Lecture Text

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Organizational Learning in the Face of Ambiguous Threats

(*edited for clarity*)

Introduction

PROFESSOR MICHAEL ROBERTO: Welcome back to HBS. It's good to see you here this morning. The first thing I'd like to do is introduce two colleagues who are also going to present with me this morning. The first is Amy Edmondson, and the second is Richard Bohmer. Over the past year, we have been studying the *Columbia* space shuttle disaster, which took place in early 2003. This disaster has been particularly interesting to us because of many of the organizational dynamics that were going on within NASA that contributed to the disaster. And that's what we'd like to talk to you about today.

After the accident, there was an investigation board named, called the *Columbia* Accident Investigation Board (CAIB), and they really did an outstanding job of analyzing this incident—one of the best investigation reports that I've ever seen. Brigadier General Duane Deal was a member of that board, and he summarized their findings in this simple phrase: "The foam did it; the institution allowed it."

The foam did it because the reason the space shuttle crashed was that foam dislodged from the shuttle during launch and struck the leading edge of the wing. And that foam strike punctured a hole in the leading edge of the wing. And upon reentry into the earth's atmosphere, hot gases were able to get inside the internal structure of the shuttle, and cause it to, essentially, disintegrate, coming back into the earth's atmosphere.

So the foam was the technical cause of the accident. But, in fact, when these kinds of things happen, we really want to push beyond that—beyond the widget, the technical thing that caused the problem—and look to the organizational causes. What allowed them not to understand and fix this problem, even though, it turns out, foam had been striking every shuttle, nearly every shuttle, since the beginning of the program in the early 1980s? So why is it that—knowing that foam had continued to strike the shuttle—for some reason, they had not been able to prevent or fix this problem, and they hadn't reacted in a different way during this shuttle mission when they discovered, on Day Two, in fact, that foam had struck once again during launch?

So what is it about the organization that contributed to this? How did the institution allow this accident to occur? And that's what we'd like to talk to you about this morning.

Lessons Learned From *Columbia*

Let me, before we dive in to all the details, give you a broad overview of what the lessons are from this incident and how they apply to management in all types of organizations.

Ambiguous threats

First, we want to point out that all organizations face ambiguous threats, at times. The foam striking the shuttle is somewhat of an ambiguous threat. Why is that? It's because we don't know, when we see the foam strike, whether it actually punctured a hole or not; whether

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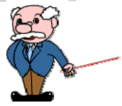

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that's a threat to the integrity of the vehicle or not; whether it will cause an accident. It's an ambiguous signal, an ambiguous threat.

And all organizations face those at times: Firestone, several years ago; Johnson & Johnson, the Tylenol incident, of course, reacting in a different way, twenty years ago, when that incident happened—more aggressively, more vigorously addressing the ambiguous threat.

The recovery window
The idea is that with those threats comes a finite opportunity for recovery, before a major failure or accident occurs. This is something we call the recovery window: some finite period of time in which you see an ambiguous threat, and you have some time before that threat turns into a major accident.

Organizations underreact
Unfortunately, our hypothesis, our theory we want to put forth this morning, is that organizations of all kinds are predisposed to underreact to ambiguous threats, as NASA did in this case. And so, we have two questions. One is, why do organizations downplay these threats? And two, how can organizations respond and recover more effectively?

And I've given you some examples of safety incidents—Merck, Firestone, Johnson & Johnson, NASA. But this also pertains to competitive threats, if you think back to the early 1970s, and how the big three automakers reacted to early signs of the Japanese imports making inroads in the US market. And there are ample examples of how they downplayed that somewhat ambiguous threat to their competitive position numerous times throughout the '70s, and into the '80s, in fact.

And so, why is it that organizations seem to naturally do that, and how could they respond differently?

So the concept, then, is that there is this period of time between an ambiguous threat and an accident, or prevented accident, during which preventive action is feasible. We've labeled that the recovery window. And we're going to spend our time now, in the next hour, looking at the recovery window at NASA, from the time the foam struck the shuttle, or they discovered that foam had struck it, to the accident that occurred about two weeks later. And we want to understand what was going on at NASA in those two weeks. And then we'll talk later about how they might have behaved differently.

Columbia's **Recovery Window**
Let's just go through the timeline.

Launch day
January 16, 2003: Foam strikes the shuttle during launch. A day later, a group that looked at photos of the launch discovers the foam strike. They see it dislodging on the photo. It's a very hazy, difficult-to-discern photo, but they can see that something dislodges, looks like foam. It's foam insulation that's used on the tanks. And that, in fact, it is striking somewhere on the wing, although they're not exactly clear if it's the leading edge, or if it struck some of the tiles that are underneath the wing. That's hard to discern.

So this is the ambiguous threat that occurs. And, of course, two weeks later, on February 1, the shuttle tries to reenter the earth's atmosphere to land in Florida, and it breaks up upon reentry. That's the major accident. So it's the period between discovering the ambiguous threat and the accident that we're labeling the recovery window. Let me give you a bit more detail about what happened during that recovery window. So launch. The foam strike actually happens eighty-two seconds into ascent—very, very early on during the launch.

Flight Day One

And on Flight Day One, which is the day after launch, the Mission Management Team learns about the foam strike. The Mission Management Team is the group responsible for, essentially, running this mission. It is lead by a middle manager, in this case, named Linda Hamm. You may have heard of her. She was responsible for overseeing this group of other managers, and engineers, and technicians, who were going to monitor this mission.

And they were responsible if any anomalies, any issues arose to resolve those during the flight. They learn about it very early on. But senior managers, both on the team and outside of the team, affirm a longstanding belief within NASA that is that foam strikes are, in fact, not dangerous: They are not a safety-of-flight risk.

This is a longstanding belief within NASA. Remember, foam has been hitting the shuttle for, at this point, twenty years. And, in fact, not only that, they know that it's doing damage to the shuttle. Because when it returns—they of course inspect the outside, and they see damage to the tiles, damage to the wings, damage they don't consider serious enough to imperil the vehicle. But, in fact, they've seen the damage. They know it happens over time.

And part of the story here is that, over time, this went from being unexpected, to expected, to accepted. That's the way sociologist Diane Vaughan, who studied NASA for two decades, describes what happening here. We're going from the unexpected, to the expected, to the accepted. And that's what's going on. This longstanding belief has made this a very accepted thing by now. So they consider it not dangerous, and they reaffirm that belief very early on after hearing about it.

Concerned engineers, however, form something called the Debris Assessment Team (DAT). They are a bit more concerned than the senior managers, and they decide to form a group, an ad hoc group, and to investigate a bit. And they and others begin to make requests for additional imagery: "We need better photos to understand how big was this piece of foam, how much of an impact did it have and, very importantly, where did it hit the shuttle?" Where matters. If it hits the tiles that are underneath the wing, that's much less dangerous than if it hits the leading edge, which is a different kind of material and a much more perilous point on the shuttle at which damage could occur.

And so they ask for more imagery. In fact, many people do. There are three requests for additional imagery that happen, the first of which happens on Day One.

Flight Day Five

On Day Five, the Mission Management Team has an important meeting at which its leader, Linda Hamm, says, "The foam strike is not really a factor because there's not much we can do about it." Meaning, even if, in fact, it did puncture the leading edge and create a sizeable hole, we can't help these people. And this isn't just her view, this is actually a view that's fairly prevalent among people at NASA. It turns out it is rather difficult to go save these folks, although not impossible.

Flight Day Six
Flight Day Six: The imagery requests are cancelled. They never even took additional photos to investigate. Never mind trying to save the astronauts. They didn't even take additional photos. What's going on? We're going to try to explain that today.

Flight Day Eight
Flight Day Eight. Without imagery, the Debris Assessment Team—these engineers who are, by the way, both from NASA and Boeing, who's just one of the contractors—they rely on computer models for analysis; very imperfect computer models, by the way. And they understand that but, without images, that's all they can do. Well, they can't prove the strike is unsafe. And we'll talk more about why the burden of proof was: "Prove it's unsafe," as opposed to "Prove it's safe."

They couldn't prove it was unsafe, and so they had to conclude that there was no safety-of-flight risk. Now, importantly, there's a lot of uncertainty in that conclusion. But their findings were summarized by a midlevel manager who was not a member of their team, who went to the very senior Mission Management Team and told them, "Hey, the engineers analyzed this. No safety-of-flight risk."

No discussion of, "Well, what were their assumptions in the analysis? How good are those computer models? What uncertainty is there in that analysis?" They don't really dig to that level of detail in the discussion during the meeting.

Flight Day Sixteen
And, of course, eight days later, *Columbia* burns up upon reentry. And we're going to talk about what's going on in this chain of events: Why no imagery? Why does the team handle this discussion as they do? What's going on here?

Downplaying Ambiguous Threats
OK. Downplaying ambiguous threats. The key idea here is that we're saying that organizations are predisposed to underrespond. What does that mean? What do we mean, "Underrespond to ambiguous threats?"

Characteristics of underresponsiveness
Well, that is to say, there's active discounting of risk, and we saw that at NASA. It's not just that they chose not to pursue more analysis. They were actively discounting the risk and discouraging people from doing more analysis.

There is a fragmented, largely discipline-based analysis. What do we mean by that? We mean there isn't a coherent, centralized, coordinated effort to go look into the foam strike. Instead, we have various groups, ad hoc, in different parts of the organization, in different parts of the country, looking at this in their spare time, on an informal basis.

And they're discipline-based groups. It's not a cross-functional, cross-disciplinary team. It's a set of engineers, who all have similar technological experience, who happen to be drawn in because of their interest in foam as an issue. Pamela?

__: Can I ask a question? Was this the only thing that went wrong?

PROFESSOR ROBERTO: During the mission?

__: During the mission.

PROFESSOR ROBERTO: No, of course not. Things do go wrong.

__: So this is the one that got them.

PROFESSOR ROBERTO: This is the one that got them. It turns out, interestingly, that this is not the first time that a longstanding ambiguous threat that had been around a while caused a shuttle to disintegrate, or to encounter a problem. *Challenger*, in fact, follows this exact same pattern. That is to say, the O-ring problem was known for some time, and had been happening, and it was downplayed. And, of course, it led to the *Challenger* explosion.

So here on this mission, there are other things that happened. The interesting thing about foam is, it's not just a problem that arose on January 17, 2003. It, like the O-rings, happens to be a particular kind of ambiguous threat, one that had been around a while. And that's what makes it so interesting. If it was just a signal that all of a sudden arose, we might have a different take on it.

The last piece is this "wait-and-see" orientation to action, which is to say, there was not an active attempt to go out and do some things to actually investigate—run some experiments, and the like. Instead, there was sort of "wait and see." It was, "Let's wait for the shuttle to return. Then we'll take it and do lots of analysis based on the amount of damage we assessed when it returns—this wait-and-see orientation.

So these are the characteristics of what we call underresponse to an ambiguous threat. And we'll talk about what the alternative to that would be in a bit.

Now, there's one take on this that said, "Look, that underresponse is irresponsible and incompetent management. It's just incompetence. You knew about the foam strikes for twenty years, and you totally discount them. You don't do any analysis, you deny imagery requests. This is just incompetent management that should be fired."

We're not taking a position on that. We're not absolving these people of individual accountability. We're not condoning their behavior, nor are we condemning their behavior. We're just saying there's more to it than individual malfeasance. We think there's more to it. We think there's an organizational predisposition to downplay ambiguous threats; that this is a natural pattern of behavior. We've seen it in many different organizations now. So we think there's more to it than just personal malfeasance.

Factors causing underresponse
So what is this natural underresponse? Why does it happen? What causes it? We think it's caused by factors at three levels: factors that go on in the human brain, that are at the human cognition level; factors at the team level: How are teams organized and led in organizations?; and then, broader organizational forces regarding the structure and the culture at NASA, or at any organization.

Three Levels of Analysis
And we want to talk you through those three levels of analysis. I'll take you through cognition. My colleague Richard Bohmer is going to take you through the team level and the organizational level, and help explain why there was this underresponse. And then, Amy Edmondson is going to take you through a discussion of how might they have responded

differently. What's an alternative way of responding to ambiguous threats that's more effective? And, interestingly, we will use as an example another case of a threat at NASA to help us talk about that issue.

So what do we mean by these three levels of analysis?

The cognitive level
Well, first, at the cognitive level, it turns out there are two things going on in the minds of people at NASA that are not unique to the individuals at NASA, but that go on in all of our minds that contribute to downplaying ambiguous threats.

First, we all hold certain biases in the way we make judgments. They're natural, they happen to all people—experts, novices, people of all ages, in all fields—and they're shaping the actions of decision makers here. And the second is, we all frame problems, we all frame issues.

We'll talk about what a "frame" means. It's around how we define issues. And how we define problems and issues affects, then, the solutions we come up with, the answers we get to. And so that's also going on. It affects how we organize the way we work, and we'll see that as well. So at the cognitive level, there are things going on that cause people to downplay these threats.

The group level
At the group level, the way you design teams, and the climate in which they operate, affects how effective those teams are at investigating and examining ambiguous threats. And we'll look at the problems in team design and team climate at NASA. And we'll show, and we'll give you examples, and help you understand how those problems happen in all kinds of organizations and contribute to these problems.

The organization level
And lastly, issues of structure and culture, which contribute to the downplaying of ambiguous threats, to underresponse. Again, we'll give you examples from NASA. We'll just see that many of these patterns—structural complexity, cultural issues—happen in many kinds of organizations. So NASA's not unique here. Obviously, the consequences are more catastrophic than in many other organizations, but they're not unique.

So with that, let's make one final point, which is that these levels of analysis are not alternative explanations of the tragedy, but they work together. Culture affects how teams work, it affects how people think, and the like, and so these are related. And we'll talk about that as we go on.

Cognition
With that, that's dive into cognition.

Cognitive biases
What do we mean by cognitive biases? It turns out that the way our minds naturally tend to work causes us to downplay ambiguous threats. This is sort of a scary thing, right? That in fact, we're hardwired to downplay ambiguous threats in all aspects of our lives. And psychologists have been showing this now for many, many years.

Let me talk you through some of those biases. The first and most important, here, is the tendency to rely on information that confirms existing views, while discounting evidence that disconfirms initial positions.

The other bias related to this is that, in fact, views tend to polarize. People looking at the same information often actually watch their views polarize over time, not come together, because people are relying on the information that confirms their existing view, and they're discounting information that is not consistent with their existing view.

And that's going on here. People have a longstanding belief at NASA: Foam is not dangerous. And every piece of information and data that they get during the mission gets interpreted through that lens. And that's natural. Turns out we all do it.

Why is that? Roberta Wohlstetter, who studied Pearl Harbor, and the fact that we downplayed the possible threat of Japan attacking us, said, interestingly, that individual political and military leaders had this stubborn attachment to existing beliefs—existing beliefs about people attacking the American homeland, about Japan's intentions, and the like.

And psychologist Daniel Goleman says, well, it goes beyond just the fact that some people are more stubborn than others. It's actually hardwired into the brain. The mind can protect itself against anxiety by dimming awareness. And so, ambiguous threats cause anxiety, right? The possibility that these astronauts could die is something we want to avoid in our minds. And that's going on.

So this happens. What are the consequences? Well, it turns out that, not only do we discount, but there's also this phenomenon of escalation of commitment. That is to say—if we've had this longstanding belief for a long period of time; if we've been embarked on this course of action for a long period of time that says we're going to keep sending shuttles up, even though we know foam is there—we become wedded to this prior course of action, even if the signs are that it may not be a prudent course of action. And not only do we continue with it, we escalate our commitment. We send more missions up, and at a faster rate. We escalate our commitment to failing courses of action. This is a tendency of all of us.

And we become more and more overconfident over time. Overconfidence, again, is a bias that affects all of us. The Lake Wobegon effect, right? We all think we're better than average.

Cognitive biases at NASA

How did this manifest itself at NASA? Well, before every mission, they do something called a Flight Readiness Review. This is a very important meeting where they go through all possible issues that could impair the safety of the astronauts and of a mission. And they have to resolve all of those before they can fly that mission.

Well, think about, if you are a manager, like shuttle program manager Ron Dittemore, or Mission Management Team leader Linda Hamm, or even the engineers. You've been in those meetings. You've been at those meetings where everyone publicly concludes that foam is not dangerous. You've taken a stand on that in front of all of your colleagues, perhaps. And now, how can you go against what you said publicly just a few weeks earlier, during the Flight Readiness Review?

So, in fact, by making this public commitment, by going through this analysis, by drawing a conclusion with all of your colleagues that foam is not dangerous, it's pretty hard, then, when given some evidence that maybe it is on this particular mission, to go against what you've just concluded publicly in a meeting.

Of course, each safe return of the shuttle confirms your initial hypothesis about foam. Every time the thing keeps coming back safe, and you look, and yes, foam dislodged, but it only caused a small, little hole, and that's not dangerous—and the hole has to be quite larger than that to be dangerous—you've got evidence, right, that confirms your existing view.

And the language system at NASA was very interesting. Over time, it made people more and more comfortable with this very dangerous condition. They had a word for something that they weren't expecting on a mission. It's called an "in-flight anomaly." An in-flight anomaly is something that you need to address and resolve, because it's potentially dangerous.

And, over time, they slid to something they called "out of family," meaning it's not something we've seen before, it's not something consistent with our specifications—it's out of family. But, of course, then slowly they kind of meandered to, "maybe it's in family," because now we've seen it for ten or fifteen years, and each one keeps coming back safely.

So we've gone from "it's an anomaly," when it first happened, to "it's out of family," meaning it's out of our experience base, to "oh, it's part of the family." And we'll hear from one of the members of the Accident Investigation Board about that slippery slide, from it's something totally unexpected to, as we said, the unexpected becomes the expected, becomes the accepted.

There's also the failure to see disconfirming data going on at NASA. Let me give you some examples. During the mission, management repeatedly sought the advice of an internal expert who confirmed their existing shared beliefs about foam. But, interestingly, he wasn't an expert on the material on the leading edge of the wing. He was an expert on the tiles underneath the wing, which is where most of the foam had hit, over the years.

And so, going to him—and they knew very well his very public view on foam—they went to him early and often to confirm their longstanding belief. Think about the dynamic that creates in the organization if a very prominent expert on the wing early and often reaffirms that existing belief.

Worse than that, it turns out they actually hadn't maintained the cameras that took pictures of the launch, over the years. So they wouldn't have had to request imagery, additional imagery, if they'd had well-working cameras, well-functioning cameras that were taking pictures of the launch. The additional imagery we're talking about would have had to come from the Department of Defense, from space satellites, from military satellites.

But they could have had better images from their own cameras. But, again, because they weren't out there looking for disconfirming data, they weren't even taking pictures. They had just let the cameras fall into disrepair. After all, the shuttle works. It's worked since '86—seventeen years of success—and so they hadn't maintained them.

Even worse, only one of the shuttles had a flight data recorder, like every airplane on earth has—only one, the first one. And after that, they said, "Jeez, well, we don't need one of these. This thing works." So they weren't out looking for any evidence, any issues, during flights. They were actually not looking for disconfirming information.

So we see the biases actually manifest themselves in their behavior, both in their attachment to existing beliefs and in their failure to look for disconfirming data. Let's actually hear from two members of the Accident Investigation Board about some of these issues. These people spent an enormous amount of time, over the course of a year, studying this incident. They are the world's experts on issues of safety and organizational catastrophes.

Sheila Widnall, whom we'll hear from, is a former secretary of the Air Force. She was a member of the Accident Investigation Board. She is an aeronautics professor at MIT. Roger Tetrault, long-time executive in the aerospace industry, also was on the board, and here's their take.

ROGER TETRAULT (video): As I mentioned, foam had been striking the bottom of the wing. And each time that it struck the bottom of the wing, or even the belly of the aircraft, and nothing bad happened, a confidence grew within the organization that it was an acceptable condition, even though it was a totally unacceptable condition from the perspective of the specifications that had been written, and the people who had designed the aircraft. But this confidence, unfounded confidence, grew.

PROFESSOR ROBERTO: So Tetrault told us, in an interview we conducted with him, just a few months ago. These are all, by the way, clips from interviews we conducted with the board members, on our own.

Here's Sheila Widnall.

DR. SHEILA WINDALL (video): Now, this whole question of "out of family"—that's a very casual term. I don't believe it has a precise technical meaning. And so, I think what I saw happening at NASA was NASA was sliding from a precise term of "anomaly," which should carry with it a very definite process—to resolve an anomaly before the next flight—to this more casual term. "Out of family," sort of means something we haven't seen before. It's not as well defined.

And, obviously, if you see it enough, it becomes part of the family. And I think that's a very dangerous slide. And I think, again, we were quite critical of the slide that NASA took from seeing "out-of-family" behavior, and becoming comfortable with it, and then treating it as if it were part of the family, which sounds very comfy and cozy, and everything will be OK, guys. That's a very dangerous attitude.

PROFESSOR ROBERTO: So that's Tetrault and Widnall talking about how these biases manifested themselves, how this confidence grew, and how they had begun to use language that made them feel more comfortable with this threat.

Shared cognitive frames
Let me shift from the biases in the human mind to talk to one other aspect of cognition, which is how we frame things, how we define things in our minds, and in our organizations. Cognitive frames. What are they, first of all? They're mental structures, tacit beliefs and assumptions, that simplify the world for us and guide our understanding of a complex reality. What do I mean by that? Let me give you a concrete example.

In the shuttle program's early years, it was framed using language and, in terms of the processes and procedures that they put in place, it was framed as a routine, operational entity, an operational process; not a developmental, experimental, high-risk endeavor. Why is that?

Well, as it turns out, it has to do with how they funded the program. To fund the program, to get funding from Congress and the president in the early 1970s, they actually had to advocate for this on a cost-benefit basis. That is, they would run enough flights so they could launch enough satellites and other "payloads," so they could generate enough revenue to cover the development cost of a shuttle.

To make that math work, they needed to fly fifty shuttle flights a year eventually. Well, when you now have made the argument that it's going to be fifty flights a year, and you call it "a shuttle," by the way, that's a very operational, production, routine view of the world; a routine frame, as opposed to a very developmental frame.

You saw that in a number of things that were said in the early years. Two wonderful examples: President Nixon, in 1972, on announcing the start of the program, said, "It will revolutionize transportation into near space by routinizing it." Look at the word: routinizing it. Right? Think about how risky space travel is. And we're using that language, right from the outset. And it all has to do with fifty flights a year.

And then, President Reagan, after the fourth successful shuttle mission, says, "*Columbia* and her sister ships will be fully operational with the next flight." With the fifth flight of this enormously complex piece of technology, it's going to be fully operational.

Let's hear from Tetrault and former shuttle astronaut Jim Bagian about this issue of being operational. Jim Bagian actually flew *Columbia* in the years before the disaster.

ROGER TETRAULT (video): There was an interest, if you will, for funding purposes, to sell the program, to some degree, on the basis that at least these things were, in fact, reusable, and that we were getting into a normal mode of operation. And even though we couldn't launch 100 a year, we could launch these things every two months or so. And that this was a fairly normal operation, as opposed to a "risky" operation.

There is nobody in the aircraft industry who builds a new plane who would say after 100 flights, or even fifty flights, that that plane was operational. In spite of that, the shuttle was declared as being an operational aircraft, if you will, after substantially less than 100 flights.

So I think the whole approach was that we want this thing to be perceived as being operational and not particularly risky. In fact, it is a risky endeavor. Space flight is a risky endeavor. And it is easy to try to underemphasize the riskiness of this in order to get funding.

PROFESSOR ROBERTO: That's a very important point: how they allocated resources for the program. The way they sold it to senior management, and then to Congress, and the president; the language they used, and the rationale they used, affected everything they did thirty years later, in how they operated the program.

It's a lesson. If you think about capital investment decisions that you make in your own organizations, how are the investments sold to senior management and the board? And how does that frame the way you're going to actually run and use that technology over time?

Here's Jim Bagian, a former astronaut.

JAMES BAGIAN (video): At that time, they were saying, when they sell to the Hill and to the public, that flying this shuttle will be like flying a 727 to Disney World. That was the party line. And John Young, the most senior astronaut in the astronaut office, used to laugh and say, "If flying a shuttle was like flying a 727 to Disney World, there wouldn't be anybody going to Disney World."

PROFESSOR ROBERTO: And yet, that was the party line. OK, so, my last comment, before I turn it over to Richard. What are the implications of framing something as operational, as a production technology, not as a developmental technology, as an experimental one?

Well, you become obsessed with schedules and deadlines. After all, that's what production environments have. They have lots of schedules and deadlines. Mind you, framing something as a production or operational technology is not a bad thing.

Some things in manufacturing, of course, are routine and should be treated with a frame that's operational and routine. The shuttle, we're arguing, should not have been framed in that way. It was inappropriate for this technology.

So you get schedules and deadlines that are appropriate on the plant floor if you're making widgets, but not necessarily as appropriate when you are running a shuttle. In fact, schedules were really an obsession at NASA. They had a screensaver on the computer of every manager at NASA with a countdown, right to the minute, to when the space station needed to be completed and, therefore, how many space shuttle missions had to go up in the next two years to do that. Imagine the pressure if, every day, you're staring at a screensaver that is clicking down, like a clock, by the minute, to when you need that space station completed. It's a fairly dramatic thing.

The belief that shuttle missions had become routine. You hear that in all the language, right? The focus on rigid rules and procedures. Richard will talk more about how rigid the procedures had become at NASA; how wedded they had become to following the procedure.

You see that in the imagery requests. Linda Hamm, it turns out, and other senior managers denied the request for imagery, not because they judged whether or not imagery was needed, but because they determined that the imagery requests had not followed official procedure. So they were obsessed with procedure the way you might be in a very routine production environment.

There's insufficient emphasis on the imperfect state of knowledge. And there's a lack of new data-gathering tests and experiments going on here. The chairman of the Investigation Board asked some old-time engineers at NASA about this whole imagery thing, and about the procedure for requesting additional imagery. Was it a bureaucratic procedure? Could that have inhibited them?

Should they change that procedure? And the old-time engineers told them, "Forget the procedure. You would have wanted those images on every flight. You should have wanted them on every flight, regardless of whether foam was hitting, because it's an experimental technology!" But by framing it in a production frame, you weren't looking to gather new data that might disconfirm your view of the world.

So those are the implications of framing something as very routine, when in fact it's not. But you can see that how they funded the program caused them to frame it this way, inappropriately.

OK, with that, we want to shift to understanding how these teams operated at NASA, both the Debris Assessment Team and the Mission Management Team. And Richard's going to take us through that.

Team-Level Factors

PROFESSOR RICHARD BOHMER: Thanks, Mike. So, as if there were not enough going on at the level of human cognition, there are factors at both the team and the organizational level that are very important and very significant in contributing to this tragedy.

Team design

And the first of these is the very design of the team, this Debris Assessment Team, the critical team that's responsible for assessing whether or not the piece of foam striking the wing at more than 500 miles an hour is actually a significant event.

You know, it's not simply sufficient to put a bunch of incredibly talented and highly expert engineers in a room, and expect that they will function as a team. A team is not a team simply because we label it as such. Teams need to be deliberately designed: groups of people with complementary skills, selected because of those skills, given a set of performance expectations, to which they themselves can hold themselves mutually accountable.

As Richard Hackman says, effective leaders set the stage for great team performances by creating the conditions that enable teams to work very well. They design teams for their purposes, and they create a climate within the team that allows the team to realize its goals.

So let's just think about the Debris Assessment Team from the point of a view of design. This was, in fact, an ad hoc team, brought together by a group of very concerned engineers. And they became labeled a Debris Assessment Team. Rodney Rocha, whom we'll hear from in a moment, was one of the key people who brought this team together.

But, in fact, they had a very poorly defined mission. They had a very poorly defined line of authority. They had no specifically assigned resources. They didn't have a budget. They didn't have status within the organization.

And, in fact, NASA had a protocol for bringing together teams to assess anomalies during flights. These were called Problem Resolution Teams, PRTs. Mike's already pointed out the importance of language. A Problem Resolution Team is a team that's brought together to assess a problem. Labeling this the Debris Assessment Team subtly says, "We don't actually think this is a problem. We're assessing the debris. We're not resolving a problem created by foam striking the wing."

Let's hear from Dr. Widnall again, as she gives us her take on this team.

DR. SHEILA WINDALL (video): A group of engineers was formed into something called the Debris Assessment Team. And they were given the responsibility to try to assess what had happened on launch and whether it was a serious problem. From my point of view, I thought their charter was very vague. It wasn't really clear who they reported to. It wasn't even clear who the chairman was.

Team climate
PROFESSOR BOHMER: Now, beyond the design of the team, there is the climate in which the team is operating, or the climate actually within the team, that facilitates and allows effective communication and effective problem solving within the team. And, perhaps most important of these, is an issue that Amy [Edmondson] has called "psychological safety." That's the shared belief that the workplace is safe for interpersonal risk taking.

Taking risks by yourself is easy. Learning to ride a bike, learning to do something new, where you, yourself, see potential failure in trying something, and nobody else does, is very different from a team of people where discussions of possible failure, discussions of error, are very public. And one needs an environment within the team to allow people to share unpopular information, to express the possibility that we might have made a mistake, to express the possibility that an error may pose imminent danger.

And this is a very special environment, and this team did not have it. This environment, an environment of psychological safety, enables learning, enables effective problem solving. It allows people to get wild ideas out on the table. It allows people to front up to the possibility that an error has been made, and move on to say, "Well, and then how can we do something about it?"

The interpersonal climate at NASA did not facilitate sharing bad news, expressing dissent, expressing the possibility of failure. And this, as we'll see a little later on, when we hear from Jim Bagian, is a fairly new development of NASA, because NASA was not always like that.

So here, Rodney Rocha, he's the coach of the team. Notice, by the way, that the Debris Assessment Team has got two chairs, one of whom is from NASA, and the other who is from an external contractor. So when Dr. Widnall talks about inadequate and unclear leadership, here's a very obvious example of it.

Rodney Rocha is the engineer who noticed and was in the team that first saw the debris strike at the wing, or strike somewhere in the wing area, on the seventeenth. And he did not speak up during the Mission Management Teams, the senior management teams that were overseeing the mission while it was in flight. He didn't speak up. He did not feel comfortable expressing the possibility that this foam strike was actually really significant and really dangerous. And he says, "I couldn't do it! I'm too low down, and she, the chair of the Mission Management Team, is too way up there."

Several engineers expressed the sense that they didn't feel empowered to speak up about what they thought might be going wrong with this mission. Later on, when the request for imagery was denied, Rodney Rocha actually wrote a really scathing e-mail, but he chose not to send it. He chose not to send his objection to that decision.

Jim Bagian has pointed out that this is a fairly new development at NASA. At the time of Gemini, and of Mercury, and the Apollo missions, the kind of heyday of NASA, there was much more willingness to seek out dissent, and tolerate dissent, and welcome dissent. And, really, in the last decade, NASA's culture has changed so that dissent's not tolerated. And as Jim says, if you wanted to survive in the organization, then you kept your mouth shut.

So we see this kind of climate played out in this exchange between one of the investigators of the *Columbia* Accident Investigation Board and the chairman of the Mission Management Team.

"As a manager, how did you seek out dissenting opinions?"

"Well, when I hear about them."

"But, by their very nature, you may not hear about them."

"Well, when somebody comes forward and tells me about them."

"But what techniques do you use to get them?"

And the Mission Management chair offered no response to this final question.

The point here is that passive leadership of a team is not sufficient to get you the kind of dissenting opinion that you might need in this moment in the recovery window, when you're trying to understand what's going on. Team leaders have got to go out and seek and invite dissent; ask people, "What's going wrong here?"

The Mission Management Team meetings were, as Mike's pointed out, the kind of meetings that were appropriate in a production environment. They've got a Monday morning meeting that one would have on a factory floor. The issues were discussed very quickly. It was a kind of production mode, rather than a mode of inquiry and understanding.

And, again, to some extent that's an expression of the schedule pressure that, particularly, the chair of the Mission Management meeting felt because she was, in fact, going to be the flight director of the subsequent shuttle. And she knew that to request imagery, to turn a Department of Defense satellite around to take a look at the wing, to actually change the orientation of the *Columbia* in space to allow a view of that wing to be taken, was certainly going to put the next shuttle behind schedule.

Organizational Factors

Now, we then move to the organization as a whole, moving away from the team issues.

Organizational structure

NASA's an incredibly complicated organization. It's geographically dispersed: It's in Florida, it's in Texas, it's in Virginia. It's dispersed organizationally, inasmuch as there's NASA, and there are numerous contractor organizations working within NASA. It's a very complex organization, and there's a very hierarchical structure in that organization.

As Mike has pointed out, there's a very strict adherence to communication protocol. When the request for imagery data came through, the chair of the Mission Management Team was more concerned about how that request had arrived at her than with the content of the request. The obsession was that this request had been out of channel and therefore couldn't be regarded as being valid.

All of these factors go together to impede the information flow within the organization during this critical period.

Organizational culture
And then we have the culture of NASA, culture defined here as those taken-for-granted assumptions about how things work in an organization. It shapes the way in which people think, shapes the way in which people approach problems, shapes the way in which people make decisions.

And NASA was an organization of a particular kind of engineering culture. This is a data-driven organization. If you don't have the data to back up your concern about the safety of flight, then you're going to have great difficulty raising those concerns up in the organizations.

This is an organization in which it's very hard to make a case on the basis of intuition, and gut feeling, and hunch. Those were not regarded as valid sources of information, sources of data within the organization. So effectively, the organization almost cuts itself off from some of the experience base of its engineers, who have been participating in space exploration for decades.

The second part of NASA was the safety culture: the way it viewed proving whether or not it was safe to fly the shuttle. And we'll hear in a moment that the culture really was such that you had to prove that it was not safe to fly, rather than to prove that it was safe to fly—again, another sort of manifestation of the production frame versus a sort of research and experimentation frame.

Let's hear from Roger Tetrault, as he talks about this orientation.

ROGER TETRAULT (video): I spent over twenty-some-odd years, and particularly in the early part of my career development, as an engineer in the Naval Reactors program. And the Naval Reactors program has a huge history of success in driving nuclear submarines and surface ships around the world in a very safe manner.

In the Naval Reactors program, the mantra was always, "Prove to me that it's right. If something went wrong, prove to me that everything else is right." And kind of what we found in NASA was a culture that was more "Prove to me that there's something wrong. And if you prove to me that there is something wrong, I'll go look at it."

PROFESSOR BOHMER: So there's a terrible Catch-22, here, right? You have to prove that something's wrong. And in order to do so, you need some imagery. But the request from the imagery doesn't have any data to back it up. So you can't have the data, because you don't have the data to allow you to get to the data. So there's this terrible Catch-22 that people on the Debris Assessment Team found themselves in.

The point here is that all of these factors are interacting with each other, as Mike's already suggested. There was an engineer at Langley who was very concerned about whether or not the tires on the shuttle would hold up during a landing. He ran some tests, and felt that in fact there was some serious risk to the tires. He communicated the serious risk locally. But the e-mail he sent globally was much, much more positive.

So team-level factors, organizational-level factors, human cognition-level factors are all interacting to give us a net result of an underresponse to a threat that is clearly ambiguous.

Amy's going to now speculate with us on what an alternative response might look like—how one might have gone about this in a different way.

Envisioning an Alternative Response

PROFESSOR AMY EDMONDSON: Thank you. So with all of the real data analyzed and looked at by Richard and Mike, now I get to speculate. What, if anything, can organizations facing ambiguous threats—whether it's the possible harmful side effects of Vioxx or the possible very harmful effects of foam strikes—do differently, given this overwhelming tide of explanation for how we get in trouble?

OK, so, to not be pulling completely from our own heads, as we think about a possible alternative, let's go back to another very famous story in NASA's history. Now, many of us have seen the *Apollo 13* movie. Most of us recall the event, living through it in some way, glued to the news reports.

But in the late '60s, with the *Apollo 13* moon mission, there was a very serious threat encountered halfway through the mission: the threat of complete oxygen depletion in a finite number of hours. So very clearly a recovery window. So let's take a look at what happened during that recovery window.

Video

So our core proposition here is that organizations can, in fact, choose an alternative response. They can develop a culture, processes, systems, team mechanisms through which they can respond effectively in a window of opportunity or a recovery window, just as we've seen here.

However, it's quite counternormative to do so. So Mike explained in some detail how easy and natural it is for human beings to discount risk, especially when the threat is ambiguous, not clearcut. In the case of *Apollo*, clearly that threat was very clearcut, not at all ambiguous. Given the more ambiguous context that we're talking about, it's quite natural to discount the possibility of bad things happening.

So, what we propose, in contrast, is to deliberately exaggerate the threat. It's ambiguous, it may amount to nothing, but let's go around somewhat like Chicken Little and say we've got a problem here. It seems a little bit counterintuitive, and a little crazy, so we'll have to keep going here and then dig into it.

Instead of that very natural "wait-and-see" orientation, let's try a "try-and-see," "do-and-see," or "do-and-learn" orientation of just running little experiments, seeing what we can learn, getting those imagery requests fulfilled, so that we can at least have more data with which to think while we're waiting, while we're in this window.

And, finally, instead of the kind of ad hoc, laissez-faire, self-initiated analysis in action, let's have a Gene Krantz-like, top-down, team-coordinated effort, where people are focused on solving problems, learning more, figuring out possibilities for action.

OK? So at first glance, this can seem quite ad hoc, "teamy," organic. And in fact, it's not. It's leader-driven, it's hierarchical. The leader is saying, "I want this team to work on this. I want this team to work on that. I want this team to work on that, and failure is not an option." All right? So very, very organized, in a kind of counterintuitive way, and not a natural response to a situation like this.

Confirmatory versus exploratory response modes
So in proposing this, let's just dig in a little to characterize it further. The confirmatory response is more or less the natural response, particularly facing an ambiguous threat. The exploratory response is kind of counternormative, unnatural, a learning-oriented response. It all starts with, and it's all triggered by our tacit thoughts, our tacit assumptions about the nature of the situation we're in.

So do we believe we fundamentally have it under control and understand the situation we're in pretty well? Or do we believe that our knowledge is incomplete, our data inconclusive, our need to learn very great and real? With that deep belief, it becomes almost automatic to go out and try to learn, rather than to perform.

Performance orientation is basically a mindset that says, "I have to get it done. I have to get it done and, by the way, I hope to perform quite well, and have others in my vicinity feel pretty pleased with the way I've performed." The learning orientation says, "I absolutely have to learn more. And I have to do whatever it takes to learn more, and I'm driven by this sense of incompleteness and curiosity that wants me to do that."

It's interesting. Social psychologists have done quite a bit of research with children that shows that those who have a natural mindset of a learning orientation tend to persist longer in difficult tasks, tend to achieve mastery over time more readily and more fully than children who have a performance orientation, which is, fundamentally, "I need to look good. I need to do the task perfectly. My ability to do the task perfectly is a reflection of how smart I am," and so forth. Over the long haul, these kids don't do as well. So very interesting analog, there.

And so, in this column, this learning-oriented column, again, it's going to take effort. It's counternormative, which to us means that there's a very important and central role of leadership to make this happen. So we saw the example of Gene Krantz. If organizations and human beings can't be trusted to jump into an exploratory mode on their own, they're going to have to be led.

So leaders can engage people. Give them the structure, and then let their wonderful abilities, curiosity, and creativity flourish in that environment.

Simple experiments
And so, what do we mean? Let's dig into a little bit more of this exploratory mode. We do not mean vast, expensive, potentially peer-reviewed research that is perfectly done, so on and so forth.

Our thoughts about the kind of experimentation—it's more a mindset, a little bit closer to the kind of experimentation a very young child might do in the high chair, when he's trying to check out what happens: How does gravity work, when I drop my spoon? It turns out, you know, it works for the fifth, sixth, seventh time. I drop my spoon and gravity is still there. So a wonderful mindset of curiosity and experimentation doesn't have to be expensive.

Mike and Richard and I have gone through newspaper accounts and many others to look for examples of not expensive, not difficult, not time-consuming, but terribly informative experiments, and we've found quite a few.

Probably we all know, or those of us who've read the Accident Investigation Board know that, even though NASA didn't, during the recover window, the Accident Investigation Board conducted a very careful test to actually determine whether foam striking those tiles could, in fact, cause the kind of damage that would lead the shuttle to burn up upon reentry. They determined conclusively that it could.

That was a relatively expensive test, although small compared to the cost of a shuttle mission. But there were some other very simple ones. Dr. Hallock, whom we saw earlier, has a very simple experiment that he does with a number-two pencil, which I believe costs about fifteen cents. And he does that. And what he showed definitively was that the specifications for the tiles on the shuttle were, in fact, woefully inadequate for the conditions that that shuttle was going to routinely face.

Very inexpensive, very quick. Creative guy sitting home alone figures this out. Actually, he got a little help from his secretary, who supplied the number-two pencil.

So another example.

__: What was that experiment?

PROFESSOR EDMONDSON: Excuse me?

__: What was the pencil experiment?

PROFESSOR EDMONDSON: Well, the pencil experiment is really more of a thought experiment. So what he does is he takes the pencil, and he does the calculation to figure out, "How high do I have to lift the pencil before it would do damage to the foam tiles, based on the specifications provided?" And he does the calculation.

I don't have the numbers in my head of what the foam tile specs were, but he finds out what they are. And then says, "What's the impact of a number-two pencil at, say, two feet above?" And finds out that that's basically what the specifications would allow. So it's more of a thought experiment than an actual experiment.

So what he's saying is that the specs are good enough so that I can drop a number-two pencil from a distance of two feet, and it will withstand that. No better. Now, of course, the actual tiles were better than that, but that's the criterion they had to meet.

OK, so a wonderful classic example of an inexpensive experiment, thought and practical experiment, is Richard Feynman—a wonderful physicist, Princeton professor, actually somewhat of a specialist in the art of communicating to a lay audience about complex phenomena.

So Feynman was part of the *Challenger* investigation board. And in his own participation and in Senate hearings, what he did—now, let's back up. Mike mentioned the O-ring. There were months, in fact, years of active debate inside NASA on the following question: Does temperature have any relationship to the functioning of the material in the O-rings? OK? And the real problem being, if it gets too cold, will the O-rings malfunction?

Later on, we know, yes, indeed they will. But this was the subject of active, contested debate in the organization. So what does Feynman do? He says, "I don't need $100,000, I don't need a large team and a large staff." He says, "I happen to have a glass of ice water, right here at the hearings."

And he drops a little piece of the O-ring material in the ice water, leaves it in there a minute or so, pulls it out, and shows the disintegration of the springiness of that material from that little exposure to the ice water. All right? Again, that little child in the high chair could have done that for us, too, although he might not have thought of it.

So we're talking here about a mindset of curiosity, of "What if?" Well, gosh, if we're so curious about O-rings and temperature, what kinds of things could we do, in the absence of full-fledged scientific research, that could get us there?

Yes?

__**:** You're talking about experiments, though, prior to, in this situation, the launch, right?

PROFESSOR EDMONDSON: Yes. Well, prior, yes. Yes.

__**:** I mean, how do you deal with the number of anomalies that occur during the . . . ?

PROFESSOR EDMONDSON: Absolutely. I mean, the O-ring thinking should have been done in a very different "recovery window," shall we call it. There was a recovery window in the *Challenger* incident between the moment at which weather reports indicated that the very next morning was going to be extremely cold in Florida, and the moment at which they launched.

So they had about a twenty-four-hour period to think this through. That's when that kind of experiment might have happened.

__**:** We're dealing now prelaunch. When are we going to start to deal with what happens after stuff happens?

PROFESSOR EDMONDSON: Well, so, this is *Apollo 13*, right? And *Columbia*? Vioxx, maybe? So what we have here is, OK, we've got something that may be a problem. We're not sure. So our suggestion is for now we're going to assume it is a problem. OK? Now we're going to structure those teams, we're going to get to work, and we are going to learn everything we can, and figure out a recovery solution for what we'll do if it's a problem.

__: I really don't know anything about this at all. I'm clearly not a rocket scientist. But I've got to believe that, during a normal space shuttle mission, there's got to be a half a dozen to a dozen anomalies occurring. How do you decide when to start putting experimental teams together?

Is exploratory behavior too costly?
PROFESSOR EDMONDSON: Well, that's a great segue into the next slide—so, the '"cry wolf" problem, right? So we simply cannot chase all of these things down, right? Is that behind your question?

__: Well, I don't know. It seems like a leadership issue, here. It's a serious leadership issue. And, granted, there's got to be some type of development in the atmosphere, in the conditioning of the team and the organization ahead of time. But once things happen in this type of environment, how does the leader start to make the decisions on what's critical? What's mission critical?

PROFESSOR EDMONDSON: The leader is going to have to make some judgments, no question about it. But our speculation here is that we can chase down ambiguous threats to a far greater degree than we think we can. So we can set up, "Hmm, that looks funny. That looks funny." Throw a team at it. Don't have a team be in a situation where Rodney Rocha was, where he thought, "God, there are some real issues here but I'm not allowed to talk about them." So huge cultural shift.

__: That's the precondition.

PROFESSOR EDMONDSON: Yes. So our question is, how do you get there? And our answer is, you've got to start somewhere. And where you start is the little bit of practice we're going to get when we start, "Ah, ambiguous threat. Let's track it down." Well, it turned out to not be a problem, but good practice. Right? Ambiguous threat—moderate problem. Good practice.

So here's our possibility. We do it: low cost, early, exploratory, maybe amounts to nothing, short-term consequence. We're going to improve the quality and safety somewhat. You might add, "At what cost?" At the same time, we may have some positive spillovers, which I think are easiest to conceptualize in terms of the learning we just got from this little experiment: "Ah, we now know something we didn't know before."

But, over time, we will also get to the point of developing new, what we call "organizational learning capabilities"—the capability of throwing teams together, tracking them down. Very hard to do what Gene Krantz did without having practiced.

And that's the interesting thing about the old NASA, and the interesting thing about the *Apollo 13* era, was that they were having drills all the time. They were doing this even when there wasn't a crisis. And they had team leaders, and other psychologists, and others watching the teams, and seeing, "How do they do under stress? How do they work together? Are people listening to each other?" and so on and so forth.

So they had this as an organizational capability. And over time, we get to really a profound cultural change of the type that you're suggesting almost needs to be there in the first place. So, again, a little bit of a Catch-22.

But our suggestion is that this is how learning organizations are created. They're not created just by using the right words, just by saying it. They're created through practice, and the practice is at the micro level of action—task-focused action—so that this is a capability-building exercise. We don't have time to go into any of these examples from other organizations. But we do have in our repertoire some organizations that are very, very good at this in partly some counterintuitive ways.

The DNA of the Learning Organization

And so, what we're talking about here is this is not the only, but one mechanism, one way of building the DNA of the learning organization. The DNA of the learning organization is built through many other leadership and group activities. But how you respond to an ambiguous threat is merely one way to begin to build these capabilities, to begin to literally see errors and failures as opportunities for learning.

It doesn't mean you have to like them. None of us is going to wake up in the morning thinking, "Gosh, I hope I get another mistake today to learn from." It does mean you have to welcome the opportunity to do it better next time, and a very different mindset, and a mindset that NASA simply didn't have at the time of this incident.

A lot of wonderful skills and activities that we can begin to develop, but it's going to take proactive leadership action to get there—the openness to discordant information; the psychological safety to take these interpersonal risks of raising the unpopular view.

And so, we end by saying that we are what we repeatedly do. Go way back in history to Aristotle to say this. It's got to become a habit. You've got to build it slowly. Overreact, rather than underreact to the ambiguous threats as a strategy to get there. So I don't want to keep you any longer than promised. We want to thank you very much for your participation and attention in this session.