia Accident Investigation Board (CAIB)'s report after the space shuttle accident and disagreed with the CAIB's conclusion that NASA should emulate the characteristics of a High Reliability Organization (HRO) or one that is able to avoid accidents even in complex, high-risk endeavors (Roberts 1990). Examining the history of the space flight program, the authors concluded that NASA never has been, and never could be, an HRO. They assert that NASA is instead a reliability-seeking organization and should be assessed as such, rather than as an HRO. Under their proposal, safety should be a core value, there should be a continual search for error in day-to-day operations, and the organization's institutional integrity should be preserved.

Recently, Mahler and Casamayou (2009) examined organization learning at NASA with a view toward identifying constraints on learning and factors that undermine learning. Through an extensive examination of reports, testimony, and government documents produced after the *Challenger* and *Columbia* accidents, they take on the charge that NASA did not learn from these events and conclude instead that NASA's record with respect to learning and change is complex and mixed. Their analysis identifies conditions that enable or inhibit learning and the array of learning outcomes that can arise as a result. Mahler and Casamayou distill several reasons why NASA did not learn from problems revealed by the *Challenger* accident. They show that NASA's analysis of the problems related to *Challenger* was inadequate to allow managers to make the causal inferences that undergird learning. They also point out that although NASA complied with the accident investigators' recommendations after *Challenger*, they did not make the fundamental cognitive changes required for learning. Finally, they explain that NASA did learn in some cases but that the changes they made were later reversed by new priorities, resource pressures, and political agendas.

RESEARCH PROBLEM AND APPROACH

These observations and others about NASA in the literature were no surprise to us. Based on our own close and sustained interactions with many NASA managers over a period of 5 years, our perception was that despite the exceptionally high quality of the NASA workforce, and the shocks of three space shuttle accidents, NASA's record with respect to implementing the changes accident investigators recommended was mixed. In particular, NASA appears to have succeeded at implementing many technical changes, but to have been less successful addressing organizational and managerial problems. What we wanted to know is *why?* Specifically, our research objective is to examine the NASA case in light of select models of organizational change in order to determine whether the theorized requirements for organizational change were present at NASA.

This objective could viably be met by analyzing any of several facets of the NASA organization—structure, design, technology, information technology, power, motivation, human relations, management, goals, effectiveness, strategy, decision making, leadership, communication, culture, and many more. Further, each of these features could be dissected for NASA's headquarters and all its fifteen facilities and centers. In this article, however, we narrow our spotlight to NASA's manned space flight program and the three major accidents that program has experienced. We concentrate on the changes that expert commissions recommended, that NASA said it was going to make, and that NASA did or did not make, in response to these shocks. We give most of our attention to the *Columbia* accident since we had direct interaction with NASA before and after this accident. We also reflect briefly on the Apollo and *Challenger* accidents because they serve to highlight some persistent themes about change at NASA. For these cases, we rely on the reports of accident investigators and the analyses of other scholars.

To tackle this topic, we began by identifying the requirements for successful organizational change identified in the literature. Against these criteria, we examined the organizational and managerial conditions at NASA surrounding each accident. We used two main research strategies to accomplish this appraisal. The first was to review existing assessments of NASA documented in the academic literature, reports published by NASA, and analyses generated by independent commissions and boards. The second was to take advantage of the opportunity we had to study NASA as participant observers as we each served on two prominent NASA investigative and oversight bodies in the period immediately following the *Columbia* accident. In addition, one of us served as a special assistant to the NASA Administrator before the *Columbia* accident and was deeply involved in the field recovery operation in the wake of the accident.

Participant observation is a naturalistic research approach employed to gain intimate knowledge of the context-specific opinions and practices of a group of individuals. To accomplish this, researchers assume roles that involve them with a group in its usual environment, typically over an extended period of time. Protracted interaction allows an observer to gain more valid data about the subjects under study because issues and topics are confronted multiple times with multiple members of the group, permitting the range of perspectives present in the group to be revealed and cross-checked. In addition, more subtle perceptions and behaviors can be observed over time to gain a deeper understanding of their meaning (Lofland and Lofland 1995). Participant observers typically use multiple methods to gather data, including informal interviews, direct observation, participation in group activities, collective discussions, and analyses of documents generated by the group, all of which we used in this study. This multimethod approach also improves validity (Johnson 1997).

Major criticisms of participant observation are that the people under observation modify their behavior because they know they are being observed (a problem termed "reactivity") and that they do not permit the observer to see what goes on "behind the curtain." Observations may therefore be biased and may not reveal true the true opinions and behaviors of group members (Babbie 2007). Countering this view are experts on ethnographic techniques who argue that reactive effects do not contaminate observation and disrupt behavior; rather these effects offer a means by which the observer can witness and understand the subtleties of why people behave as they do (Emerson, Fretz, and Shaw 1995). In the case of NASA, because our role as participant observers was primarily as members of panels whose very job it was to make observations and assessments, we think it unlikely that the people we observed altered their behavior from how they typically react to scrutiny by overseers. In addition, both these panels had deep access to probe the activities of NASA in detail outside the meeting room—much more access than an outside observer would have been afforded.

The panels on which we served were the Aerospace Safety Advisory Panel (ASAP) and the Return to Flight Task Group (RTFTG). Collectively, our involvement with NASA and on these panels spanned the period 2002–07. Each of these panels used a systematic fact-finding approach that included numerous presentations by NASA employees to the panel, extensive small group meetings and individual interviews, many opportunities for direct field observation, as well as frequent informal "watercooler" conversations with NASA staff.

The ASAP is an independent oversight body that has advised NASA and reported on the agency's safety performance for over 40 years. The ASAP was created by Congress and is charged as follows (NASA Authorization Act of 1968, PL 90-67, U.S. Code 42, 2477, sec. 6):

> The Panel shall review safety studies and operations plans that are referred to it and shall make reports thereon, shall advise the Administrator with respect to the hazards of proposed operations and with respect to the adequacy of proposed or existing safety standards, and shall perform such other duties as the Administrator may request.

After the *Columbia* accident, the ASAP's mission expanded to include reporting on NASA's implementation of recommendations made by accident investigators. The ASAP bases its advice on direct observation of NASA operations and decision making at all its centers and contractors sites "to review, evaluate, and advise on a wide range of program activities, systems, procedures, and management policies that contribute to risk . . . Priority is given to programs involving human space flight safety" (http://oiir.hq.nasa.gov/asap/). More specifically, in addition to undertaking specific assignments or investigations as requested by the NASA Administrator and Congress, the panel (http://oiir.hq.nasa.gov/asap/activities.html):

- Continuously examines the technical management capability of NASA programs from a safety/reliability viewpoint to assess their strengths and weaknesses.
- Selects a small number of specific program/project functional hardware/software areas and assess their worthiness with regard to safety/reliability.
- Assesses those judgments rendered by internal and external review groups.
- Acts to cause NASA and its contractors to be introspective regarding critical hardware/software systems and subsystems and the decisions affecting them.

The ASAP's findings are detailed in annual reports, usually published in quarterly installments (available at http://oiir.hq.nasa.gov/asap/reports.html). As members of the ASAP, we were fully involved in the panel's fact-finding and assessment activities.

The RTFTG was established by the NASA Administrator in June 2003, to independently assess the agency's plans and efforts to respond to the recommendations of the CAIB and to return the space shuttle to flight after the *Columbia* accident. The RTFTG operated in a similar manner to the ASAP, employing direct observation of NASA operations and decision making coupled with extensive interviews of NASA employees to allow it to delve deeply into the full array of activities related to the manned space flight program. As members of the RTFTG, we were fully involved in the panel's fact-finding and assessment activities. The task group worked for 2 years and published its report in August 2005 (available at http://govinfo.library.unt.edu/returnflight/reports/).

Both the ASAP and the RTFTG operated in accordance with the Federal Advisory Committee Act (FACA, Public Law 92-463). FACA was enacted in 1972 in response to the unregulated proliferation of advisory bodies in the federal government that were perceived to have a profound influence on the decisions and activities of the agencies they advised. FACA helps assure that only essential advisory bodies are formed and that their deliberations are visible to the public. It formalizes rules and procedures for establishing, operating, overseeing, and terminating advisory bodies. Panels chartered under FACA must open advisory meetings to the public, but subgroups of the panel may conduct fact-finding that is closed. During our involvement on the ASAP and the RTFTG, many of our observations were therefore made in confidential settings. Thus, although we have insights from scores of interviews and meetings, our ability to cite sources by name or quote directly is very limited. At the same time, the conclusions drawn by both panels, a list of fact-finding activities, and much supporting evidence is presented in detail in their reports, which were prepared with our active participation. Meeting minutes for both panels are readily available (ASAP at http://oiir.hq.nasa.gov/asap/minutes.html; RTFTG at http://govinfo.library.unt.edu/returnflight/activities/).

THEORETICAL LENSES

The literature is replete with theories concerning organization change, including but not limited to evolutionary, teleological, life cycle, dialectical, social cognition, and cultural models, and theories that combine multiple models (for good explanations of these typologies, see Kezar 2001; Van de Ven and Poole 1995). From this vast literature, we have chosen three theories that we find offer the most useful lenses through which to examine whether shocks change organizations. We present them here with explanations about why they are especially useful theories to employ and then combine them to yield our own lens through which to analyze NASA.

Lewin's Theory of Change

"The fundamental assumptions underlying any change in a human system are derived originally from Lewin (1947)," writes Schein (2004, 319). Likewise, Fernandez and Rainey (2006) note that many of the 1 million articles relating to organization change are grounded in the work of Lewin. Hence, Lewin's theory of change is the very best place to start when trying to understand NASA's response to shocks.

Lewin put forth a three-stage model of change that he described as unfreezing the present level, moving to the new level, and freezing group life on the new level. His view was that "a change toward a higher level of group performance is frequently short lived: after a 'shot in the arm,' group life soon returns to the previous level" (1947, 344). Therefore, under his conceptualization, for organizational change to occur, behavior at the present level must be "unfrozen" (what Lewin described as creating a motivation to change), then the change needs to occur in the form of moving to the new level, and then the new behavior needs to be "frozen," or reinforced, on the new level.

Organization theorists such as Cyert and March (1963), Emery and Trist (1965), Katz and Kahn (1966), Thompson (1967), Lawrence and Lorsch (1969), and Aldrich (1972) all maintain that organizations both are shaped by and seek to shape their environments. Yet Lewin (1943) argued that a profound impediment to change in human systems is the presence of a "force field" that resists organizational change and tries to maintain equilibrium in the ever-changing environment described by classic organization theorists. This force field is comprised of driving forces and restraining forces that must be altered for change to occur. A shock to an organization often generates an immediate counterforce to maintain the existing equilibrium. In order to move the equilibrium, the organization's restraining forces must be removed or reduced. Those restraining forces are very difficult to get at because they often involve group norms or personal psychological defenses embedded in an organization's culture, and they are not easily observed.

Schein's Theory of Change

The second theory of change that guided our research was developed by Schein. Schein is considered one of the top organizational theorists in the world, known especially for his model and empirical studies of organizational culture. Among his many theoretical contributions, Schein extended Lewin's model of change by unpacking the concept of unfreezing, honing, and refining Lewin's work within the context of organization change and culture. Culture is to an organization what personality is to the individual; hence, every organization has a unique culture. Culture is the underlying set of values, beliefs, understandings, and norms shared by employees. It is manifest in a variety of ways, primarily through basic assumptions, values and beliefs, and artifacts (Schein 2010). Khademian (2002, 18–9) explains:

> . . . [B]asic assumptions . . . capture fundamental notions of how the organization and its members relate to the environment, time, space, reality, and each other. Basic assumptions are taken for granted and [are] below the level of consciousness for most members of the organization. This is the heart of culture and motivates behavior .... [V]alues and beliefs . . . [are] what members believe "ought to be" in the work of the organization. Ideologies, attitudes, and philosophies are found within this layer .... [A]t the most visible level are cultural artifacts—the language used, stories told, ceremonies performed, rewards given, symbols displayed, heroes remembered, and history recalled.

Therefore, Schein's theory of change, particularly as it links to organization culture, is the next conceptual link in understanding NASA's response to shocks.

Schein (2010) theorized that unfreezing, as essentially motivation to change, consists of three processes unto itself, each of which must be present to some degree for change to be generated. The first part of unfreezing concerns disconfirmation within the human system. Schein maintained that all forms of change start with some form of dissatisfaction or frustration generated by data that refute reigning expectations or hopes. Just the presence of disconfirming information is not enough, however, because workers "can ignore the information, dismiss it as irrelevant, blame the undesired outcome on others or fate, or, as is most common, simply deny its validity" (Schein 2010).

Schein maintained that such disconfirmation must arouse the second step of unfreezing—"the connection of the disconfirming data to important goals or ideals, causing anxiety and/or guilt" (Schein 2004, 320). What he calls "survival anxiety" is the sense that if the organization does not change, it will fail to achieve its goals and ideals. In order to experience survival anxiety and move to this stage of unfreezing, the disconfirming data must be accepted as valid and relevant. What typically prevents this stage from occurring are denial and a different kind of anxiety, "learning anxiety": the feeling among members of the organization that if they admit to themselves and others that something is wrong, they will lose their effectiveness, their self-esteem, and perhaps even their identity. Learning anxiety and denial are the fundamental restraining forces on an organization which can controvert the effects of disconfirming information, leading to the maintenance of the status quo equilibrium. Furthermore, Schein (2010) argues that survival anxiety must exceed learning anxiety and that change depends on reducing learning anxiety (not increasing survival anxiety).

Schein's third step to unfreezing behavior is creating some degree of "psychological safety for workers that helps them see a possibility of solving the problem and learning something new without loss or identity or integrity" (Schein 1980, 1999, 2004, 320). Schein theorized that unless sufficient psychological safely is created, the disconfirming information will be denied, ignored, or otherwise countered, and no change will take place. The key for change in an organization becomes balancing the threat posed by disconfirming data with enough psychological safety to allow the organization to accept the information, sense survival anxiety, and become motivated to change.

Once an organization is motivated to change, Schein notes that reframing or "cognitive redefinition" is needed. This occurs by adopting the new information and yields, among other things, new standards of judgment or evaluation, which must be congruent with the rest of the organization culture. If organization members do not find the new standards plausible and sensible, this will set off new rounds of disconfirmation that often lead to unlearning. At the same time, for refreezing to occur, changes to old norms and behavior must be embedded throughout the entire organization, and rewards must buttress the new desired behavior.

Kanter's Theory of Change

The third theory of change that guided our research comes from Rosabeth Moss Kanter. Kanter studied corporations and compared those organizations that were able to change successfully with those that were not able to change successfully. She pays special attention to the role of crises in change, and so her work is the third important conceptual link necessary to understand NASA's propensity to change in the face of the shocks of the spaceflight accidents.

Kanter outlines five forces that must converge in order for major change to occur from a shock. Force 1 is "grassroots innovations," which Kanter defines as positive departures from tradition, or new ways of thinking in the organization. These "aberrations" pop-up in an organization oftentimes by accident or, if deliberate, are seen initially as insignificant or nonthreatening. These are "'unplanned opportunities' that permit entrepreneurs to step forward . . . they may work best at the periphery, in 'zones of indifference' where no one else cares enough to prevent a little occasional deviance" (Kanter 1983, 291).

Force 2 is a "crisis or galvanizing event." The event might be a lawsuit, a change in the economy, or—as at NASA—a disaster. Kanter, Stein, and Jick (1992, 499) explain:

> The event or crisis seems to require—even demand—a response. If the crisis is defined as insoluble by traditional means, if traditional solutions quickly exhaust their value, or if

> stakeholders indicate that they will not be satisfied by the same old response, then a nontraditional solution may be pushed forward. ... In effect, variations from tradition create potential, but until the system has enough of a "crack" in its shell, they are not able to penetrate.

Notably, a crisis need not be exogenous to constitute a force for change. That is, a crisis may be precipitated by the organization's own actions, and yet still be an abrupt, unstable, or even dangerous condition that demands response.

Forces 1 and 2 in combination set the stage for change, but neither new ideas nor crisis alone guarantees change without two other conditions: explicit strategic decisions in favor of change and individuals with enough power to act as "prime movers" for its implementation. Force 3, then, is "change strategists and strategic decisions." This is where most change management or strategic planning literature begins: Leaders enter and develop strategies that use Force 1 to solve the problems inherent in Force 2. "A new definition of the situation is formulated, a new set of plans, that lifts the experiments of innovators from the periphery to center stage, that reconceptualizes them as the emergent tradition rather than as departures from it" (Kanter 1983, 294).

Force 4 is "individual prime movers," which Kanter defines as people able to push the new organizational reality, often by empowering the champions or advocates of change. Prime movers may sell the new strategy in many ways: by repetition (mentioning the new idea or new practice on every possible occasion), by making clear that they believe the new vision, by visiting subordinates to answer their questions about the new vision, by developing slogans that communicate a new way of operating, by changing the agenda at staff meetings, by demanding that new items be contained in reports, and by concentrating on symbolic management. The point is to change the organization's culture and direction through "signposts in the morass of organizational messages" (Kanter 1983, 298).

According to Kanter, one last Force (#5) is needed for true organizational change to occur: "action vehicles." Action vehicles transform abstract notions of change into reality—ideas become actual procedures, structures, or processes. They are important because, in order for change to take hold, change recipients need to know what the change means for their own unique activities. Changes need to be written into the fabric of the organization—into job descriptions, work processes, contracts, and so forth. On top of this, individuals need to be convinced that using the new practices clearly creates benefits for them so that they will use them, and incentives must support desired actions. Employees are also encouraged to look for broader applications of the new ideas. Ultimately, the goal is to create momentum and critical mass. "... [M]ore and more people use the new practices, their importance is repeated frequently, and on multiple occasions. It becomes embarrassing, 'out-of-sync,' not to use them" (Kanter 1983, 301). Kanter further argues that when organization change efforts fail, it is often because of a weak Force 5, rather than an inherent problem with the innovative ideas themselves.

Table 1 weaves together Lewin's, Schein's, and Kanter's theories of change and distills from all three the necessary ingredients for successful organizational change. Our review of these theories and the broader literature argues that the answer to the question of whether shocks change organizations is: It depends. The conditions on which these theorists suggest it depends most fundamentally are summarized in this table. Now our question is whether or not these conditions have existed and/or now exist at NASA. We begin to explore this by describing the three manned space flight accidents in the next section.

Table 1
Organization Change Criteria Derived from Lewin (1947), Schein (2010)-Originally published 1985, and Kanter (1983)

Phase of Change	Required Causal Factors
Unfreezing	Grassroots innovations are present. Crisis or galvanizing event occurs. Disconfirming information is present. Restraints of group norms and psychological defenses are reduced. Survival anxiety drives acceptance of disconfirming information. Psychological safety permits motivation to change.
Change	Cognitive redefinition. New standards of judgment and evaluation are developed. Change strategists exist and make explicit strategic decisions in favor of change. Prime movers sell change strategy and empower change advocates.
Refreezing	Action vehicles transform abstract ideas into reality. Rewards buttress new desired behavior. Changes to old norms and behavior are embedded throughout the organization.

SHOCKS AND CHANGE AT NASA

NASA put humans on the moon in 1969. They first launched the space shuttle in 1981 and that fleet of vehicles has logged over a thousand days in orbit. The International Space Station has been inhabited continuously since late 2000. NASA's bold successes have come at a high cost, however. NASA's administrator, in an e-mail message to employees in early 2008, said

> On Jan. 27, we marked 41 years since the loss of the crew of Apollo 1, and with it NASA's loss of innocence. The Apollo fire made it clear that we bring to spaceflight the same human flaws as our forebears who first sailed the ocean or went aloft in stick-and-wire contraptions. Successive generations have known the same harsh truth; the crew of *Challenger* was lost to us on Jan. 28, 22 years ago, and on Feb. 1 we mark five years since the loss of *Columbia* (Griffin 2008).

In the wake of each accident, investigators and analysts have identified causes and recommended improvements that NASA should undertake. These have been both technical and organizational. This section briefly reviews this history of accidents, investigations, and responses.

Apollo I

The Event

The Apollo/Saturn 204 mission was to be the first manned orbit of a command and service module. In January 1967, a fire during a test destroyed the Apollo 1 module and killed the three crew members. The ignition source is believed to have been an electrical arc that ignited oxygen-saturated combustible material (Collins 1988). After the accident, the NASA Administrator charged a review board to investigate and "consider all other factors relating to the accident, including design, procedures, organization, and management" (Apollo 204 Review Board 1967, iii). The board ultimately attributed the accident to a range of hazards that existed because, "in its devotion to the many difficult problems of space travel, the Apollo team failed to give adequate attention to certain mundane but equally vital questions of crew safety" (*Apollo 204 Review Board* 1967, 5-12). Reviews of research about manned space chambers in the years preceding the accident suggest that the science and engineering community was skeptical that space systems were well enough understood to support NASA's ambitious aims (Benson and Faherty 1978). Yet NASA was said to be infected with "Go Fever" syndrome—a sense of urgency that drives people to overlook inherent risks and promulgates shortcuts, schedule compression, and other symptoms of poor quality control. The board also concluded that organizational factors were germane to the accident, asserting that "problems of program management and relationships between Centers and with the contractor have led in some cases to insufficient response to changing program requirements" (*Final Report* 1967, 6-3).

The Agency's Response

NASA grounded the Apollo program for 8 months and made many procedural, technical, and facility modifications. Much more thorough protocols were implemented for documenting spacecraft construction and maintenance. And, in an effort to mitigate Go Fever, Congress established the ASAP in 1968 to assure adequate attention to safety concerns.

Challenger

The Event

Nineteen years after the Apollo fire, the space shuttle *Challenger* disintegrated shortly after launch when a seal on its right solid rocket booster failed. President Reagan appointed the Presidential Commission on the Space Shuttle *Challenger* Accident (known as the Rogers Commission, after its chairman) to investigate. The commission determined that the O-rings failed for several technical reasons. It also concluded that NASA's organizational culture and decision-making processes—especially an unrealistically optimistic launch schedule, management isolation, and a weak safety program—had been key contributing factors.

The commission referred to "the unrelenting pressure to meet the demands of an accelerating flight schedule" (Rogers Commission 1986, vol. 1, chap. 7), and argued that NASA might have handled this pressure if its safety program had not deteriorated to the point of ineffectiveness. The commission cited failures that included "a lack of problem reporting requirements, inadequate trend analysis, misrepresentation of criticality and lack of involvement in critical discussions" (Rogers Commission 1986, vol. 1, chap. 7). The commission critique of the management decision-making process highlighted communication failures that resulted in a decision to launch "based on incomplete and sometimes misleading information, a conflict between engineering data and management judgments, and a NASA management structure that permitted internal flight safety problems to bypass key Shuttle managers" (Rogers Commission 1986, vol. 1, chap. 5). Vaughan (1990) wrote that the organizations responsible for regulating safety at NASA failed to identify flaws in management procedures and technical design. She later concluded (1996) that managers had not responded to danger signals because the threatening technical deviations had been normalized into engineering risk assessments over time. As a result, both senior NASA and contractor Thiokol managers had chosen to disregard warnings from engineers about potential leaks (Smith 1986).

The Agency's Response

The Rogers Commission offered nine recommendations for improving safety that were to be implemented before flights resumed. The agency halted manned space flight for 32 months and substantially redesigned the space shuttle's solid rocket boosters. To reduce the burden on the existing shuttle fleet given the demanding launch schedule, NASA worked with the Department of Defense to launch more satellites using other vehicles and added another orbiter, *Endeavour*, to the space shuttle fleet. NASA also made specific organizational and personnel changes, many of which were intended to rationalize the decision-making process by clarifying lines of authority and making the involvement of managers in the program more direct. Others were designed to strengthen the agency's safety regulatory system. Most notably, NASA created a new Office of Safety, Reliability, and Quality Assurance that reported directly to the Administrator, designed to provide independent oversight of all critical flight safety matters.

Columbia

The Event

In January 2003, the Space Shuttle *Columbia* launched on the 113th shuttle flight to begin a scientific research mission. On February 1, *Columbia* broke up upon reentry. The crew was killed, and 2000 square miles in Texas and Louisiana were littered with tens of thousands of pieces of shuttle debris. Once again NASA confronted a major accident investigation. This time, NASA convened the CAIB, chaired by Admiral Gehman (CAIB 2003, 231). Once again the investigation revealed both technical and organizational causes. The technical cause was ultimately determined to have been a hole in the shuttle's thermal protection system caused by a piece of insulating foam that struck the left wing shortly after launch.

Saying that "NASA's organizational culture and structure had as much to do with this accident as the ... foam," the CAIB dedicated a chapter of its report to the accident's organizational causes. The CAIB reported that, in the post-*Challenger* NASA that had purported to have responded to the Rogers Commission, it expected to find a vigorous safety organization engaged at every level of program management. According to the CAIB's assessment, however, shuttle safety was compromised by "blind spots in the organization's safety culture," including "reliance on past success as a substitute for sound engineering practices; 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" (CAIB 2003, 177).

The Agency's Response

In addition to numerous findings and observations, the CAIB made 29 recommendations for changes to the vehicle, the Space Shuttle Program, and the agency overall. They characterized 15 of these as required before the shuttle should fly again. NASA committed to fulfilling these "Return to Flight" recommendations before launching again: "NASA accepts the findings of the CAIB, we will comply with the Board's recommendations, and we embrace the report and all that is included in it" (NASA Implementation Plan for Space Shuttle Return to Flight and Beyond 2003, xiii). NASA established an RTFTG charged with determining whether the agency met the 15 critical recommendations. By the time of the next launch, the Task Group decided NASA had fulfilled the intent of 12 of them but that the other three were too technically challenging. Despite the RTFTG's affirmation of NASA's efforts, the group also observed recalcitrance on the part of NASA managers toward change (Return to Flight Task Group 2005, Annex A.2).

The agency also made several organizational changes designed to strengthen managerial decision making, improve communications, and make the safety organization more robust and independent. Many changes targeted two underlying issues: the lack of respect safety personnel commanded in the agency and the perception that managers suppressed dissenting opinions from line engineers. As it turned out, shortly before NASA flew its next shuttle mission, a new Administrator took over the agency. Among his earliest actions was to restructure the leadership, undoing some of the changes the agency had implemented in response to the CAIB. Since then, yet another new Administrator has assumed leadership. This has created a period of turbulence that makes it difficult to evaluate the likely stability of organizational changes at NASA. At the least, these leadership changes have dramatically slowed and altered implementation of organizational changes, but technical authority, accountability, and dissenting opinion processes are now judged to be much more robust by safety overseers (ASAP 2009).

Commonalities

In the wake of each accident, investigators identified relevant causal conditions. Many of these were technical in nature and unique to each accident. Some, however, were organizational and environmental conditions that appeared relevant to all three accidents. One of these common threads is schedule pressure, a condition where personnel feel compelled to compromise safety in order to meet a timeline. In a sense, Apollo was born under pressure, when President Kennedy first set the audacious goals for the program. The Phillips report notes that the Apollo program was continuously behind schedule, saying that "As the program progressed NASA has been forced to accept slippages in key milestone accomplishments, degradation in hardware performance, and increasing costs" (Phillips 1965). The Rogers Commission noted that the pace of shuttle flights compressed schedules ahead of the *Challenger* accident resulting in "unrelenting pressure to meet the demands of an accelerating flight schedule" (Rogers Commission 1986, 152). The CAIB noted that *Columbia* was plagued by "intense" pressure to deliver core components to the badly over budget International Space Station expediently.

A second theme is the lack of attention to safety, or a weak "safety culture," which resurfaced as a critique after each accident. The Apollo 204 review board cited inadequate oversight and quality control. After *Columbia*, CAIB noted that the agency had not learned from *Challenger* and had not set up a truly independent office for safety oversight, and in fact, "NASA's response to the Rogers Commission did not meet the Commission's intent." Failures that led to both the *Challenger* and the *Columbia* accidents were exacerbated by a safety program that was "largely silent and ineffective" (CAIB 2003, 25).

Finally, a third thread common to all three accidents is fractured communications and management processes, particularly with regard to the interaction between the agency and its contractors and between agency managers, engineers, and safety personnel. The senate viewed weak communications with contractors as contributing indirectly to the Apollo accident (US Senate 1968, 7–8). The Rogers commission noted that those who decided to launch *Challenger* were unaware of "the initial written recommendation of the contractor advising against the launch at temperatures below 53 degrees Fahrenheit and the continuing opposition of the engineers at Thiokol after management reversed its position"

(Rogers Commission 1986, 82). CAIB largely attributed NASA's failure to understand the danger to *Columbia* to lapses in leadership and communication by the Mission Management Team, resulting in several missed opportunities to act to avert disaster (though whether NASA could have saved *Columbia* even if they had been aware of the damage is unknown). Likewise, dissenting opinions were regularly stifled: "management techniques unknowingly imposed barriers that kept at bay both engineering concerns and dissenting views, and ultimately helped create 'blind spots' that prevented them [shuttle program managers] from seeing the danger" (CAIB 2003, 170). Thus, it is evident that particular organizational and behavioral conditions persisted in the agency across all three accidents, despite the fact that NASA responded to the recommendations of investigators after each.

FINDINGS

We now consider whether the conditions required for change identified in the literature discussed above and in table 1 have been present at NASA. Table 2 summarizes our findings.

Table 2
Organization Change at NASA

Phase of Change	Conditions at NASA that Hinder Organization Change from Shocks
Unfreezing	• Disconfirming information present but rejected: Bias toward dismissing information that did not arise from NASA's own procedures and analysis. • Schedule pressure thwarted survival anxiety: NASA could not admit increasing risk, and that changes were required to bring schedules, budgets, and results into more reasonable alignment. • Learning anxiety is profound: Characterization of NASA personnel as "the right stuff" makes it hard to admit weakness or failure. • Psychological safety absent: "Failure is not an option" is deeply engrained in NASA's culture. • Grassroots innovation stifled: Engineers' concerns ignored by managers.
Change	• Cognitive redefinition undermined: Change agenda superseded by new programmatic goals. • New standards of judgment are not stabilized: Leadership instability undermines initial efforts to evaluate and change culture. • Change is more tactical than strategic: Change targets are typically technical in nature and narrowly construed. Some reorganization does elevate and enhance the "voice" of safety and make it more independent. • Prime movers do not persist: Leadership changes undermine stability of message and approach.
Refreezing	• Action vehicles create new structures and processes: New safety institutions and procedures implemented. Spaceflight program management remains fractured. • Rewards buttress actions: Recruiting and assignments changed to give safety engineers more stature. NASA budget shortfalls remain severe.

Theory suggests that the ground for change is most fertile when a crisis happens in an environment of innovation and where the seeds of new ways of doing things are already sown. Then, for the notion of change to take root, organization members must both believe it is necessary (accept disconfirming information and experience survivor anxiety) and be unafraid of it (overcome learning anxiety and feel psychologically safe). At NASA, each accident presented an impetus to change—an opportunity for the agency to decide that traditional solutions were no longer viable and to adopt new approaches to engineering and program management. In each case, external stakeholders—especially accident investigators, review boards, and Congress—expressed dissatisfaction with past NASA practice and the expectation that NASA would not revert to it after the accident. These expectations were levied on an organization created to innovate. We now explore the circumstances at NASA surrounding the *Columbia* accident with respect to unfreezing, change, and refreezing.

Unfreezing

In our work with NASA before and especially after the *Columbia* space shuttle accident, we perceived that some, but not all, of the criteria needed to unfreeze behavior were present:

Grassroots Innovations

Grassroots innovations are potentially productive deliberate and accidental departures from organizational tradition (Kanter 1983). NASA is populated by scores of creative thinkers who routinely surface new ideas. At the same time, much of the shuttle program is highly routinized and contracted out. In 2003, for example, NASA had 1,700 civil servants and 17,000 contractors (Sawyer 2003). Shuttle processing and preparation for flight, launch procedures, flight and mission control, and landing procedures are all governed by strict, very detailed protocols. Moreover, 113 shuttle flights over 22 years had allowed NASA managers and engineers to settle into routine behaviors much more consistent with a mature operational vehicle than the experimental vehicle the shuttle actually was. As Admiral Gehman, CAIB chair, noted to us, "the shuttle is a test system that the NASA workforce thought of as an operational system" (discussion: 2003). Gehman also explained that NASA's reliance on past successes was detrimental to safety (testimony to Congress, 2003). This orientation—toward specified procedure, toward an operational system, and toward past practice—does not mean that grassroots innovations were absent in the shuttle program, but they do suggest that the prevailing culture did not overtly encourage and nurture them. On top of this, Gehman noted that, "the Shuttle Program placed all responsibility and authority for schedule, manifest, cost, budgeting, personnel assignments, technical specifications and the waivers to those specifications and safety in one office" (testimony to Congress, 2003). This narrows the field from which innovations that could influence the program might emerge and be recognized. Thus, we conclude that opportunities for grassroots innovations to be generated, surfaced, and considered were limited in the shuttle program before and after the *Columbia* accident.

Crisis or Galvanizing Event

Clearly and unambiguously each accident constitutes a crisis or galvanizing event. Whatever weaknesses may have existed in the shuttle program management, procedures, and structure, NASA employees at all levels are deeply dedicated to the space program, and these tragedies rocked the NASA workforce to its core.

Disconfirming Information Is Present

Schein (1995, 3) tells us that, "all forms of learning and change start with some form of dissatisfaction or frustration generated by data that disconfirm our expectations or hopes." And, as he notes (2010), disasters are themselves a disconfirming force. In NASA's case, the impact of each accident was escalated by a subsequent investigation that brought extreme scrutiny to bear on the space flight program. Each generated extensive findings to which the agency was expected to respond. In the case of *Columbia*, the CAIB made 29 recommendations, some of which were broad and incorporated several additional detailed subordinate recommendations. A quarter of the CAIB's major recommendations targeted organizational and management changes. On top of these, the CAIB made an additional 23 recommendations that were formally characterized as "other significant observations." Many of these also argued for new organizational and management practices. Overall, the CAIB levied a comprehensive critique that described problems in the shuttle program in detail. Thus, it is evident that disconfirming information existed.

Notably, however, the sources of disconfirming information and the concomitant changes expected of NASA after each accident tended to be independent authorities and were not driven by the agency's own sense of a new reality and the changes that would be required to contend with it. Independence is prized in accident investigation because it is presumed to make more likely the articulation of objective, candid assessments that may be unpalatable to the agency. At the same time, independence means that demands for change are imposed from without by external reviewers, investigators, and other stakeholders, rather than conceived within the organization. In NASA's case, the various external task forces convened to critique NASA met organizational resistance that legitimated current practice and defended it against efforts to shift the existing equilibrium. Thus, although independence is a valuable guard against the threat of bias, it is not, on its own, an effective tool for change. As Kanter tells us, the highest hope for change is when ideas already exist somewhere in the organization.

Another challenge here is NASA's laudable commitment to analysis. In a discussion with Sean O'Keefe in January 2010, he reflected about the tension between data and disconfirmation. As he explained to us, decisions, and especially changes, at NASA rest on accepted engineering principles, which require systematically presented data and analysis. Although this orientation is unquestionably asserted as sound and appropriate practice—and, in fact, some have criticized the agency for not being rigorous enough in the analysis used to justify return to flight after *Columbia*—it does dissuade people from pursuing hunches or offering disconfirming arguments that are as yet unsupported even if they might turn out to be valid. As Vaughan shows, the danger is that analytic procedures may "normalize" deviations rather than highlighting them, as long as the deviation is without incident repetitively. Thus, one organizational challenge is how to maintain high analytic standards but nonetheless give due consideration to intuition that, if pursued, may reveal important new insights. Otherwise, as the former NASA Administrator told us, "group think comes to accept deviations as long as they're within an 'acceptable' bounds without defining why something should be considered 'acceptable." At the individual level, organization members face an analogous challenge. They must guard against the human tendency toward believing that circumstances are tolerable, if not fully satisfactory, even when disconfirming information might be present.

Restraints of Group Norms and Psychological Defenses Are Reduced

NASA's group norms are deeply engrained. The notion that "failure is not an option" has been the bedrock of NASA's culture ever since Flight Director Gene Kranz spoke those words to his team during the Apollo 13 crisis. It is a point of extreme pride for the agency—and the nation—that NASA is successful in the face of very difficult challenges. This is exemplified by artifacts like the space collectibles that bear this slogan sold at the Kennedy Space Center and marketed with the explanation that "Relentless determination has been the philosophy of the NASA program since its inception in the 1960's. This product line commemorates its endless courage and conviction" (see http://www.thespaceshop.com). NASA also has a culture of extreme confidence in its abilities. Astronauts view themselves as "the right stuff," a label popularized by Wolfe's (1979) book about the U.S. manned space program.

Time and again, we were struck by the "Can Do" attitude that pervades NASA's line workforce to this day. This attitude cut both ways as NASA grappled with the CAIB's recommendations. On one hand, NASA headquarters direction was clear: The agency would embrace the CAIB's recommendations. As the Administrator testified to the Senate Committee on Commerce, Science, and Transportation when the CAIB released its report, ". . . the CAIB has provided NASA with a very helpful roadmap for returning to safe flight activities, one that we intend to faithfully follow. I can assure you, that we will not only implement the CAIB's recommendations to the best of our ability, but we are also seeking ways to go beyond their recommendations" (O'Keefe 2003). In this sense, NASA applied the same determination it used to solve the Apollo 13 crisis to address the problems that brought down *Columbia*. On the other hand, we observed the impatience of several NASA managers with the CAIB-driven return to flight agenda. Some thought the agency's seemingly wholesale commitment to the CAIB recommendations was not warranted. As one senior astronaut told us, "The process that worked so badly on STS-107 worked so well on other missions that experienced and responded to threatening problems—it is important not to throw out the good with the bad" (discussion: August 2003). Thus, NASA's powerful resolve is the driving force behind accomplishment, but it also inculcates reticence about admitting flaws or failure and gives rise to the condition Schein termed "learning anxiety."

Survival Anxiety Drives Acceptance of Disconfirming Information

Theory tells us that in order to unfreeze, disconfirming information must not only be present but accepted. In the space program, the impetus to change ran headlong into group norms and individual psychological defenses that made it difficult for NASA personnel to accept disconfirming data that indicated the need for change. In his history of NASA, Handberg (2003, 223) wrote that "NASA's difficulties have been compounded by its certainty (others say arrogance) that the organization alone truly knows the best way to achieve . . . [its] goal[s] and remains the agent best equipped to do so." He went on to write that "[a]dmitting to mistakes remains . . . extraordinarily difficult for NASA . . . drastically reduc[ing] its credibility" (2003, 225). Likewise, in its analysis, the CAIB noted that past change had not penetrated NASA's deep-seated norms: "Though NASA underwent many management reforms in the wake of the *Challenger* accident . . . the agency's powerful human space flight culture remained intact, as did many institutional practices, even if in a modified form . . .. This culture . . . acted over time to resist externally imposed change'' (2003, 100).

It seems that NASA has not historically felt enough survival anxiety (the sense that if the organization does not change, it will fail to achieve its goals and ideals) to surmount its learning anxiety (inability to admit weakness or failure). Urgency and complacency are both culprits here. The *Apollo* and *Challenger* accidents each occurred at the beginning of their programs, viewed as victims of ''Go Fever,'' a sense of urgency that pushed NASA managers to neglect safety concerns. The *Columbia* accident happened well into the shuttle program and was caused in part by comfort that crept in as NASA managers succumbed to pressure to view the program as mature and the vehicle as operational, though in fact it was still experimental. As one engineer phrased it to us, NASA was not open to external scrutiny and was not performing self-scrutiny, self-analysis, or self-criticism (discussion: April 2005). Another high-level NASA administrator lamented that there have been no real agency-wide lessons learned from accidents beyond better mishap reporting (discussion: August 2005). Another experienced senior administrator described his instinct that severe accidents occur as a result of ''process creep,'' where people develop bad habits of neglecting procedures over time, ultimately resulting in a relaxed process. Even as people turn over, the underlying attitude is retained in the culture of the organization (discussion: August 2006). On top of this, NASA felt compelled to deliver on the pledge that the shuttle could offer routine access to space. This made it harder for the agency to admit—or even notice—that the program was subject to ever-increasing program and technical risk. NASA became trapped in a mode of overpromising with respect to what it could do and how quickly it could safely do it and was fearful that acknowledging the need for changes (and thus more resources) would kill the manned space program. Thus, the combination of schedule pressure (a condition where personnel feel compelled to compromise safety in order to meet a timeline), comfort with longstanding processes, and the desire for the program to prosper made it difficult for survivor anxiety to overcome learning anxiety.

In addition, although there was an abundance of disconfirming information brought to light during the *Columbia* accident investigation, NASA did not always display the inclination to accept and use this information. This was most evident as NASA worked to decide that it had adequately understood, identified, reduced, and managed the risks associated with the insulating foam that had fatally damaged *Columbia* and that it could therefore safely return to flight. A prime example is the concern RTFTG panel members had that NASA engineers were not using risk assessment models appropriately and were overstating what they knew (Return to Flight Task Group 2005, Annex A.2). Some panel members believed that NASA employees were—or at least spoke as if they were—deluding themselves and the public into thinking there was no longer any appreciable risk from the foam. NASA managers argued that they had addressed the risk because they had ''fixed'' the external tank, there would be a repair capacity, and they would be able to harbor on the International Space Station in the event of damage. Yet they could not show that the external tank was indeed fixed, the repair techniques were incipient capabilities at best, and the ability to use the space station as a safe haven was a variable and uncertified option. As one senior NASA manager told us, ''We're flying again because we think we've fixed the tank. But we've thought we've fixed the tank before'' (discussion: January 2005).

We saw that, at times, managers were not forthright about the status and results of the work they had done; some internal observers thought NASA was instead adjusting their models and requirements to yield acceptable answers (discussion: March 2005). Likewise, these observers perceived that NASA engineers did not articulate success criteria before they examined their data but instead appeared to review their data first and then decide if results were adequate. One engineer expressed the opinion that this behavior sent the message to young engineers was that it was all right for them to ignore their discipline and to set (or change) their own rules (discussion: March 2005). Thus, with respect to mitigating the hazard that destroyed *Columbia* (liberating insulating foam and damaging the external tank), some at NASA were more inclined to avoid, rather than to accept disconfirming information. Although this is not the only domain where NASA was confronted with evidence that its practices were problematic—and indeed there are other areas where NASA acknowledged and responded to such evidence—"fixing" the external tank was at the center of NASA's effort to return to flight.

Psychological Safety Permits Motivation to Change

According to theory, the final element needed to unfreeze behavior so change may occur is "psychological safety" or a condition where people feel confident that they will not be penalized if they attempt the change process and make mistakes along the way (Edmondson 2003). Unless sufficient psychological safely is created, grassroots innovations will not emerge, disconfirming information will be denied or in other ways defended against, no survival anxiety will be felt, and no change will take place.

The CAIB's (2003, 171) findings suggest that psychological safety was lacking in the shuttle program ahead of the *Columbia* accident: "There were lapses in leadership and communication that made it difficult for engineers to raise concerns or understand decisions." Evidence of this permeated our tenures on the ASAP and the RTFTG as well. Beginning in 2003, we heard from NASA managers that there were tensions between engineers and management and that floor technicians and engineers did not believe that management listened to them. Throughout the RTFTG process, engineers wondered aloud how to promote healthy engineering debate within the agency, rather than an Inspector General-type adversarialism. NASA managers also struggled in good faith with how to contend with the CAIB's findings. For example, headquarters-level managers asked the RTFTG "How can NASA keep it's 'can do' attitude, but prevent dissenting views from being stifled?" (discussion: September 2003). Another NASA leader explained that the engineers' professional code exerts pressure not to "propound outside your area of expertise," and then asked how, in light of this, he could get NASA engineers to raise their concerns (discussion: September 2003). Two years later, a NASA manager spoke to us about "real communications failures" that still existed within the agency (discussion: April 2005). Even at the highest level, signals that top managers were closed to questions and concerns persisted years after the *Columbia* accident: For example, in 2006, we heard the NASA administrator say, "I only want advice on things I don't know" (discussion: November 2006).

Change

Theory suggests that the change process depends on organization members reexamining their assumptions, expanding their thinking, and changing the standards by which performance is rewarded to align with new goals and values. The change process is inculcated by strategists who plan changes and other agents who support and sell the change through widespread activity.

Cognitive Redefinition

The evidence that NASA substantially reframed its perspective is mixed. In the wake of all three accidents, NASA developed a specific set of affirmative responses to many of the investigators' findings, particularly their technical recommendations. Yet, in some cases, NASA managers and engineers did not find the proposed new requirements or approaches plausible or necessary. Schein tells us that this kind of skepticism can set off new rounds of disconfirmation that undermine learning. Some amount of this is evident after the *Columbia* investigation. After the CAIB released its report, NASA developed a Return to Flight approach, convened an oversight board to review its compliance with CAIB recommendations, and prepared and regularly updated an "Implementation Plan for Space Shuttle return to Flight and Beyond," which detailed its approach with respect to each of the CAIB's recommendations, showing what it was learning and the changes it was making.

Consistent with this evolving document, NASA managers appeared committed to addressing the problems that investigators found, including some that had been pervasive since the agency's inception, like schedule pressure. The mantra chanted in nearly every meeting we witnessed after the CAIB's report was that the agency would be strictly "milestone driven, not schedule driven," and would not fly until it had fulfilled all fifteen recommendations the CAIB identified as requirements for return to flight. We observed that after the *Columbia* accident NASA managers heard the Administrator's admonition to, as one center director told us, "accept, comply, embrace, and implement the CAIB's recommendations" loud and clear (discussion: December 2003). Nonetheless, employees told us that schedule pressure was as present as ever as managers discovered that implementing the CAIB's recommendations was not feasible under the conditions of other constraints and priorities (such as retiring the shuttle).

NASA managers legitimately struggled with how to balance schedule and performance. As they explained, it is impossible to remove all schedule pressure (discussion: September 2003). Absent a schedule, excitement would flag as employees lacked a sense of when the work was due to be complete. Moreover, there are only limited launch windows during which to get to the International Space Station, and these deadlines must be met for the program to succeed at all. At the same time, when schedule is the predominant driver, performance and quality may be sacrificed when they should not be. One engineer explained his view that solutions were driven by schedule and not by performance: "If we had known we had until March 2005 before we flew again, we'd have done things differently in the return to flight process." As it turned out, NASA did not fly again until July 2005, further illustrating the possibility that if NASA had known up front how long it would take to launch again, they might have made different use of that time, rather than making choices as if time were much shorter.

It is unclear how much adjustment NASA was ready to make in the wake of *Columbia*. One example of this is NASA's struggle to mitigate the risk that insulating foam could come off the external fuel tank and strike the orbiter, the very problem that fatally damaged *Columbia*. By the time NASA launched *Discovery* in July 2006, NASA's head of safety and mission assurance and its chief engineer both judged that the foam still posed a threat, and they both therefore voted ''NO-GO'' on the Certificate of Flight Readiness that confirms that the shuttle is ready for launch. This hints at a senior-level capacity for cognitive re-definition, but the inclination did not carry into more than symbolic action. Despite their nonconcurrence, neither of these officials opposed the Administrator's decision to proceed with the launch anyway. They both decided that the launch could proceed since the space station could be used to harbor the shuttle crew (Harwood 2006; STS-121 CoFR Endorsement 2006). This was a tenuous rationale since this notional ''safe haven'' safeguard was not itself certified and would trigger a cascade of profoundly challenging implications should *Discovery* be damaged catastrophically, including the question of whether to launch yet another shuttle to rescue the crew now stranded on the space station. In the end, it appears that the seeds of cognitive redefinition were sewn at NASA as they came to understand new threats in a technical sense, but they failed to arrive at an entirely new way of thinking about and responding to the problems they faced.

New Standards of Judgment and Evaluation Developed

In the wake of *Columbia*, there are important examples of NASA's concerted efforts to make its engineering and safety standards much more robust. NASA created an Engineering and Safety Center to provide technical assessments across the program and restructured the Safety and Mission Assurance office to enhance its independence. The systems engineering and systems integration activities were reorganized to address ambiguities that had led to confused communications. NASA also established an Independent Technical Authority (ITA) in the Chief Engineer's office in order to provide a check on the approval of waivers or deviations and more importantly to serve as the ''technical conscience'' of the agency. These changes were embedded in new structural arrangements, new authorities, and new chains of command, which gave clear expression to what might have otherwise remained a nebulous ideal rather than a new set of standards.

Even in light of these positive reforms, there is also evidence that NASA resisted the opportunity to rewrite standards that it knew to be problematic. One prominent example of this is the approach to the Constellation program we witnessed. Constellation is the manned space flight program that was announced by the Bush Administration as the successor to the shuttle program (though it was recently cancelled by President Obama). We were repeatedly briefed about the opportunity Constellation presented to design safety in to the system, to correct past mistakes related to safety, and ''do things right this time around'' (discussion: August 2006). But the pace of the program, the pressure to fulfill expectations, and the need to deliver results to warrant budget commitments meant that the agency could not afford the zero-based approach this would require. Instead of developing new action plans, the agency capitalized on existing practices, procedures, and designs, even if they were imperfect. In effect, we saw that new priorities can confound, rather than enhance, the opportunity to develop new standards. In NASA's case, initiatives such as the Mars rovers, retiring the shuttle, the new moon agenda, and developing a new vehicle have diverted people's efforts and activities toward these priorities and away from the less-tangible change agenda.

A core issue here is what organizational strategies and standards NASA adopts with respect to safety. Two important conceptual frameworks have developed in the literature to explain organizational safety and reliability: Normal Accident Theory (NAT) and the theory of HRO. NAT follows from a body of work by Perrow (1999) in which he describes how systems characterized by complex interactions and highly interdependent components can thwart human expectations and yield disastrous results that cannot be prevented. He also argued that attempts to improve safety by building in redundancy (a common engineering strategy to mitigate risk) only adds complexity, thus making accidents even more likely. The HRO literature offers an alternative view of safety (see, e.g., Weick and Stucliffe 2001; La Porte and Consolini 1991; Rochlin, LaPorte, and Roberts 1987, and other works by these authors). These scholars argue that organizations engaged in hazardous work can adapt their structures to allow them to perform well in the face of unexpected emergencies and therefore avoid catastrophes. Organizations do this by achieving a state of "mindfulness" that involves continuous scrutiny, refinement, and reinvention of expectations to improve foresight and function (Weick and Stucliffe 2001, 42).

These two perspectives help illuminate why making changes to improve safety is especially challenging at NASA. NASA is certainly a tightly coupled, complexly interactive system in which redundancy is a common strategy to improve safety, which does not bode well for NASA's ability to avoid accidents if the NAT view is accepted. The CAIB examined NASA in light of the HRO framework and concluded that NASA lacks but could and should adopt the characteristics of an HRO. Boin and Shulman (2008), on the other hand, argue that NASA never has been and cannot be an HRO because it is a research and development organization designed to continually advance spaceflight capability, not a stable organization employing a predictable technology and repetitive production process. These bodies of theory thus leave NASA in a quandary about what organizational choices to make if it is to both pursue its mission and fly safely. As we note in the literature review above, Boin and Schulman offer some recommendations.

Change Strategists Exist and Make Explicit Strategic Decisions in Favor of Change

Historically, NASA has struggled to initiate and sustain broad change strategies. One important impediment to long-term change efforts is NASA's vulnerability to political pressures, resource limitations, and other environmental constraints. Since the inception of the shuttle program, NASA has never been in control of its own destiny. Political administrations, policies changes, and Office of Management and Budget (OMB) actions resulted in budget cuts, for example. These actions external to NASA affected NASA leaders' decisions about goals, schedule, and safety allocations and have been raised by many observers.

In their analysis of the *Challenger* accident, Romzek and Dubnick's (1987, 227) analysis turns on NASA's "efforts to manage the diverse expectations it faces in the American political system." Moreover, they argue, the more the agency responds to particular reform requirements, the more distracted it becomes from its core expertise and the less well it can perform. Similarly, after the *Columbia* accident, the CAIB asserted that

> 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, 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. (2003, 9)

The CAIB concluded that this turbulent environment of countervailing pressures impinges on NASA's performance. Likewise, in their detailed study of organizational learning at NASA, Mahler and Casamayou (2009) point out how much the political and budgetary environment creates resource and schedule pressures that impede a public agency's ability to work consistently on a change agenda over a sustained enough period to institutionalize solutions. They explain that external pressures are a distraction that draws energy away from learning and change efforts. Moreover, change requires resources and thus change agendas compete with other political goals for scarce resources. And if change processes do succeed, they may later be overturned by new political requirements. In short, the context of public agencies adds a layer of complexity that fundamentally constrains managerial discretion and limits the ability managers have to advance and implement long-term strategies.

Even under these conditions, NASA Administrator Sean O'Keefe clearly made decisions focused on catalyzing change. Many of these were controversial with vocal supporters and detractors, but all were bold attempts to respond to the lessons of *Columbia* and move the manned space program forward. From the day of the *Columbia* accident, he articulated the agency's approach: "Figure out what happened, fix it, and return to flight." Subsequently, he spearheaded the stark stance the agency took with respect to the CAIB's findings: Fulfill all 15 of their return to flight recommendations, following a milestone-driven, not schedule-driven, approach. He cancelled the Hubble telescope repair agenda, arguing that it was too risky, and focused the agency on completing construction of the International Space Station. His efforts culminated when President Bush announced an ambitious plan to retire the shuttle, return to the moon, and go on to Mars.

Both O'Keefe's decision to suspend Hubble repair and Bush's agenda to return to the moon fell victim to political opponents; however, another mission to Hubble was launched after O'Keefe left NASA, and the moon-to-mars plan was shelved after Bush left office. O'Keefe's change agenda was also confounded by the abundance of changes that were attempted simultaneously. Kanter points out that successful transformational change requires clear goals, followed by roadmaps that orient multiple change proposals toward achievement. One NASA employee told us that in 2003 and 2004, there were so many change initiatives (technical, organizational, personnel) under way that it was hard to see a clear path forward. This employee pointed to confusion about which core competencies were relevant and how they were to be sustained in the face of multiple reforms (discussion: January 2005). In effect, the change efforts NASA embarked upon may have succeeded better if they had been grounded an overarching strategy that employees could see, understand, and follow. The literature shows, however, that it is difficult for change agendas to cohere and remain intact in turbulent political and fiscal environments such as NASA has faced throughout its history.

Prime Movers Sell the Change Strategy and Empower Change Advocates

Administrator O'Keefe was the prime mover, promoting the strategy of implementing every CAIB return to flight recommendation in testimony to Congress, to the media, at staff meetings, in internal documents, on the agency Web site, and to advisory groups. Yet there were limits to the impact his message could have. Notably, the recommendations identified as return to flight requirements were predominantly technical—mostly limited to the physical causes of the accident. Likewise, NASA's primary motivation was to fly again as soon as possible, and its approach to change was therefore dominated by, and narrowly focused on, technical requirements. The cultural aspects of change received less emphasis, though NASA managers did make explicit attempts to understand and assess cultural deficiencies with a view toward changing behavior. Changes in the agency's senior leadership later allowed this to fall by the wayside in favor of other approaches, as the ASAP reported in its 2008 annual report:

> NASA responded to the CAIB findings comprehensively, starting with a cultural assessment to establish a baseline. Efforts to address culture deficiencies followed at three NASA Centers, with plans to expand to nearly all of them . . .. Despite promising results . . . Administrator Griffin decided not to continue with the approach. Instead, he opted to decentralize the focus of measuring and changing safety culture . . .. In response, the ASAP said it was concerned about NASA's shift away from an approach aimed at modifying safety culture to one that appeared to only monitor the status of culture. The Panel also noted that it was less confident than it had been that the issues identified by the CAIB were being addressed.

Hence, changes in NASA leadership undermined the stability of the change message, as well as the approach to modifying and measuring change.

Administrator O'Keefe's change strategy was also hampered by the fact that most of the suggested changes did not come from within. Instead they were recommended from the outside by the CAIB, the RTFTG, the ASAP, and other overseers. The policy changes they recommended were, as Vaughan (2006, 304) describes them, "political in effect," not socially constructed by the agency. It was therefore difficult for Administrator O'Keefe to "lift innovators [within the agency] from the periphery to center stage," to carry change forward as Kanter says is optimal, or to reconceptualize the needed changes as an emergent tradition rather than as a departure from the comfort of the status quo.

Refreezing

Even in the face of sound innovation, change can fail if it is not fully embedded in the daily business of the organization. In addition, new norms and behaviors are solidified when the use of new structures, practices, processes, and procedures is rewarded, and individuals use new practices because they are convinced that doing so creates benefits for them.

Action Vehicles Transform Abstract Ideas into Reality

To transform abstract ideas into reality, changes need to be written into the fabric of the organization's procedures—into job descriptions, work processes, and contracts. After the Apollo accident, program manager Samuel Phillips was able to dramatically strengthen configuration management (processes for assuring the consistency of a system's performance and attributes with its design, requirements, and operation over time) as an aggressive procedural control on safety. NASA established safety offices at each of its centers and introduced the first safety plans. Clearly, NASA embraced many new structures and procedures. In fact, their conversion was so profound that it eventually became unworkable as hierarchies and accountability structures steepened and slowed the work of the agency. NASA eventually relented and relaxed some procedures so that work could proceed at a reasonable pace (Johnson 2001). Nonetheless, it appears that NASA was able to inculcate real change after the Apollo accident and thereby transitioned from a pioneering organization to a more mature engineering organization.

After the *Challenger* and *Columbia* accidents, NASA's ability to realize new organizational norms and constructs is more mixed. In part, this arose from disparate views within the agency about what the new NASA reality ought to look like. For example, one group of NASA employees told us that NASA's culture problem is that "the top of the agency gets it, the bottom gets it, but the middle doesn't," suggesting that both the senior administration and line employees saw the value of new ways of working, but middle managers did not see change as necessary (discussion: March 2005). A NASA engineer told us that the lessons of *Columbia* provided no constraint to the next launch precisely because abstract ideas about culture were not recast in concrete, actionable terms (discussion: March 2005). Uncertainty about the agency's future agenda also undermined the pursuit of specific changes that were possible, but that would take time. Since the shuttle was to be retired, many seemed skeptical about the utility of efforts to fundamentally transform the program. Continuous improvement was not seen as sensible in a program that was shutting down (discussion: April 2005). Finally, one senior official told us that NASA managers continued to be guided by an informal hierarchy because specific new structures and procedures had not been fully articulated. Flight directors knew this and saw it as problematic but would not voice this concern because they did not believe the shuttle program would support them (discussion: August 2003). As Khademian (2002) and Schein (2010) point out, organization culture is hard to change under the best of circumstances.

Despite these countervailing pressures, NASA made scores of concrete improvements in the wake of the *Columbia* accident. Among the most significant accomplishments were some key leadership changes; the creation of new independent safety structures in the agency; a strategic management handbook; a program analysis and evaluation office that focused on uncompromising analyses; the establishment of strategic, program, and operations management councils; the empowerment of center directors to proceed with culture changes; stronger and clearer performance appraisals; the availability of tools (such as 360-degree surveys) that provide comprehensive performance feedback; and a robust ombuds program (discussion: August 2005). On the technical front, the focus on excellence included "more than 100 major maintenance modifications and upgrades" in the 2 years following the *Columbia* accident (Johnson 2005); the designation of system warrant holders, discipline warrant holders, and discipline leads and fellows; and core agency-wide standards (discussion: February 2006). Each of these improvements operationalized abstract notions of change and institutionalized new ways of doing business.

Rewards Buttress New Desired Behavior

The evidence that rewards then reinforced these new behaviors is mixed. In part budget constraints have impeded performance. As the *New York Times* described the views of a former shuttle commander who served as a leading safety official at the Johnson Space Center (Schwartz 2005a):

> The deeper cultural problem at NASA is the same one that has dogged the agency for decades: under pressure to stick to budget and schedule, managers suppress safety concerns from engineers and others who are closest to the equipment and astronauts . . . Managers 'ask for dissenting opinions because they know they are supposed to ask for them,' but the managers 'are either defending their own position or arguing against the dissenting opinion' without seriously trying to understand it.

Hence, although NASA sought to improve free and open communication, dissent still was not valued enough to overcome the schedule and budget pressure that persisted in the agency's environment. To help guard against these pressures, the *New York Times* (Wayne 2005) reports that NASA "made changes to eliminate any temptation to cut costs at the expense of mission safety, or even any appearance of temptation. In the past, eighteen percent of contractors' fees were determined by their ability to cut the costs of the shuttle program. That is no longer a requirement." On the other hand, Michael Griffin, who succeeded Sean O'Keefe as NASA Administrator, was welcomed by Congress with a request that he reduce the workforce by 15 percent (Leary 2005). Budgetary constraints continue today.

Changes to Old Norms and Behavior Are Embedded Throughout the Entire Organization

Two years after, Administrator O'Keefe hired a firm called Behavioral Science Technology to help him implement long-lasting culture change in the agency, managers' perceived change. Specifically, 40% of managers at Kennedy Space Center's safety and mission assurance office said the culture was improving. Among nonmanagers, though, only 8% said they saw real change in the agency (Schwartz 2005). This despite the fact that managers had participated in coaching on desired management and communications behaviors, including one-on-one counseling about administrative styles (Leary 2004). An anonymous worker at Johnson Space Center in Houston said "I have seen the managers who have created our current cultural problems dig their heels in order to do everything within their power to keep things from changing" (Schwartz 2005).

On the other hand, some employees are less skeptical and suggest that real changes have taken hold in the wake of *Columbia*. As soon as 8 months after the *Columbia* accident, Admiral Gehman told Congress that in the past, the agency largely required dissenters to prove that any part of the system was not safe, rather than requiring program officials to prove it was safe. When the issue of whether to send astronauts to the space station arose post-*Columbia*, Gehman noted that NASA staff were now required to prove it was safe to do so. "I see a glimmer of light [that NASA is changing]," he said (Leary and Wald 2003). Two years after the accident, an engineer who tried to raise warnings about *Columbia*, confirmed change: "We [now] have a voice .... Engineering is more independent than ever, more assertive than ever, and more in your face" (Schwartz 2005). Scott Hubbard, the direct of NASA's Ames Research Center in California said he saw a new "philosophy of safety at the top" (Johnson 2005). Other positive changes touted by Wayne Hale, a former flight director and then shuttle program manager, include an $857,000 reconfiguration of the room where mission managers meet daily, which included putting a round table in the main meeting room to signal that no one is person is dominant. An anonymous suggestion box was added, and the pace of meetings was slowed to allow more discussion (Johnson 2005). Managers also have taken classes in active listening, though Hale acknowledged that managers did sometimes slip and quash vigorous discussion (Schwartz 2005).

One NASA Chief Engineer told us in 2005 that NASA's ITA, the new set of organizational structures, processes, and norms that were to embody a new technical conscience, "is the single biggest litmus test of culture change at NASA." For 2 years thereafter, progress toward fully developing and establishing the authority limped along in a context of leadership changes and shifting priorities. In early 2007, the ASAP worried publicly that NASA was in grave danger of failing once again to inculcate robust, independent technical conscience at all levels of the agency. Recently, however, the ASAP reported being "impressed with the new organizational emphasis on NASA-wide independent TA" (ASAP 2009, 7), and noted that "safety leadership is on the rise, including an increasing focus on critically important open discussions that encourage dissenting opinions on risks" (ASAP 2009, 9). The ASAP qualified its encouraging report, however, pointing out that NASA still faces significant challenges in improving its safety culture and presented a long list of actions NASA must take if it is to transform abstract change into permanent reality.

CONCLUSION

In sum, our assessment of the NASA case is that even in the face of dramatic shocks, change has proved difficult. NASA's culture, once cutting-edge innovative, has become more staid and stolid. The organization has become more hierarchical, and greater distance between managers and engineers has attenuated communication. With time, NASA also has become confident in its expertise and resisted countervailing evidence from outside observers. Thus, although NASA's stated objectives immediately following the third major shock of its experience (the *Columbia* accident) were to "find the problem, fix it, and return to flight," NASA was reticent about acknowledging that much of "the problem" was organizational, managerial, and cultural and was reluctant to focus its efforts on fixing these things. On top of this, leadership changes (two administrations and three agency administrators since the *Columbia* space shuttle was lost) have stymied the pursuit of a consistent mission, much less a stable change agenda. That said, NASA is a large, complex, and varied enterprise, and although change has progressed slowly in some parts of the agency, it has thrived in others. We therefore conclude that NASA has not failed to change but that its success has been uneven.

This study used social science theory, 5 years of participant observation, news articles, and an analysis of government documents to examine whether shocks change organizations. With respect to our research question, our analysis of the NASA case yields the conclusion that shocks may crystallize pressure for change, but a shock will not cause change on its own. Thus, this case provides empirical substantiation of Lewin's, Schein's, and Kanter's theories, all of which propose that for a shock to change an organization, it must be coupled with several enabling factors.

This case has also allowed us to synthesize three seminal theories to better explain the puzzle of shocks and organization change than each theory can alone. Neither Lewin's theory nor Schein's embellishment of Lewin's theory includes Kanter's idea of the need for grassroots innovation as a precursor to future change. Further, neither Lewin nor Schein directly deal with the need for a crisis or galvanizing event (but rather focus on "disconfirming information," which may or may not come from a crisis or galvanizing event). Kanter offers a crisp view of the role of a crisis. Yet Kanter's theory alone does not adequately explain the complexities of unfreezing-change-refreezing process that both Lewin's and Schein's theoretical work offer. Hence, each theory on its own tells part of the story. Together, though, they tell a much more comprehensive story. Thus, employing this body of theory more holistically as we have shows why change is so difficult for organizations to accomplish. The intuition that change is hard is broadly shared—most people have experienced the pain and challenges of change in their workplaces. The popular literature addresses this reality, and the academic literature has explored aspects of the challenge of change. This case analysis reveals one important reason why change is hard and that is because a long list of conditions (e.g. those listed in Table 1) must be satisfied in order for change to be realized.

At the same time, a major conclusion of this research is that the contextual characteristics of the real world of public management are not very well accounted for in the three theories of change alone or together. Complicating the NASA change situation was the complex environment in which it operates: numerous external authorities (CAIB, RTFTG, ASAP, the White House, OMB, and congressional committees, to name a few), the media, and demands by interest groups and citizens affected what the agency could and could not do. These forces are not directly addressed by Lewin, Schein, or Kanter apart or together. As Mahler and Casamayou's (2009, 15) put it in their study of NASA, "the public sector is a particularly harsh learning environment." Change was also made difficult at NASA by its complex organization structure consisting of a headquarters and 15 centers and facilities, plus numerous contracting organizations, each with its own variation of group norms, survival anxiety, interpretation of disconfirming information, and various levels of psychological safety. An organization culture still afflicted by "Go Fever," a "failure is not an option" mentality, a "right stuff" pride, an engineering discipline with a narrow approach to problem solving, coupled with the fact that flight safety demands that mistakes are not forgiven, made it difficult for group norms to be restrained and for disconfirming information to be accepted. The real world of public management during budgetary cutbacks yielded few ways to incentivize and therefore buttress new desired behaviors. Therefore, we conclude that as seminal and revelatory as the social psychological theories we used in our research are, they only explain part of the challenge of instigating and sustaining change in a complex public organization.

Thus, although there has been quality research on change in public organizations that explores other aspects than those addressed in our research (e.g., Fernandez and Rainey 2006; Mahler and Casamayou 2009; Nutt 2004), more work is needed to fully explore and explain the real world of public management. Our analysis of the NASA case suggests that the literature on organization change would be enhanced by examinations of a larger and more diverse set of organizations—not only big and complex government agencies. Shocks happen to all types of organizations—large, medium, and small; public, private, and nonprofit. Examples of potential foci for future research include hospitals, corporations, banks, and regulatory agencies. Our analysis of the NASA case suggests several hypotheses. Three are offered here:

H_1 The more that change recommendations are developed by those who work inside organizations, the higher the likelihood that those changes will actually be implemented after a shock. This hypothesis is informed in part by Kanter's understanding that if the seeds for change were sewn inside an organization by those who work in the organization, the chances for real change increase. Although independent reviews can be enlightening and are often considered less biased, external observers may not fully understand the nuances of the organization, are not necessarily motivated to contend with the impracticalities and unintended consequences of their recommendations, and do not have to live with the changes they recommend. This hypothesis does not negate the need for fresh perspectives to shed light on compelling public problems facing public agencies. Rather, it realistically predicts that change imposed from the outside after a shock is likely to be opposed on the inside of any organization.

H_2 The more that external stakeholders do not understand and accept the implications of change, the lower the likelihood of sustained change in an organization after a shock. Large organizations are complex and difficult to understand—especially by those on the outside looking in. There are unanticipated consequences of changes imposed on public organizations that external stakeholders oftentimes do not recognize. When agencies change, their outputs and outcomes also change. If external stakeholders—overseers, investigators, advisory boards, contractors, concerned citizens—have expectations for what the organization will accomplish that are inconsistent with what will result from the change agenda, post-shock change will not be sustainable. Moreover, change requires substantial investment of resources, which means those resources will not be available to fulfill other priorities that may also be levied on the organization. External stakeholders may not have examined the trade-offs their expectations for change require vis-à-vis other demands these same stakeholders also impose. Finally, change takes time—often longer than the attention span of stakeholders. Absent an explicit long-term commitment, other external demands will likely displace the change agenda.

H₃ The greater the acceptance of the need to change by members at all levels of an organization—including regional offices, centers, and facilities—the greater the likelihood of sustained change after a shock. Sustainable change cannot be driven solely from the top. Disconfirming information is the ''canary in the coal mine'' that warns an organization that its status quo way of operating is not working and highlights the need for change. For an organization to change in response to a shock, members throughout the organization must be willing to accept information that challenges current ways of operating. If organization leaders hope to drive change, but members on the front lines or in regional offices, centers, and facilities are skeptical of disconfirming information or unwilling to accept it, then change efforts will stall. Likewise, if those in the trenches perceive problems that leaders do not acknowledge, post-shock change efforts will not be developed and resourced.

Future research should examine the complexity of change requirements after a shock applied to a variety of organizations: large, small, and medium; public, private, and nonprofit. In addition, future research should examine how the environment of an organization—particularly external authorities that analyze and advise public organizations—affect or do not affect change within those organizations after a shock. Whether it is more effective to have the driving force for change come from within or outside an organization, or from the top or bottom of an organization, are empirical questions. We must answer them if we are truly to understand under what conditions a shock will yield change in complex organizations.

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