Do Exogenous Shocks Change Organization Culture? The Case of NASA

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ABSTRACT

The fifty year history of NASA's 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 entire crew. In the wake of each accident, investigators and analysts have identified causes, and have recommended technical and organizational improvements that NASA should undertake. Nonetheless, assurances that NASA can fly safely and avoid further accidents are tenuous, and the prospect of another disaster looms large as the next generation of space flight begins. In short, there is evidence that despite these disasters—which were severe exogenous shocks to the organization—there has not been the expected change in organization culture. This research undertakes a theoretical and empirical examination of the question: Do exogenous shocks change organization culture? The paper begins with an overview of literature concerning organizational culture and change. Then, using data derived from participant observation, interviews, and government reports, an empirical analysis of the impact—or lack of impact—of the spacecraft tragedies on NASA organization culture is presented. The results of this examination suggest that there are barriers embedded in the cultural fabric of the agency that have thwarted safety improvements. We examine the prospects for culture change at NASA.

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The fifty year history of NASA's spaceflight program is marked by spectacular accomplishments. These triumphs and ambitions 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 entire crew. Now, every winter, NASA revisits a week of tragedy during which the nation lost seventeen astronauts and three space craft (*Apollo I* in 1967, *Challenger* in 1986, and *Columbia* in 2003). 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 forestall further catastrophe. Nonetheless, assurances that NASA can fly safely and avoid further accidents are tenuous, and the prospect of another disaster looms large as the next generation of space flight begins. In short, there is evidence that despite these disasters—which were severe exogenous shocks to the organization—there has not been the expected change in organization culture that our current literature would predict.

This research undertakes a theoretical and empirical examination of the question: Do exogenous shocks change organization culture? After an overview of relevant literature, using data derived from participant observation, interviews, and government reports, an empirical analysis of the impact—or lack of impact—of the manned spacecraft tragedies on NASA organization culture is presented. The results of this examination suggest that there are common causal factors embedded in the cultural fabric of the agency that have produced these accidents and thwarted safety improvements. We examine the prospects for culture change at NASA,.

This research is important for several reasons. First, no one to date has examined the NASA phenomenon through the lenses of organization change that we are using. Next, we join Vaughan (who wrote over 20 years ago in 1986), as among the few scholars who have written about NASA as participant observers in NASA change efforts. Last, while one study discovered that over one million articles that address organization change have been published across nine disciplines(Van de Ven and Poole 1995), there is a paucity of articles in the public administration literature on organization change (Fernandez and Rainey 2006).

NASA in the literature

There is no shortage of analyses of NASA's organizational challenges in the literature. Perhaps most well known is Vaughan's *The Challenger Launch Decision* (1986), in which she analyzed in great detail the decision to launch the *Challenger* above the objections of some NASA technical staff. Among her conclusions is that the *Challenger* disaster was socially organized and systematically produced. Vaughan closed by criticizing environmental forces torquing NASA's culture, stating that she was cynical about the future of the organization.

In 2003, Hall 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. Further complicating necessary change are path dependence limiting reactions to stimuli, and the routinization of "acceptable deviance"—which at least one scientist has likened to Russian roulette. Finally, 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 indicate a troubling ability of bureaucracy to thwart legitimate inquiry, and a clear hierarchical problem. Problematic cultural features unique to NASA are specifically identified by Hall along with their potential for, and historical involvement in, disaster.

Boin and Shulman (2008) analyzed the Columbia Accident Investigation Board's (CAIB) report after the space shuttle accident, and disagreed with the CAIB's conclusion that NASA is a high reliability organization. Rather, examining the history of the space flight program, the authors concluded that NASA never has been, and never could be, a high reliability organization. Rather, it is a reliability-seeking organization. As such, 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 largely through an examination of government documents and reports. Among their conclusions is that for NASA to be a true learning organization, it needs to institutionalize lessons from the past in its standards and procedures; share and integrate information; encourage skepticism and imagination; preserve institutional memory; be responsive to professional standards and judgments; and apply past lessons. This echoes the conclusions of investigators who have proposed changes in the wake of accidents at NASA.

Research Problem and Theoretical Lenses

These observations and others about NASA in the literature were no surprise to us. Both of us served on the national Return-to-Flight Task Group formed in response to the space shuttle *Columbia* accident, and on NASA's Aerospace Safety Advisory Panel, a Congressionally mandated oversight board that examines NASA's operations and decision-making with a view toward improving safety performance. One of us also helped to coordinate the field recovery after the *Columbia* accident and served as special assistant to the NASA administrator. Our collective experience with NASA is a perception that despite the exceptionally high quality of the NASA workforce, and the exogenous shocks of three space shuttle accidents, the organization has failed to change in a way that might prevent future similar disasters. What we wanted to know is ***why?***

[Figure 1 about here]

Figure 1 presents our original conceptual model of organization change given an exogenous shock. Our primary research question is what determines whether an organization pursues Option A (change) or option B (no change)? The literature is replete with theories concerning organization change, including evolutionary models, teleological models, life cycle models, dialectical models, social cognition models, cultural models, and theories that combine multiple models. Given our research question, we focus on theories concerning the change of organization 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 key 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 as portrayed in Figure 2 (Schein 1985).

[Figure 2 about here]

Khademian (2002: 18-19) 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 philosphophies 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.

In the vast literature concerning organization change, there are three theories that offer the best lenses through which to examine whether exogenous shocks change organization culture. We present them here, then combine them to yield our own theoretical lens through which to analyze NASA.

Lewin’s Theory of Change

According to Fernandez and Rainey (2006), a large portion of the one million articles relating to organization change are based on the work of Karl Lewin (1947). Lewin put forward a three-stage model of change that has become known as unfreezing-change-refreezing approach to change. For organizational change to occur, behavior needs to be unfrozen, then the change needs to occur, then the new behavior needs to be frozen. The largest challenge is the presence of a force-field that resists organizational change. This force field comprises driving forces and restraining forces that must be altered for change to occur. Just imposing a shock to the organization often produces 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 are often group norms or personal psychological defenses embedded in an organization's culture. In the NASA example, we suspect that both group norms and individual psychological defenses are at work.

Schein's Theory of Change

The second theory of change that guided our research was developed by Edgar Schein, who built on Lewin's model of change primarily by unpacking the concept of unfreezing. Schein (1985) theorized that unfreezing is basically motivation to change, and consists of three processes unto itself, each of which needs to be present to some degree for change to be generated. The first part of unfreezing concerns disconfirmation. Schein maintained that all forms of change start with some form of dissatisfaction or frustration generated by data that disconfirm 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 1985). We suspect that NASA's confidence in its own data and analyses thwart its acceptance of independent disconfirming information.

Schein maintained that such disconfirmation must arouse the second step of unfreezing - "survival anxiety" or "survival guilt"—which, as applied to an organization, 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 is what Schein called "learning anxiety" which is the feeling that if we admit to ourselves and others that something is wrong, we will lose our effectiveness, our self-esteem, and perhaps even our identity. Learning anxiety is the fundamental restraining force on an organization which can meet disconfirming information head on, leading to the maintenance of the status quo equilibrium, according to Schein's theory.

Schein's third step to unfreezing behavior is creating some degree of "psychological safety" for workers that mitigates learning anxiety. Schein theorized that unless sufficient psychological safely is created, the disconfirming information will be denied or in other ways defended against, no survival anxiety will be felt, and no change will take place. The key for change in an organization such as NASA, then becomes balancing the amount of threat produced 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, reframing or "cognitive redefinition" is needed. This occurs by taking in the new information and often yields, among other things, new standards of judgment or evaluation. The new standards must be to some degree congruent with the rest of the organization culture. If organization members do not find the new standards plausible and sensible, they 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. Our interpretation of Kanter's theory is at Figure 3. Her theory states that major change in an organization comes about when five forces come together. Force 1 is "grassroots innovations," which Kanter defines as positive departures from tradition or news ways of thinking in the organization. These “aberrations” pop up in an organization often times by accident or if deliberate, are seen initially as insignificant or non-threatening. 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).

[Figure 3 about here]

Force 2 is a “crisis or galvanizing event.” The event may be a lawsuit, a change in the economy, or—in the case of NASA—a space shuttle 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.

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 strategies are developed 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 with power pushing 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).

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. Action vehicles are important, because in order for change to take hold, change recipients need to know what the change means for their own unique activities within the organization. Changes need to be written into job descriptions, standard operating procedures, and contracts. Individuals need to be convinced that using the new practices clearly creates benefits for them. Employees are encouraged to look for broader applications of the new ideas. Rewards must buttress desired actions. The point 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). When organization change efforts fail, it is often because of a weak Force 5, rather than an inherent problem with the innovative ideas themselves, Kanter argued.

Table 1 consolidates Lewin, Schein, and Kanter's theories of change, and identifies the necessary ingredients for successful organizational change. We now examine the case of NASA and consider whether permanent change to a new culture is likely in light of these criteria.

[Table 1 about here]

Accidents 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. NASA has nearly completed construction of the International Space Station, which has been inhabited continuously since late 2000. In 2004, NASA announced that it will retire the Space Shuttle in 2010. It is now developing the Orion, a new vehicle that is designed to take humans to the Moon. NASA aims to put a person on Mars by 2037.

These successes have come at a high cost, however. NASA's administrator, in a message to the agency on January 28, 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*." In the wake of each accident, investigators and analysts have identified causes, and have recommended improvements that NASA should undertake. These have been both technical and organizational. This section reviews this history of accidents, investigations, and responses.

Apollo I

The event. On January 27, 1967 a fire during a final pre-launch test and training exercise destroyed the Apollo 1 command module, which was on the launch pad at Cape Kennedy, atop a Saturn rocket. The three crew members were unable to escape the module and were killed. The Apollo/Saturn 204 mission was to be the first manned flight of a command and service module to Earth orbit. The test was designed to demonstrate the vehicle systems and operational procedures in a simulated launch. The ignition source of the fire was never determined definitively, but it is believed that an electrical arc ignited combustible material that burned fiercely in the 100 percent oxygen atmosphere (Collins, 1988).

The investigation and findings. In the wake of the accident, the NASA Administrator charged a review board with reviewing the circumstances surrounding the accident, investigating the cause of the accident, and making recommendations about how to minimize hazards. Among the guidelines NASA provided to the board, NASA directed the board to "consider all other factors relating to the accident, including design, procedures, organization, and management" (*Apollo 204 Review Board: Final Report*, 1967: iii). The board ultimately concluded that the accident and astronaut deaths were attributable to a range of hazardous conditions related to combustible materials, the hatch configuration, and the cabin atmosphere. These conditions existed because, according to the board, "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" (*Final Report*, 1967: 5-12). 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).

Prior to the accident, there were indications that NASA was or should have been aware of the specific safety concerns at hand. NASA's history office documents reviews of research about the operation of manned space chambers by scientists in the community in the years preceding the accident (Benson and Faherty, 1978). These suggest that the science and engineering community was skeptical that space systems were well enough understood to support NASA's ambitious aims. One scholar claimed, "With reliability figures and flight schedules as they are, the odds are that the first casualty in space will occur on the ground" (Newswald, 1966: 83).

The Apollo Program Director, Major General Samuel C. Phillips, also had concerns about the performance of the contractor that built the spacecraft, North American Aviation (NAA), well ahead of the accident (Benson and Faherty, 1978). In late 1965, the program director initiated a review of NASA's contract to determine why work on the Apollo spacecraft was behind schedule and over budget (NASA History office, 2003). The review noted that substantial technical problems were forcing NASA to miss deadlines and adjust its schedule. In General Phillips' 1965 letter to NAA that accompanied his report, he says, "Even with due consideration of hopeful signs, I could not find a substantive basis for confidence in future performance." Among the problems identified in the report are fragmented planning and control functions and a failure to clearly define responsibility and authority (*Phillips Report*, 1965). Despite what appeared to be grave concerns, NAA retained its role as prime contractor.

Certainly the Apollo command module was far more complex than any previously implemented spacecraft design. This complexity is evident in the debate between the agency and its contractor over design choices. For example, NAA originally suggested the hatch open outward and carry explosive bolts in case of emergency. NASA disagreed, contending the hatch could open accidentally. The astronauts did argue for an outward-opening hatch on future command modules to ease of exit and entry for spacewalks and after splashdown. NAA also proposed an oxygen/nitrogen mixture for the cabin, but NASA objected, citing heightened risks to the astronauts such as catastrophic decompression sickness and mismanagement of nitrogen levels. NASA asserted a pure oxygen atmosphere had been used without incident in the Mercury and Gemini programs, and this design also saved weight. Ultimately, there was significant incomplete work when the spacecraft was delivered to NASA, and hundreds of design flaws were identified. In an act emblematic of NASA's awareness of these inherent weaknesses, Gus Grissom, the Commander of Apollo 1, notoriously hung a lemon on an Apollo simulator a few days before the accident (Grissom and Still, 1974: 24).

The agency's response. NASA grounded the Apollo program, and made many procedural, spacecraft, and facility modifications in response to the accident and the review board's recommendations. Much more thorough protocols were implemented for documenting spacecraft construction and maintenance. After almost 21 months, NASA launched and completed its first successful manned mission, Apollo 7. These technical modifications are well documented. Less well documented are changes the agency sought to make to its culture. After the Apollo 1 fire, NASA was viewed as being infected with a "Go Fever" syndrome—a sense of urgency that drives people to overlook inherent risks that, with more deliberate analysis and action, could be mitigated in order to move ahead expeditiously. Go Fever was first galvanized by the Russian success with sputnik in 1957, and later reinforced by President Kennedy's 1961 speech that sent us to the moon by the end of that decade. Adequate attention to safety concerns would require time, create delay, and add cost. Go Fever promulgates shortcuts, schedule compression, and other symptoms of poor quality control.

As one clear response to Go Fever and the Apollo accident, Congress established the Aerospace Safety Advisory Panel in 1968, and gave it the following mission: “The Panel shall review safety studies and operations plans referred to it and shall make reports thereon, shall advise the Administrator with respect to the hazards of proposed or existing facilities and 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.”

<u>Challenger</u>

The event. Nineteen years after the Apollo accident almost to the day, on January 28, 1986, the space shuttle *Challenger*, embarking on its tenth mission, disintegrated shortly after launch when a seal on its right solid rocket booster failed. The failure allowed pressurized hot gases and flame to “blow by” an O-ring and impinge on the booster’s attachment strut and on the shuttle’s external fuel tank. This, in turn, caused the structural failure of the tank and allowed the booster to rotate into the orbiter. As a result, aerodynamic forces broke the system apart catastrophically. The crew of seven was killed and the shuttle was destroyed.

The investigation and findings. After the disaster, President Reagan appointed the Presidential Commission on the Space Shuttle *Challenger* Accident (known as the Rogers Commission, after its chairman) to investigate the accident. The commission determined that the O-rings failed for several technical reasons, including degraded gasket performance as a result of unusually cold air temperatures preceding launch. The commission also concluded that NASA's organizational culture and decision-making processes had been a key contributing factor to the accident, criticizing NASA’s unrealistically optimistic launch schedule, coupled with management isolation, and the silence of the safety program as contributing causes to the accident.

Specifically, the commission referred to “the unrelenting pressure to meet the demands of an accelerating flight schedule” (Rogers Commission Report, Vol. 1, Ch. 7, 1986), 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 undermined the safety program, including “a lack of problem reporting requirements, inadequate trend analysis, misrepresentation of criticality and lack of involvement in critical discussions” (Rogers Commission Report, Vol. 1, Ch. 7, 1986). NASA managers were unaware that contractor Morton Thiokol’s design of the solid rocket boosters contained a potentially catastrophic flaw, though Thiokol was concerned about the effects of cold temperature on the O-rings. 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 Report, Vol. 1, Ch. 5, 1986). Both senior NASA and Thiokol managers had ignored warnings from engineers about potential leaks in the joints of the shuttle’s booster rockets due to low temperatures (Smith, 1986).

The agency’s response. The Rogers Commission offered NASA nine recommendations for improving safety that were to be implemented before shuttle flights resumed. The agency halted manned space flight for 32 months and undertook a substantial redesign of the space shuttle’s solid rocket boosters before it successfully launched its next shuttle mission. NASA addressed the commission’s concern about an overly ambitious flight rate by working with the

Department of Defense to launch more satellites using expendable launch vehicles rather than the shuttle, and by adding another orbiter, Endeavour, to the space shuttle fleet.

NASA also made specific organizational and personnel changes. Many of these were structural changes intended to rationalize the decision-making process by clarifying lines of authority and making the involvement of managers in the program more direct. There were many personnel changes as well, including the assignment of several current and former astronauts to senior leadership positions. Other changes 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 NASA Administrator, designed to provide independent oversight of all critical flight safety matters. This office was supported by a Space Flight Safety Panel.

In effect, the commission had suggested that Go Fever still infected the agency. NASA acknowledged this problem and claimed to have addressed it in its 1987 report to the President on implementation of the commission's findings:

> Special attention is being given to the critical issues of management isolation and the tendency toward technical complacency, which, combined with schedule pressure, led to an erosion in flight safety. It is imperative that return to safe, reliable space flight be accompanied by an intensified awareness that no space flight is without risk, and that NASA's responsibility is to control and contain that risk without claiming its elimination. This philosophy of space flight operations is the controlling one in today's Space Shuttle Program.

Although NASA seemed to have made substantial changes because of the *Challenger* accident, many have argued that the changes in its management structure and organizational culture were neither deep nor enduring. This view was bolstered seventeen years later…

Columbia

The event. In January, 2003, the Space Shuttle *Columbia* and her crew of seven launched on the 113th shuttle flight to begin a sixteen-day scientific research mission. On February 1st, *Columbia* broke up upon re-entry over the western United States at an altitude of 200,000 feet and a speed of Mach 18. The crew was killed, and 2000 square miles in Texas and Louisiana were littered with tens of thousands of pieces of shuttle debris. Amazingly, nobody on the ground was hurt, but the crash demanded urgent response. Of greatest priority was the need to protect the public from the potentially dangerous shuttle material. Likewise, it was imperative to recover the remains of *Columbia*'s astronaut crew. In addition, the investigation of the accident cause dictated that as much debris as possible be retrieved to support forensic analysis. Solving these problems ultimately required the collaborative effort of over 450 federal, state, and local government agencies, private companies, and nonprofit organizations.

The investigation and findings. Once again NASA confronted a major accident investigation. This time, NASA convened the Columbia Accident Investigation Board (CAIB), chaired by Admiral Hal Gehman, to conduct an investigation. To assure that its investigation could be independent, the board's charter was revised to allow the board to have its own staff and budget, and to be able to release updates and its final report simultaneously report to Congress, the White House, NASA, the public, and the astronauts' families.

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. A piece of insulating foam from the shuttle's external tank had come off shortly after launch and struck the leading edge of the left wing. During re-entry this breach allowed hot gasses to penetrate the wing and melt its structure, which led to failure of the wing, loss of control, and eventual break-up of the orbiter.

Saying that "NASA's organizational culture and structure had as much to do with this accident as the External Tank foam," the CAIB gave explicit attention to cultural traits as well as organizational structure and practices (CAIB, 2003: 177). The CAIB dedicated an entire chapter to the accident's organizational causes, including a section entitled "A Broken Safety Culture." 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 CAIB also demonstrated that NASA itself had recognized the challenges of sustaining a robust safety culture. In the late 1990's NASA had chartered a Shuttle Independent Assessment Team to review program practices. That team discovered and reported problems of lack of independence, poor communications, and schedule pressure. NASA formed an action team to recommend solutions to these problems, yet apparently could not fix them.

The agency's response. In addition to numerous findings and observations, the CAIB made 29 specific recommendations for changes to the vehicle, the Space Shuttle Program, and the agency overall. They characterized fifteen of these recommendations as required before the shuttle should be allowed to fly again. NASA committed to fulfilling these "Return to Flight" recommendations before launching the next shuttle mission, and continuously reported its actions and progress in a regularly updated "Implementation Plan for Space Shuttle Return to Flight and Beyond: A periodically updated document demonstrating our progress toward safe return to flight and implementation of the Columbia Accident Investigation Board recommendations." In the introduction to this document, the agency made a strong commitment to change: "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 RTF Plan, 2003: xiii). NASA established a "Return to Flight Task Group" charged with reviewing the degree to which the agency fulfilled the CAIB recommendations.

By the time of the next shuttle launch, the Return to Flight Task Group determined that NASA had fulfilled the intent of the CAIB for twelve of the fifteen required recommendations. For the other three recommendations, all of which pertained to technical problems, the task group concluded that these "were so challenging that NASA could not comply completely with the intent of the CAIB, but conducted extensive study, analyses, and hardware modifications that resulted in substantive progress toward making the vehicle safer" (RTF TG Report, 2005: 11). Despite the Task Group's affirmation of NASA's efforts, the group also observed recalcitrance on the part of NASA managers toward change requirements. Some evidence of this is documented by a subset of the Task Group in Appendix 2 of its report.

With regard to safety oversight, NASA continued to employ the Aerospace Safety Advisory Panel (ASAP), which had been created in the wake of the Apollo accident. Notably, though, the ASAP members who served at the time of the *Columbia* accident resigned en masse after the accident. The CAIB had critiqued the ASAP, saying it lacked influence. Likewise, the Senate Appropriations Committee said the ASAP failed to spot potential danger signs in the operation of the space shuttle. At the same time, the ASAP members described NASA's lack of responsiveness to their recommendations ahead of the accident. In an interview, one former ASAP member is quoted as saying "Many of the cultural issues identified by the CAIB are in our annual reports…That underscores our lack of influence" (Recer, 2003). Congressman Ralph Hall noted, "The mass resignation of the members [of the ASAP] sends a strong signal that, despite the useful and important service that they have provided over the years, their advice has rarely been heeded. Simply changing its membership will not improve ASAP unless NASA and the Congress are willing to dedicate the resources and effort necessary to implement the Panel's safety recommendations" (Hall, 2003). NASA reconstituted the panel in 2003.

The agency also made several organizational changes designed to strengthen managerial decision-making processes, improve communications, and make the safety organization more robust and independent. NASA 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. NASA also 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. Finally, the systems engineering and systems integration activities were reorganized to address ambiguities that had led to confused communications.

Many of these changes were designed to address two underlying cultural issues: the lack of respect safety personnel commanded in the agency and the perception that managers suppressed the inclination of line engineers to voice dissenting opinions. 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 CAIB recommendations. This created a period of turbulence that makes it difficult to evaluate the likely stability of organizational changes at NASA. These changes dramatically slowed and altered implementation of the ITA, but technical authority, accountability, and dissenting opinion processes are now seen as robust (ASAP, 2009).

Discussion

It is evident that particular organizational and behavioral conditions were present in the agency ahead of all three accidents. This section identifies common organizational conditions across this history. It then considers whether NASA has fundamentally changed its organizational culture in light of the criteria and conditions of change discussed above and identified in Table 1.

Common organizational causes

Each of these accidents is, as most are, complex in its causes and effects. Review of these accidents, the findings of the investigations that ensued, and NASA's responses, however, reveals certain tendencies that are common to each. These include schedule pressure, misperception of risk, weak communications, and a weak safety culture.

Schedule pressure. Schedule pressure is persistent in NASA's history. It was evident ahead of all three accidents. 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 Report*, 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, 1986: 152). The CAIB noted that *Columbia* was plagued by "intense" pressure to deliver core components to the badly over-budget International Space Station (ISS) expediently. And despite overt attempts by NASA to orient itself to be "milestone driven," not "schedule-driven" after the *Columbia* accident, NASA seems to be subject to schedule pressure even now as it struggles to complete the ISS in 2010 so it can retire the shuttle on time. In 2004, the Orlando Sentinel noted,

> Nearly two years after the *Columbia* disaster, some NASA managers fear that cost-cutting measures and pressure to resume shuttle launches are jeopardizing critical safety reforms. Confidential interviews with shuttle officials, as well as internal NASA documents and e-mails obtained by the Orlando Sentinel, portray a program rushing to fly again despite serious money problems and growing concerns about meeting an ambitious schedule.

Risk perception. Misapprehension of risk attributable to a lack of a checked and balanced safety system likewise seems common to these incidents. The *Apollo* board indicated that NASA failed to appreciate the extent of fire hazards in an pressurized oxygen-filled spacecraft cabin on the ground. As the Senate's report notes, "There appears to be no adequate explanation for the failure to recognize the test being conducted at the time of the accident as hazardous" (Senate, 1968: 9). Similarly, the CAIB notes that the shuttle accidents indicate that the shuttle has proved "riskier than expected" (CAIB, p. 23). The Rogers Commission and CAIB both point to a NASA culture that grew increasingly inured to risk, accepting ever more. After the Columbia accident, the Return to Flight Task Group exhorted the shuttle program to "be completely honest with itself, NASA leadership, Congress and the American public, never minimizing the risks inherent in space flight, never making it appear to be easier than it is, and never forgetting that the price of failure is too high" (RTF TG, p. 22).

Weak communications. Fractured communications and management processes are also common to all three accidents, 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 (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 the management reversed its position" (Rogers, 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, p. 170).

Silent safety. Finally, the lack of attention to safety, or a weak "safety culture," has 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, p. 25). One dilemma is that safety—or lack thereof—becomes most apparent after an event. It is the quintessential “dog that does not bark,” in that safety problems may be profound, but go unrecognized if a mission happens to succeed without incident. As ASAP member Richard Blomberg noted in testimony before Congress in 2001, “Safety is an intangible whose true value is only appreciated in its absence. The boundary between safe and unsafe operations can never be well defined. As a result, even the most well meaning managers may not know when they cross it.” Thus, the question of how to institutionalize this intangible factor remains unanswered, and NASA continues to struggle to create organizational mechanisms that embed safety in its operations effectively.

The more things change, the more culture stays the same?

Despite the unique technical causes of each of these accidents, and the numerous documented changes NASA can point to in response to each, some conditions appear constant. The presence of these common threads suggests that certain fundamental organizational characteristics and behaviors have been persistent at NASA, and that NASA historically has not been able to achieve substantial, enduring cultural change. The question is, why not? And further, what are NASA’s prospects for change before another accident can strike? To answer these questions, we consider the NASA case in light of the criteria for change identified in the literature. Table 2 summarizes our findings.

[Table 2 about here]

Unfreezing. The literature tells us that the ground for change is most fertile when a crisis happens in an environment of innovation, 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 guilt) and be unafraid of it (overcome learning anxiety and feel psychologically safe).

At NASA, each accident opened an opportunity for the agency to decide that traditional solutions were no longer viable, and to adopt a different, nontraditional 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. Arguably these expectations were levied on an organization that epitomizes innovation. NASA was born solving the extremely challenging problems of space flight that no nation had solved before. Especially in its earliest days, the environment of NASA was seen as problem focused, with little attention to rank, paperwork, or procedure (Johnson, 2001). The complexity of the Apollo program prompted program managers, especially Samuel Phillips to create new management practices. Thus, the Apollo accident occurred in an environment primed to adopt new safety and engineering management approaches. Arguably, Kanter's precursors for change were present, and the agency capitalized on them..

By 1986, however, rigorous, disciplined use of these controls had faded, as had NASA's lively culture of innovation. McCurdy (1993), who conducted a close examination of the inner workings of NASA, concluded that the early culture of NASA created civil servants who felt empowered to exercise a high degree of discretion and technical judgment in carrying out their work. This culture gradually changed as the organization matured. During the second and third decades of space flight, the force of NASA's technical culture declined, as bureaucratic and political constraints grew. Vaughan (1986) also noted the regularized nature of the agency: "…[I]ts origins were in routine and taken-for-granted aspects of the organizational life that created a way of seeing that was simultaneously a way of not seeing…. [It was] the normalization of deviant joint performance" (p. 394). For example, the number of guidelines and rules increased risk by giving a false sense of security. Tied in with this, risk assessments were carried out under circumstances that made risk "fundamentally incalculable" (p. 421). By the time of *Columbia*, space flight was nearly perceived as routine. The CAIB noted this flaw: "Throughout the history of the program, a gap has persisted between the rhetoric NASA has used to market the Space Shuttle and operational reality, leading to an enduring image of the Shuttle as capable of safely and routinely carrying out missions with little risk" (CAIB, 2003: 23). Thus, the predilection toward culture change at NASA was likely weaker the more mature the agency became, as there was less of a tendency toward grassroots innovation that could be employed by change agents in the wake of a crisis.

The impetus to change at NASA also ran headlong into its group norms and individual psychological defenses that has made it difficult for NASA personnel to accept disconfirming data that indicate the need for change. In his history of NASA, Handberg (2003) 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" (p. 223). He went on to write that "[a]dmitting to mistakes remains…extraordinarily difficult for NASA… drastically reduc[ing] its credibility" (p 225). The notion that "failure is not an option" has been deeply engrained in 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 that they are successful in the face of very difficult challenges. This is exemplified by a product line of 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 www.thespaceshop.com). NASA also has a culture of extreme confidence in its abilities. The manned space flight corps views themselves as "the right stuff." (after the book by Tom Wolfe about the U.S. manned space program). Thus, it is therefore hard for NASA to believe that it is wrong. Being wrong is not available to them as a possibility. It is hard for them to admit weaknesses. Without such admissions, change cannot be made.

It is also difficult for NASA managers to allow survival guilt (the sense that if the organization does not change, it will fail to achieve its goals and ideals) to overcome their learning anxiety (fear of admitting 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 that pushed NASA managers to neglect safety concerns. The *Columbia* accident happened well into the shuttle program, endangered in part by complacency that crept in as NASA managers succumbed to pressure to view the program as mature and the vehicle as operational, though it fact it was still experimental. In effect, schedule pressure and the pitch NASA had made to the White House to establish the shuttle as a means of routine access to space prevented the agency from admitting that the program was subject to ever increasing program and technical risk, and that changes were required to bring schedules, budgets, and results into more reasonable alignment. They were trapped in a mode of over-promising, and were fearful that acknowledging needed changes would kill their programs.

In sum, the unfreezing phase of change as NASA has proved difficult. Its early innovative culture has become more staid and stolid. The organization has become more hierarchical, and greater distance between managers and engineers has attenuated communication. Schedule pressure and performance expectations have forced good managers and engineers to make bad judgments that increase risk.

Change. 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.

In the wake of all three accidents, NASA developed a specific set of responses to the findings of the investigators. For example, 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 progress with respect to each of the CAIB's recommendations. NASA managers appeared committed to addressing the problems that investigators found, including some that had been pervasive since the agency's inception. For example, the mantra chanted meeting after meeting 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.

Notably, the recommendations identified as return to flight recommendations were predominantly technical—related to the physical, rather than organizational, cause of the accident. Since NASA's primary motivation was to fly again as soon as possible, its approach to change was therefore dominated by, and narrowly focused on, technical requirements. The "soft stuff" of culture change received less emphasis, though NASA managers did make explicit attempts to understand and assess cultural deficiencies with a view toward changing behavior.

Unfortunately, changes in the agency's senior leadership allowed this to fall by the wayside, as the ASAP reported in its 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. These group activities included: leadership coaching; multiple-rater feedback; skills training; cognizant-bias recognition; and behavioral observation and feedback. Despite promising results and a survey in which 84 percent of participants said they found the training useful, 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.

Beyond this, Boin and Shulman (2008) argue that to become more reliable, NASA must continually search for error in day-to-day operations and adjust itself to correct these errors. On the technical front, NASA does this well, but culturally, it does not. Thus when technical problems are identified (such as foam), NASA not necessarily alter its decision-making behavior. One example of this is the actions by NASA's safety director and chief engineer, who both voted "no-go" on the Certificate of Flight Readiness for a July, 2006 shuttle launch. Neither opposed the Administrator's decision to proceed, however, on the basis of the claim that the space station could be used to harbor the shuttle crew, though this notional capability is not itself certified. In the end, they would not certify that the shuttle was "go" for launch, but allowed the launch to go ahead on the back of something else that was not certified.

Another challenge to the change process at NASA is that it takes time and therefore requires endurance to embed the change agenda in all of NASA's programs. The agenda is easily overtaken by competing priorities. 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. This problem is exacerbated as people fall back on what they know in the face of new challenges. For example, while the current Constellation program might have presented an opportunity to correct past mistakes and "do things right this time around," the pace of the program, the pressure to fulfill expectations, and the need to deliver results to warrant budget commitments mean that the agency cannot afford a zero-based approach. Instead of developing new action plans, the agency capitalizes on existing practices, procedures, and structures, even if they are less than ideal.

Finally, change is difficult at NASA because it tends to be directed by independent authorities. Independence is prized in accident investigation because it is presumed to make objective, candid assessments that may be unpalatable to the agency more likely. At the same time, this means that demands for change are imposed from without by external reviewers, investigators, and other stakeholders, rather than born within the organization in the form of grassroots innovation. External Task Forces are a force that meet organizational resistance that prevents equilibrium from being shifted. Thus, while 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 are already innate in the organization.

Refreezing. New norms and behaviors are solidified throughout the organization through new structures, practices, processes, and procedures, use of which is rewarded. Even in the face of sound innovation, change can fail if it is not fully embedded in the daily business of the organization.

After the Apollo accident, program manager Samuel Phillips was able to dramatically strengthen configuration management 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 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 from a revolutionary, pioneering into a more mature engineering organization.[1]

The *Challenger* accident prompts a different conclusion. Despite numerous recommendations about how and why to change and lots of pressure to change, NASA seemed unable to overcome cultural barriers and effect real change. The CAIB, in Chapter 8 of their report entitled "History as Cause," explained in detail their assessment that many of the cultural factors that contributed to the loss of *Columbia* had also led to the loss of *Challenger*. The CAIB (CAIB, p. 100) found:

> Though NASA underwent many management reforms in the wake of the *Challenger* accident and appointed new directors at the Johnson, Marshall, and Kennedy centers, 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. By the eve of the *Columbia* accident, institutional practices that were in effect at the time of the *Challenger* accident—such as inadequate concern over deviations from expected performance, a silent safety program, and schedule pressure—had returned to NASA.

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[1] Even so, the program confronted near disaster a short time later in 1970, when Apollo 13 was nearly lost, in part because NASA failed to recognize a hazard similar to one that existed prior to the Apollo 204 accident: the danger of fire in a pure oxygen environment. Furthermore, communications about the oxygen system before launch "included incomplete and inaccurate information" (NASA, 1970: 92). That said, the Apollo investigation determined that management controls were adhered to ("Management controls requiring detailed reviews and approvals of design, manufacturing processes, assembly procedures, test procedures, hardware acceptance, safety, reliability, and flight readiness are in effect for all Apollo hardware and operations" NASA 1970: 93), but that these had not been in effect at the time the system was designed.

The CAIB concluded that “the causes of the institutional failure responsible for *Challenger* have not been fixed,” and the same flawed decision making process that had caused the *Challenger* accident also caused *Columbia*’s destruction seventeen years later.

There are however, some hints that real changes may have finally taken hold in the wake of *Columbia*. One NASA Chief Engineer noted in 2005 that NASA’s Independent Technical Authority (TA), a new set of organizational structures, processes, and norms, “is the single biggest litmus test of culture change at NASA.” For two years thereafter, progress toward fully developing and establishing this authority limped along in a context of leadership changes and shifting priorities. In early 2007, the Aerospace Safety Advisory Panel worried publicly that NASA was in grave danger of failing once again to inculcate robust, independent technical conscience at all levels of the agency. A few months ago, 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 makes a long list of actions NASA must take if it is to transform abstract change into permanent reality.

Conclusion

The case of NASA is largely one of its struggle to balance schedule, cost, and quality, and the hidden threats tensions between them pose. Optimizing all three at once has been an elusive goal, and the attempt to do so has resulted in terrible failures. While there are many technical aspects to this dilemma, this discussion has concerned its cultural dimensions. From our examination of the NASA case, it is evident that NASA has struggled to specify and adopt an organizational culture that inculcates norms and behaviors that are different enough from those that precipitated its three accidents that we can be confident that NASA has mitigated the organizational threats to flying spacecraft safely. We have seen that shocks have not changed NASA in the past, but perhaps may be doing so post-Columbia. Clearly, though, a shock alone won't do it. We provide empirical substantiation of Lewin, Schein, and Kanter's arguments that it must be a shock coupled with key organizational factors.

Will NASA finally be able to adopt a permanent new culture? It seems that NASA may not have enough of an innovative bent to do so. Omnipresent schedule pressure, coupled with a "failure is not an option" mentality and an engineering discipline that leads to a very prescriptive approach to problem-solving, added to the fact that safety of flight demands that mistakes are not forgiven mean that organizational innovation generally is not rewarded. As a result, NASA is biased toward stability and against change. Certainly, the time to innovate is not during a shuttle flight. There is a time and a place for deviation from the engineering discipline. But NASA does not have the kind of robust professional development program that would help young engineers navigate these judgments appropriately. As a result, the precursor condition to change (Kanter's Force 1) is not strong and not allowed to flourish at NASA. Apollo-era NASA Administrator James Webb is known to have acknowledged that "while the technological aspects of reaching the Moon were daunting, these challenges were all within grasp. More difficult was ensuring that those technical skills were properly utilized and managed" (NASA History Office, 1989).

At the same time, NASA does solve incredible technical problems, and so it seems that NASA's greatest asset is its greatest downfall. Its audacity and spectacular successes is a positive feature, but the concomitant arrogance makes it rigid. Unfortunately, NASA's external environment is no more forgiving than it has been—even as NASA mounts its next manned spaceflight program budget cuts already threaten the program's success. The Review of U.S. Human Space Flight Plans Committee just released its report (2009), which opens thus:

> The U.S. human spaceflight program appears to be on an unsustainable trajectory. It is perpetuating the perilous practice of pursuing goals that do not match allocated resources. Space operations are among the most complex and unforgiving pursuits ever undertaken by humans. It really is rocket science. Space operations become all the more difficult when means do not match aspirations. Such is the case today.

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Figure 1: Conceptual Model of Change Given an Exogenous Shock

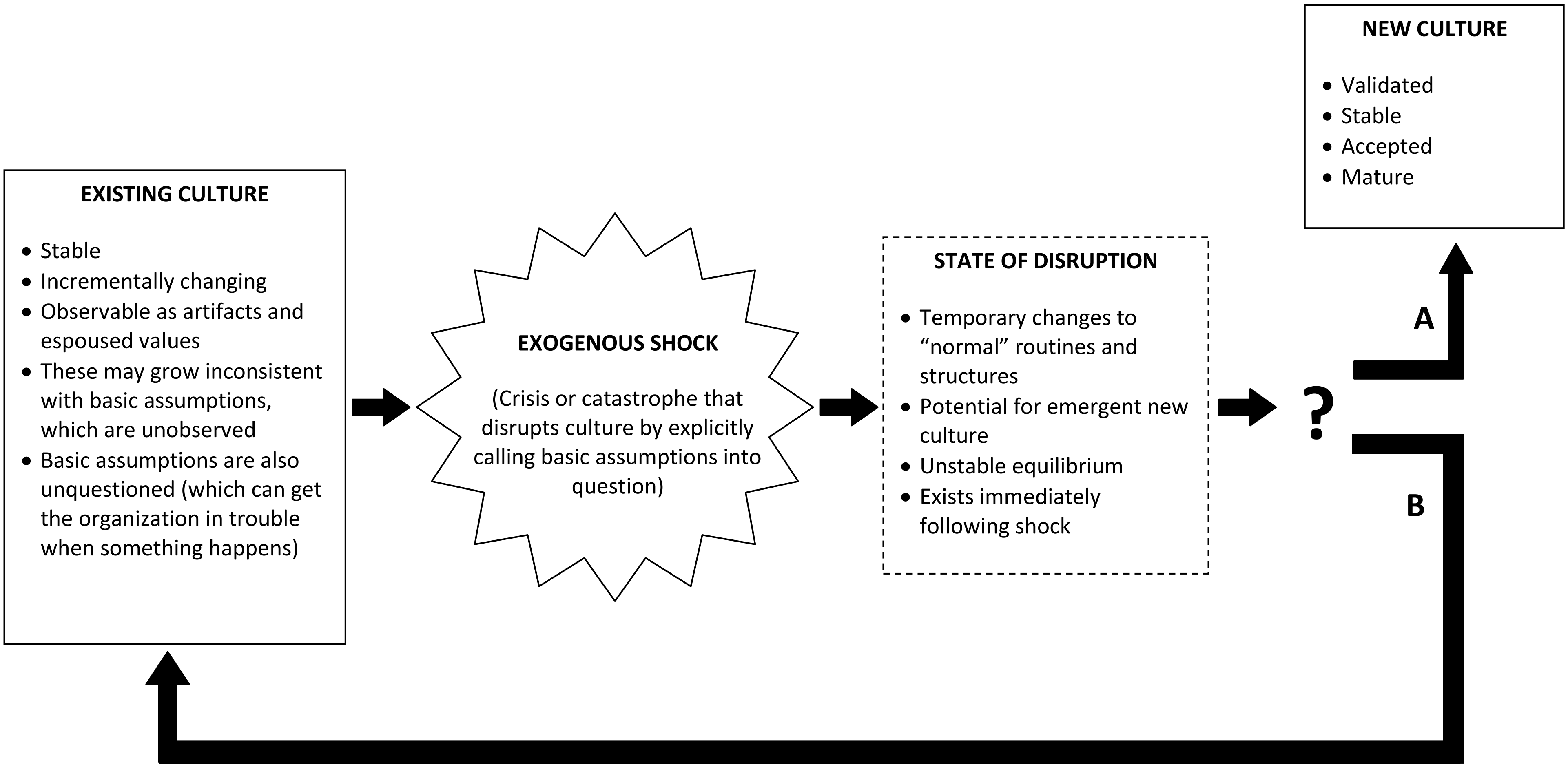

Figure 2: Manifestation of Organization Culture

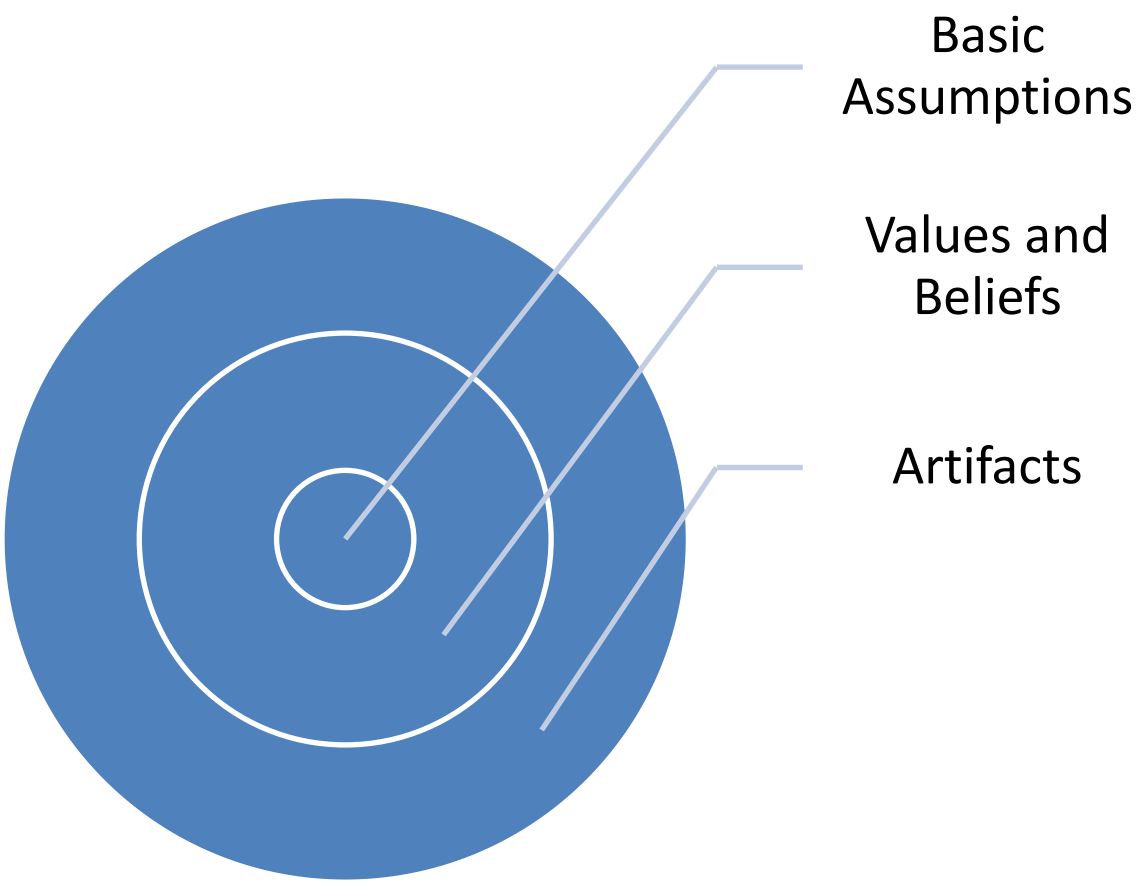

Figure 3: How Major Events Change Organizations – Adapted from Kanter's change "funnel" (1983)

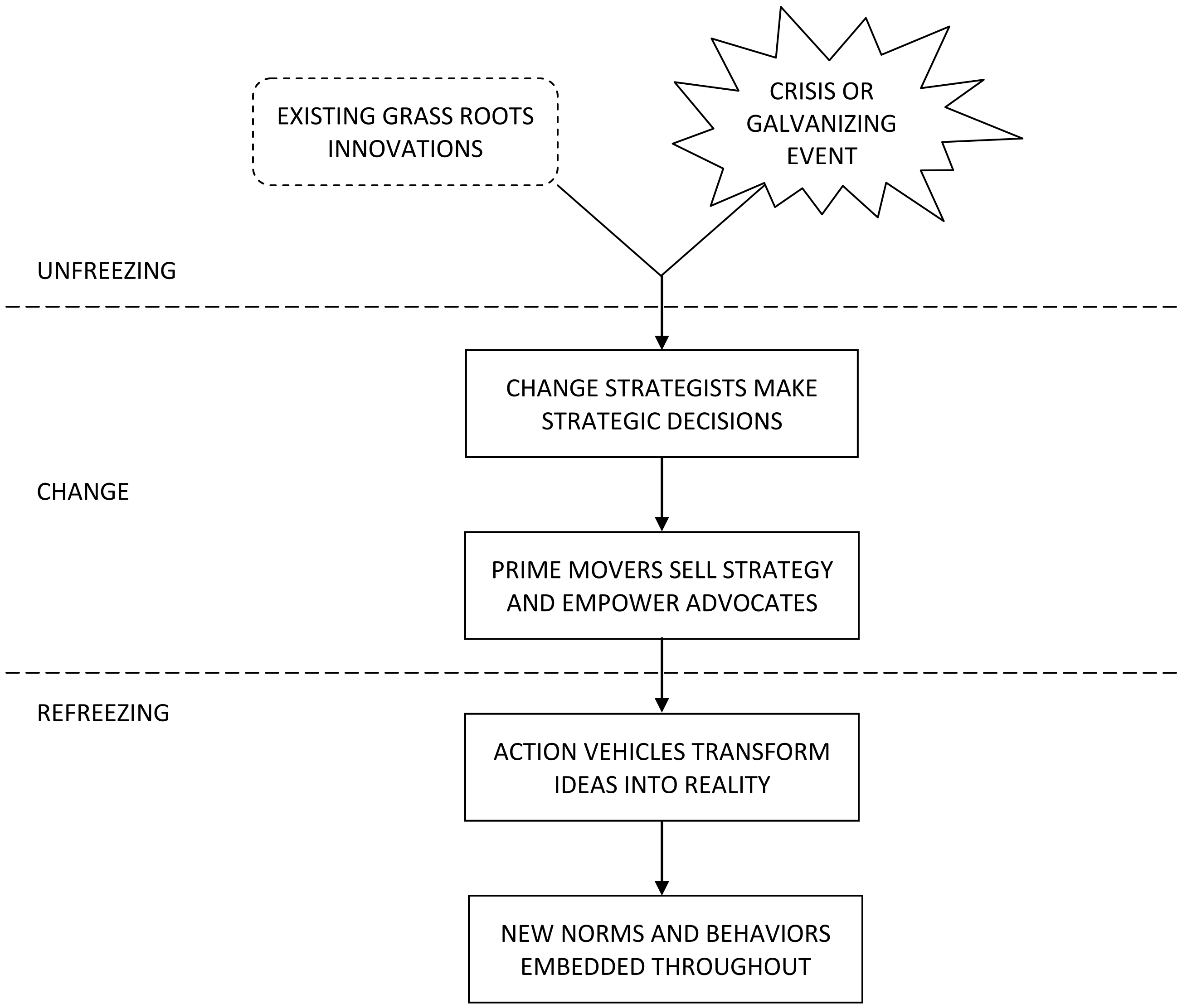

Table 1. Organization culture change criteria derived from Lewin (1947), Schein (1985), and Kanter (1983).

Phase of Change	**Required Causal Factors**
Unfreezing	Grassroots innovations
	Crisis or galvanizing event
	Restraints of group norms are reduced
	Restraints of psychological defenses (including learning anxiety) are reduced
	Presence and acceptance of disconfirming information
	Survivor guilt overcomes learning anxiety
	Psychological safety permits motivation to change
Change	Cognitive redefinition
	New standards of judgment and evaluation 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 abstract ideas into reality
	Rewards buttress new desired behavior
	Changes to old norms and behavior are embedded throughout the entire organization

Table 2. Organization culture change at NASA.

Phase of Change	**Conditions and events at NASA**
Unfreezing	• Bias toward dismissing information that did not arise from NASA's own procedures and analysis. • Schedule pressure prevented NASA from admitting that the program was subject to ever increasing risk, and that changes were required to bring schedules, budgets, and results into more reasonable alignment. • The notion that "failure is not an option" deeply engrained in NASA's culture. • Characterization of NASA personnel as "the right stuff" makes it hard to admit weakness or failure.
Change	• Change agenda superseded by new programmatic goals. • Leadership instability undermines initial efforts to evaluate and change culture. • Change targets are typically technical in nature and narrowly construed.
Refreezing	• New safety institutions and procedures implemented. • Some organizational efforts to give safety professionals more stature.