# HUMAN FACTORS IN MISSION ASSURANCE

## CULTURAL INFLUENCE ON MISSION SUCCESS AND RISK

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*Abstract*—Space projects rely completely on people for development and implementation – but project risk lists rarely include human factors as significant sources of risk. Investigations of recent space mission failures, most notably the Columbia disaster, have pointed to human issues and "cultural factors" as underlying causes. Reports have focused on behaviors and artifacts of organizational culture, which are most visible to the investigators; they have not usually identified the basic assumptions that are the essence of culture and the drivers of behavior.

An earlier paper identified and explained certain cultural and behavioral human factors related to mission success in both NASA and military space programs; it reviewed studies of both NASA and military missions, including investigations of the Mars '98 failures. It briefly described four main behavioral factors related to mission success, some risks related to such factors, and how such risks might be mitigated.

This paper takes the next step in the analysis, and integrates the work of organization development practitioners and experts who focus on the cultural imperatives that guide behavior in organizations. I reviewed psychological literature related to human anxiety and its relief, and interviewed a practicing psychologist who leads the Employee Assistance Program at NASA's Jet Propulsion Laboratory. I will perhaps raise more questions than I answer concerning the power of specific cultural imperatives; but I will suggest some effective means of changing the basic assumptions that drive "cultural" behaviors.

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## 1. INTRODUCTION – HUMAN FACTORS

When a space mission does not produce any of the results it was intended to produce, it has failed – at least according to our commonly held views within the space mission professions. A failed scientific mission is one that returns no science data. A failed military mission is one that does not achieve its military objectives, whatever they are. Even a commercial space mission can fail, if it doesn't achieve the business goals it was created for.

A mission might fail while in flight and not achieve its intended results; or fail to get to flight in the first place, and not even be able to attempt to achieve intended results. The potential for either failure to occur we call risk, and we attempt to prevent the possibility from becoming reality by identifying risks in advance and mitigating them. Space missions are very complicated to plan and to conduct, and they rely completely on people for development and implementation. Investigations of recent space mission failures, most notably the STS-107 Space Shuttle disaster, have pointed to human issues and "cultural factors" as underlying causes. Strangely, project risk lists rarely include human factors as significant sources of risk.

In an earlier paper, I tried to identify and describe a set of human factors that contribute to mission success. I conducted interviews with a variety of project mission assurance experts, and looked into reports and studies about both civil and military mission assurance. Of special interest was a report by NASA's Integrated Action Team (NIAT), conducted in response to failures of two Mars exploration missions, and to a "close call" involving Shuttle wiring. The study also assessed NASA's espoused, "faster, better, cheaper" values in mission management.

I managed to sort out four types of human factors that seemed to relate consistently to mission success:

1. Adherence to processes and principles
2. Definition and fulfillment of roles, responsibilities, and relationships for organizations and individuals
3. Individual success factors
4. Communication among project components

Since that time, other missions have been lost – most notably the Space Shuttle Columbia and all its crew. I was pushed in the direction of looking at the cultural foundations of these human factors when an acquaintance pointed out to me that, by traditional definitions of mission failure, the STS-107 mission was a success, since it got to flight and achieved its scientific objectives – however, most of us don't consider the Columbia disaster a mission success, do we? Where human flight is concerned, there is an *unstated* mission objective that all of us accept without even thinking about it – that a human mission fails if it does not return the people safely to earth. This unspoken requirement is a *cultural imperative,* connected to our basic assumptions about life, and had to be immensely important to members of NASA's space flight organization.

**Conflicting cultural imperatives**

By now, we are all familiar with the Columbia Accident Investigation Board report, which told us that the imperative of meeting a launch schedule was found to be more compelling to mission management than the imperatives of the NASA safety culture. Although foam strikes were known to have damaged the Shuttle's wings in several prior flights, STS-107 launched without a resolution of the foam anomaly. The September 1, 2003 issue of *Aviation Week* reported "the CAIB found that pressure from the top to meet a political deadline on ISS assembly might have distracted the human space flight organization from its safety obligation to the Columbia crew."

NASA did not face this type of conflict alone. The editorial in the same issue of *Aviation Week* stated, "NASA hasn't been the only high-reliability organization to have missed danger signals from its hardware. Think of Europe's Concorde operation, which treated tire failures and debris strikes on the supersonic transport's wings as maintenance issues until they sent one of the beautiful airplanes and its passengers into a hotel near Paris Charles de Gaulle airport."

This kind of conflict is not limited to situations involving performance of high-tech hardware. An earlier issue (June 9, 2003) of *Aviation Week* reported that in the rush to hire passenger and baggage screeners for airports, the security-driven Transportation Security Administration hired over 1200 screeners that later had to be terminated because of "suitability issues." These employees had discrepancies in previous employment records that the TSA had not taken time to discover, or problems that should have prevented them from being hired in the first place (such as convictions for felonies, or drug use).

There is a strange dynamic at work here. Consider the that risks which would cause a mission to fail in flight (mission risks) are usually mitigated by application of resources like time, money and work force while the mission is being developed for flight. Consider also that this application of resources could increase the second type of risk (programmatic risk) that a mission may not get into flight at all – say, if the mission is cancelled or postponed for being over a cost cap, or cannot meet its launch schedule. For some missions, not getting to flight *in time* may have a

similar effect to not getting there at all: planetary missions with launch windows determined by celestial mechanics; military missions related to specific wartime activities; and missions to relieve residents of the International Space Station.

How do we make decisions when faced with these kinds of conflicts? More importantly, how is it that we can make the wrong decision?

I believe the situation is more complicated than the reports and recommendations have explained, because the drivers not at the surface of culture, where the behaviors are. I believe we will have to "dig up" the basic assumptions about the world that are the essences of culture, to understand and to improve the situation, to prevent conflicting cultural imperatives from desensitizing workers (and management) to the mission-related risks based on human, cultural factors.

In the words of the CAIB, "In the Board's view, NASA's organizational culture and structure had as much to do with this accident as External Tank foam. Organizational culture refers to the values, norms, beliefs, and practices that govern how an institution functions. At the most basic level, organizational culture defines the assumptions that employees make as they carry out their work. It is a powerful force that can persist through reorganization and the reassignment of key personnel."

## 2. Organizational Culture

Edgar Schein is a professor of management at the Sloan School of the Massachusetts Institute of Technology, and is one of the founders of the field of organizational psychology. He is probably the first author to use the phrase "organizational culture" and actually explain it. He presents a model of what he calls layers of culture, whether organizational, national, or ethnic:

***Cultural Artifacts (surface)***
***Espoused Values (middle)***
***Basic Assumptions (foundation)***

### Cultural artifacts

On the surface are artifacts, including all the visible, audible, sensible creations of a culture. These are the most visible aspects of culture, and we frequently consider them to be the real culture itself – the language, music, style of dress, rituals and ceremonies. The behaviors of a group are also artifacts. Schein warns us, though, that these are surface aspects of culture, and do not really tell us the essence of what we are observing:

"It is especially dangerous to try to infer the deeper assumptions from artifacts alone because one's interpretations will inevitably be projections of one's own feelings and reactions. For example, when one sees a very informal, loose organization, one may interpret that as inefficient if one's own background is based on the assumption that informality means playing around and not working. Alternatively, if one sees a very formal organization, on may interpret that to be a sign of lack of innovative capacity if one's own experience is based on the assumption that formality means bureaucracy."

We must look deeper, into the espoused values and the basic assumptions, to really understand the culture and the *meaning* the people in that culture attach to their experiences. (Both the Mayans and the Egyptians built pyramids as artifacts, but until we look inside them, we don't understand that they were tombs to one group and temples to the other.)

### Espoused values and basic assumptions

Espoused values begin as purposeful or cognitive directions, usually from a respected leader of the group, regarding what the group *should* consider important, and how they *should* reflect those values through their actions. Espoused values don't become basic assumptions, however, unless they *always* lead to successful behavior. When the group learns that practicing the espoused values will further its survival, or make its internal social interactions work better, the values are gradually changed into basic assumptions about

life. These assumptions are not even discussed any more, but the rules of behavior derived from them are still on the conscious level.

Consider that the rights to practice free speech and own personal property were consciously derived concepts before becoming unspoken assumptions in the United States – and they are still not unspoken assumptions in other parts of the world. (For that matter, are they unspoken assumptions everywhere in America? Do you have the same freedom of speech at work as you would have in a School Board or City Council session?)

Edgar Schein tells us, "When a solution to a problem works repeatedly, it comes to be taken for granted. What was once a hypothesis, supported only by a hunch or value, gradually comes to be treated as reality. We come to believe nature really works this way."

Psychologist Cynthia Cooper, who heads up the Employee Assistance Program at NASA's Jet Propulsion Laboratory, sets up the background for one of JPL's basic cultural assumptions: "This is the JPL norm: that we can always pull the rabbit out of the hat, no matter how big a rabbit or how small a hat. We can always accomplish a successful mission, no matter how difficult, no matter how great the odds are against it."

A history of 87 successful Shuttle Flights without casualty contributed to the NASA norm in much the same way, according to the CAIB report: "Despite constraints that the agency was under... NASA appeared to be immersed in a culture of invincibility, in stark contrast to post-accident reality. The Rogers Commission found a NASA blinded by its "Can-Do" attitude, a cultural artifact of the Apollo era that was inappropriate in a Space Shuttle Program so strapped by schedule pressures and shortages that spare parts had to be cannibalized from one vehicle to launch another... Engineers and program planners were also affected by "Can-Do," which, when taken too far, can create a reluctance to say that something cannot be done."

Values are statements supporting a *preferred* way of action; but basic assumptions are unspoken, usually unconscious, and are often so strongly held that no one in the group can even conceive of actions incongruent with the assumptions. This is why culture exerts such power over the members of the group – *the basic assumptions of our culture define for us what we must pay attention to, what the things we experience mean, what our emotional reactions to experiences are, and what actions to take in various situations.*

**Cultural imperatives and personal risk**

Any situation that presents us with conflict to our basic assumptions disrupts our cognitive stability and fills us with incredible anxiety – not only as individuals, but also as a cultural group. Schein writes, "Rather than tolerating such anxiety levels we tend to want to perceive the events around us as congruent with our assumptions, even if that means distorting, denying, projecting, or in other ways falsifying to ourselves what may be going on around us."

In a similar way, Cynthia Cooper describes the imbalance created when events push us to act in ways contrary to our basic cultural assumptions: "Systemically, we know there's always a line of equilibrium. That's the norm, what the society has agreed upon as its norm. When a person goes against that, there's always anxiety, there's a countermove inside them to restore that norm."

Dr. Edmund J. Bourne, former Director of the Anxiety Treatment Center in San Jose, California writes that we experience anxiety when cognitive equilibrium is disturbed: "...the lack of consistent, externally sanctioned standards and values leaves a vacuum in which people are left to fend for themselves. Faced with a barrage of inconsistent worldviews and standards...people are having to cope with the responsibility of creating their own meaning and moral order."

Can anxiety about violating the unspoken cultural imperatives of an organization really have that much affect on behavior of its workers? Clearly it

can, and frequently does, because we act on basic assumptions automatically, as we push away from what we sense as counter-cultural behavior to relieve our anxiety.

The CAIB report tells us about NASA culture and behavior: "Interviews with workers provided insight into how this situation occurred. They noted that people who work at NASA have the legendary can-do attitude, which contributes to the agency's successes. But it can also cause problems. When workers are asked to find days of margin, they work furiously to do so and are praised for each extra day they find. But those same people (and this same culture) have difficulty admitting that something 'can't' or 'shouldn't' be done, that the margin has been cut too much, or that resources are being stretched too thin. No one at NASA wants to be the one to stand up and say, 'We can't make that date.'"

The CAIB report goes on to describe conflict between espoused values and basic assumptions: "A number of changes to the Space Shuttle Program structure… had the unintended effect of perpetuating dangerous aspects of pre-Challenger culture and continued the patter or normalizing things that were not supposed to happen. At the same time that NASA leaders were emphasizing the importance of safety, their personnel cutbacks sent other signals. Streamlining and downsizing, which scarcely go unnoticed by employees, convey a message that efficiency is an important goal. Working evening and weekends just to meet the International Space Station Node 2 deadline sent a signal to employees that schedule is important. When pared with the "faster, better, cheaper" NASA motto of the 1990s and cuts that dramatically decreased safety personnel, efficiency becomes a strong signal and safety a weak one. This kind of doublespeak by top administrators affects people's decisions and actions without them even realizing it."

In summary, if a cultural imperative like "Can-Do" becomes singularly focused on schedule, people begin to feel anxiety when considering actions that threaten schedule. When rewards and recognition follow schedule maintenance, we clearly recognize the message our leaders are sending us. We can literally desensitize ourselves to certain mission risks because our attention is on the cultural necessity.

## 3. Culture and the Human Factors

I mentioned sorting out four types of human factors that seemed to relate strongly and consistently to mission success:

1. Adherence to processes and principles
2. Definition and fulfillment of roles, responsibilities, and relationships for organizations and individuals
3. Individual success factors
4. Communication among project components

I would like to revisit these human factors to consider cultural imperatives that might be related to each of them, and might underlie behaviors that can either create or mitigate risks. When possible, I'll also revisit examples of missions that may have been affected by each factor; there may be new examples for some of them, too.

### Factor 1–Principles and processes

I have described principles as values – whether they are just espoused values, or basic assumptions of the culture, depends on whether they actually work in the organization over time. When they do work, principles are not imposed rules, they are part of the cultural heritage, they are "the way we do things around here."

I have described processes as linked activities that input resources and output a product. Procedures are the activities they link, that accomplish specific parts of the work step-by-step. Complex work processes in the aeronautics and space industries are constantly studied, documented, optimized, re-engineered, standardized, and trained. If processes are actually *followed,* they can have influence on mission success – and when they are not followed, they can have a large influence on mishaps. The U. S. Air Force

implemented its policy on Operational Safety, Suitability, and Effectiveness (OSS&E) based on flight mission mishaps related to "performance not aligned with appropriate processes and practices." A B1 bomber mishap was traced to a flawed design in which best design practices were not consistently followed. The crash of a C-21 commercial Lear jet, with the Acting Secretary of the Air Force on board, was traced to the flight crew not following the latest technical procedure for correcting a fuel imbalance problem. Some space program examples follow:

*Anomaly Reporting* – Almost every engineering organization, in almost every industry, has a process for reporting product anomalies. In its "Report on Project Management in NASA," the Mars Climate Orbiter Mishap Investigation Board identified a "lack of discipline in reporting problems and insufficient follow-up" in the MCO mission." They reported: "This was at the heart of the mission's navigation mishap. If discipline in the problem reporting and follow-up process had been in place, the operations navigation team or the spacecraft team may have identified the navigation discrepancies, using the Incident, Surprise, Anomaly process, and the team would have made sure those discrepancies were resolved."

What cultural imperatives might prevent serious, competent engineers from reporting a problem in this way? We know that there are organizations where messengers are usually shot after delivering bad news, and employees avoid bringing notice to problems. We have already discussed how a "Can-Do" culture might produce hesitancy to bring bad news, for fear of ridicule or scorn (just a different version of being shot). But shooting messengers and shouting down warnings are behaviors, both cultural artifacts – there must be values and basic cultural assumptions that created these behaviors and support them.

So, what if NASA had a basic cultural assumption that intellectual competence and capability are the most valuable characteristics of individuals? What if JPL, a division of a renowned university, had the same real values? In organizations with such a cultural assumption, project team members would find it difficult to bring reports of trouble to their managements, especially if the trouble were within their own areas of expertise. They would never consciously think about it, but they would believe that seeking such help would make them appear incapable. They would probably never think or speak about this assumption, but even considering behavior that violated it would bring them great anxiety.

(A note from a Systems Program Office Director at the U. S. Air Force Space and Missile Systems Center: contractor companies are very reluctant to call attention to anomalies *in writing* except in the direst circumstances. "Government agencies are used to documenting every smallest discrepancy as a part of C.Y.A. [protective behavior, known as Cover Your Assets]. Contractors want to talk about a problem and discuss it from all sides before they write it down and invoke a formal resolution process – which would involve their management right away.")

**Factor 2–Roles, Responsibilities, Relationships**

*Project-Line Interaction* – The MCO mission was lost in 1999, during the maneuver that should have inserted it into orbit around Mars, and JPL's Special Review Board investigated and reported on the loss of the mission. They found an error in the software program that generated the Angular Momentum Desaturation (AMD) files. The Board also reported that there had been "insufficient interaction between the MCO project and the line organization" and therefore the error was not found in time to save the mission. Their report said: "A timely involvement of experienced navigation experts would have revealed the small forces inconsistency or, failing that, should have led to an appropriate characterization of the targeting uncertainty."

In matrix enterprises (like JPL and many, many aerospace companies) the line organizations are responsible for keeping long-term, comprehensive functional and discipline knowledge – they are the

logical place for programs or projects to get technical help with development or operations anomalies. Let's set aside the competency and capability imperatives of the NASA and JPL culture we discussed earlier, for just a moment. Instead, let's consider the cultural imperatives of the "faster, better, cheaper" mandate during the period both MCO and the Mars Polar Lander (MPL) projects were conducted.

Whether at a for-profit company or a non-profit federal laboratory, consulting the line on technical matters costs money. JPL's Special Review Board investigating the losses of MPL MCO missions found that the combined cost of both missions, including the launch vehicles, was approximately the same as the development cost of the Mars Pathfinder mission in the mid-1990's. Even though the complexity and technical challenges for MPL were "at least as great, if not greater [than Pathfinder]," JPL managed MPL and MCO project with small teams to maintain the cost caps. The Board reported, "There was essentially no JPL line management involvement or visibility into the project," and "minimal involvement by JPL technical experts."

Could two distinct cultural imperatives – personal capability and project cost management – have been working simultaneously to keep the project from involving the line organizations in resolving discrepancies?

*Project-Contractor Interaction* – Before leaving this factor, let's consider one more example of role and relationship, the relationship with contractor companies who work at developing missions and programs. A contractor company may look like just another version of a line organization. But James Clawson, who was Mission Assurance Manager for the Mars Pathfinder project, points out that the cultural imperatives of a government organization (either military or civil) are different from those of a commercial company.

After a series of Titan and Delta launch vehicle mishaps in 1998 and 1999, the U.S. Air Force conducted a Broad Area Review (BAR) to identify and recommend measures of prevention to the Secretary of the Air Force. One of the BAR's strongest recommendations was for the Air Force, the Aerospace Corporation, and the various rocket contractors to *share Lessons Learned across programs and across contractor companies.* This was intensely controversial to the companies, who already shared a basic cultural assumption that giving information to competitors would surely disadvantage your own company. The Systems Program Office and the Aerospace Corp. assigned a consulting team to develop the formal process for sharing, and facilitated assimilation of the principle. Although the practice remains controversial after three years, it is beginning to move from being an *espoused value* to being a *basic assumption* due to its affect on the success of the companies involved and their military customer – as of December 2003, there have been no further launch vehicle failures, even on first launches of the Evolved Expendable Launch Vehicles, Atlas V and Delta IV.

**Factor 3–Individual success factors**

Individual success factors contribute to individual capability to complete the work successfully. Workers have control or influence over some of these factors (self-improvement and learning, for example); while organizational management has control over others (workload, assignments, and hygiene factors, for instance). Organizational culture influences which are considered most important, and who has control over them.

*Health, Safety, and Workload* – The NIAT report "Health and Safety" section describes increased demands placed on employees, and the "significant stresses on physical and psychological health" which have caused an "increase in the potential for safety-related errors." The report explains, "The greatest factor contributing to this stress is not having enough people with the proper skills, combined with an increase in workload. The basic nature of the work of NASA – high visibility and high risk – can create stress that is further compounded by short deadlines, increasing

hours, and fatigue. Stressful situations at work exact an emotional, physical, and productivity toll on the performance of NASA's employees and organizations. They also create the potential for safety-related errors."

The Review Board for the MPL loss identified a similar issue, pointing out the danger of "single-string" project assignments. It recommended that JPL "Revise institutional policies and procedures as necessary to preclude personnel working excessive overtime..." Norm Haynes, formerly Manager of the Mars Exploration Program at JPL, described a cultural conflict affecting JPL employees: "They have a powerful character of perfectionism and perseverance, which may make for Lab success, but sometimes not for mission success. Stress comes from an inability to predict or control what's going to result from your work, from deadlines and milestones that cannot be stretched in planetary missions. Frustration comes from not being able to do the work the way JPL perfectionists want to do it; they can't keep up with the demands on their energy."

*Capability and Competence* – The NIAT report includes a section on workforce development, which recognized that "the increase in projects accompanied by a reduction in experienced practitioners demands greater attention to the process of developing and supporting the workforce."

Both NASA and the military traditionally have strong programs for personnel development, and both have considered certification processes for selection into key project leadership positions. NASA's project management instructions, NPG 7120.5B, include a chapter of expectations about management and development of the people who work on projects. NASA mandates at least 40 hours of training for all project personnel each year, and encourages at least twice that much. NASA training courses on engineering and project management subjects are almost legendary, and are attended frequently by personnel in many other agencies. The Air Force typically provides over three weeks of training per year to personnel moving toward program management positions, and various types of training and education are recommended as rewards for good work on Officer Performance Reviews, the Air Force annual evaluation of personnel performance. What cultural foundation supports these practices, clearly demonstrating the value the organizations place on education and training?

I have already suggested that NASA may have a cultural imperative of intellectual competence as the most valuable individual characteristic. There are other artifacts of NASA culture that support this idea. NASA has a large percentage of employees with advanced degrees, at all levels in the organization, including several Associate Administrators with doctorates. At JPL, two thirds of the employees have advanced degrees, and one third hold doctorates. Also at JPL, there is a measurable general perception that promotions to management positions are primarily based on personal level of expertise in a technical area – interviews show that both line and programmatic managers hold this perception. Administrative, interpersonal, management and leadership skills are considered important, but secondary (though they rate higher among programmatic managers.) The basic assumption is perpetuated in the culture, since managers who advance in the organization select replacements for themselves using the same set of criteria.

Do the same values prevail among the military space professionals? I have discussed the issue with some Air Force program office personnel, including program directors; with consultants from the Aerospace Corporation; and with management professor Peter Senge from the Sloan School at the Massachusetts Institute of Technology. It's anecdotal evidence only, but there seems to be a different focus for military promotion, especially into the higher ranks, and into senior program management positions. Military training courses have a very strong focus on administrative and leadership skills. Air Force personnel who hold advanced degrees in Business and Management, and who have experience in leading operational elements in their service, seem

most often selected to run programs and program elements. The unspoken assumption here seems to be that if you want to lead a program, you need to have practice leading an operational unit in the field somewhere. (The Aerospace Corporation, a Federally Funded Research and Development Center for the Air Force, presents a cultural view that looks very much like NASA and JPL with respect to the value of intellectual competence. Nearly all Aerospace employees have advanced degrees, usually in technical fields; and in parallel with academic cultural imperatives found at NASA and JPL, they are encouraged to publish research papers in technical journals and at conferences like this one…)

**Factor 4–Communication**

The NIAT report emphasized communication as an essential component of mission assurance: "The essential knowledge for success is embedded in the systems and processes used within the Agency and the skills of NASA employees and partners. This knowledge is what makes NASA uniquely capable. It is not easy to capture and share information and key lessons across the Agency. To succeed, NASA must sustain an open learning environment that is facilitated through an effective communications process."

*Team-to-Team Communication* – JPL's Special Review Board for the MCO loss found that lack of team-to-team communication was a major factor in the mission failure. They observed that the problem during flight could have been resolved with better communication among the navigation team, the spacecraft team, project management, and line management. The Board recommended that future projects emphasize *knowledge sharing* and team-to-team communication, through *cross-team* orientation seminars and training sessions. The report described trust as an important enabler to communication: "Team members must feel free to express concerns without fear and openly communicate potential risks and issues... Barriers that can inhibit effective communication, such as… organizational and cultural barriers, fear, and lack of trust, must be minimized."

Is this a cultural inconsistency, when members of an organization that values knowledge don't share knowledge about their disciplines with each other? I have participated in workshops with the leaders of NASA's Knowledge Management Program, representatives from every center, and all complain about one cultural proclivity more than any other – the tendency of individuals to hoard knowledge rather than to share it. I suggest that knowledge hoarding behavior might be a common cultural artifact wherever individual knowledge is valued more than any other personal characteristic. The knowledge an individual possesses without sharing could be the knowledge that leads to that person's career advancement. The NIAT report espouses team behaviors, but does the culture support those behaviors over individual competence?

## 4. Changing Culture

NASA has established a disciplined, defined risk management process, which requires all projects to develop a risk management plan, and present their critical risk list for review. When new risks arise, they are to be included into the risk management process and reviewed by the Governing Program Management Council. The Air Force Space and Missile Systems Center (SMC) has established an Independent Readiness Review Team to examine and conduct risk reduction reviews on all missions launched by SMC program offices.

There are clearly human factors that create project schedule, budget, and performance risk; and these factors should be included in every project and program risk management plan. They should be mitigated with as much enthusiasm and integrity as technical risks are, until they are either retired or accepted. *The fact that this doesn't happen very often is itself an artifact of the "Can-Do" culture.*

Does this mean the "Can-Do" culture has to go? If so, how many positive, exciting, and inspiring parts of the national space program would go with it? Anyway, isn't changing a culture a long and arduous process? Could a large government agency really do it? How?

**Paying attention to culture**

The May 26, 2003 issue of *Aviation Week* magazine reported, "The Mars Exploration Rovers are complex spacecraft developed under a tight schedule, a classic recipe for disaster." The risk was demonstrated through a technique developed by Aerospace Corporation, in which complexity and schedule are compared – historical failed missions tended to be high in complexity index and short in development time. MER was found to be nearly as complex as Cassini and Galileo spacecraft, but had much less development time in its project schedule. The article reported that program and project management understood the cultural push: "Knowing there would be pressure to cut corners if the schedule proved too tight, the project and JPL top management signed onto a list of tests that must be passed before launch approval is granted. Changes must be OK'd by laboratory management." Naturally, the agreed testing would add work time to an already belabored workforce, and would certainly invoke the "Can-Do" cultural attitude among the project team.

During the month prior to the completion of this paper, both Mars Exploration Rovers landed successfully on Mars, and began sending back data. The first rover, *Spirit,* developed a computer glitch during its first ten days on the planet, and was unable to communicate properly with mission operations at NASA. The project team worked constantly for four days from the time the problem developed, and had identified a workable solution by the time the second rover, *Opportunity,* landed. The "Can-Do" culture had been invoked again; and it was witnessed by a media corps who were able to report a mission success to the world.

The point is, sometimes cultural imperatives are very useful, valuable, and help maintain the esteem of the outside world for the organization – at the same time they work to create internal agony. It may be that certain imperatives or basic assumptions should change, while some should remain but be directed toward producing different behaviors or other cultural artifacts.

Edgar Schein writes, "Cultural assumptions evolve around all aspects of a group's relationship to its external environment." This means changes in culture will be created by environmental changes. It also means that deliberate changes in culture can only be created by deliberate changes in how the group interacts with its environment.

We have to remember that cultural imperatives, basic assumptions, are only derived from espoused values that *always work in the real world.* The model of cultural change I have used to illustrate this concept is the biblical story of Moses leading the Israelites out of Egyptian slavery. According to the story, they wandered through wilderness for 40 years, before arriving at Canaan – which they then had to coerce from its current occupants.

If you look at a map of the Middle East, you will immediately notice that it would not take 40 years to go from Egypt to Israel, even if you walked. Why the delay? The population who had lived their lives with the cultural imperatives of slavery died out, and the members of the group who had grown up with the cultural imperatives of freedom took their places, rising to positions of leadership. Only the change in environment could make the change in basic assumptions that are the essence of culture, and the drivers of behavior. (The change did not affect all aspects of Israelite culture. Religion and ethical values, for example, survived the long hike, partly because the change in environment did not make these systems unworkable, and partly because the leadership continued to support and espouse these values.)

If organizational leaders create focused change in the way the group must conduct itself to be

successful, they have a good chance of creating new cultural imperatives. *The leadership must articulate the changes they want, though, as value guidance to the group.* The risks that cause the most anxiety are the ones that receive the most attention from organizational leadership – and they are the ones that will be addressed with the most fervor by the group, because these are the risks that are aligned with the strongest cultural imperatives.

**How leaders help make culture**

Schein writes "[Leaders] choose group members, and bias the original responses the group makes in its efforts to succeed in its environment and to integrate itself." In this way, leaders affect which espoused values become effective, and eventually become cultural assumptions. Leaders also choose the second generation of leaders, and in that way help to continue the shared values they originally espoused and articulated.

Schein also points out that leaders determine the socialization processes of the group, and use these social mechanisms to communicate their espoused values consciously. He describes what he calls "culture-embedding mechanisms," as methods that leaders use to impress cultural assumptions, either deliberately or unconsciously.

Heading a list of primary embedding mechanisms, Schein places "What leaders pay attention to, measure, and control on a regular basis." In any human social dynamic, *attention* is the currency of interpersonal transactions. Leaders are the models of social interaction in the group, and what they pay attention to tells the group what is valuable to the social order. For example, if project leaders consult with line management frequently and publicly, asking for reviews of decisions, then project team members will do the same with their line counterparts. If project managers go through the project risk list at the weekly project staff meeting, expecting to find more risks retired each time, project team members will make a lot of effort to identify and mitigate project risks.

Another embedding mechanism on Schein's list is: "Observed criteria by which leaders allocate scarce resources." All resources – time, money, facilities, etc. – are budgeted before being used. How budgets are created in the organization demonstrates the basic assumptions of the leaders, and influences the assumptions and behavior of everyone in the group. The June 2, 2003 issue of *Aviation Week* magazine reported that Adm. (ret.) Harold W. Gehman, Chairman of the CAIB, questioned the structure of the Space Flight Operations Contract with Shuttle operators United Space Alliance. "The board is trying to determine whether the SFOC is structured correctly to 'reward the kind of behavior that you want' and not inadvertently reward the wrong kind. If you have a contract for which you can get paid bonuses for an on-time launch, that itself installs a 'certain kind of performance' among contractors. If you are going to get paid bonuses for launching on time, then how many bonuses do you get for slowing a launch down for safety?"

Other mechanisms by which leaders embed cultural imperatives include:

- "How leaders react to critical incidents and organizational crises."
- "Observed criteria by which leaders allocate rewards and status."
- Observed criteria by which leaders recruit, select, promote, retire, and excommunicate organization members."

A note: Schein finds methods such as organization structure, and formal statements of philosophy and values, as secondary mechanisms – reinforcement, but not primary embedding methods.

As we become more aware of the role culture plays in our organizational and personal actions, we will be better able to address the human factors in mission assurance, and make them work for us toward mission success.

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