CHAPTER 1

Think You Can Ignore Context? Hubble's Flawed Mirror Might Wake You Up

Hubble Space Telescope—April 23, 1990

It was late in the evening at the Kennedy Space Center. A TV camera technician was taping a large cable onto my leg. I had just returned from a final look at the Hubble Space Telescope in the Space Shuttle's cargo bay. It was an awesome sight—the gleaming telescope surrounded by the shiny cargo bay doors of the Space Shuttle. After 15 years, $1.7 billion, and the hard work of thousands of people, the time had come. Tomorrow morning, Hubble would launch into space.

I was the featured guest on "Nightline," the nationally televised news show with Ted Koppel. Not being much of a TV watcher, I had never seen the program. The local producer had me stare into glaring lights for more than 30 minutes before the show. I suppose that tired, unnerved (and scared) people made good late-night television guests. They promised that questions would be polite and easy. They were neither. After all the usual stuff about whether NASA money would be better spent on social programs, I was asked the big one, "Will it work?" I expressed strong confidence in our team, talked about the thoroughness of the test program. and said squarely, "It will!"

Actually, I had my doubts, but that was the only rational response. If difficult times were to come, I needed my Hubble team to see me as confident and fully behind them. They deserved this kind of support. Moreover, there was no alternative except to launch the telescope and see what happened. Either it worked or it did not. It was time.

After a few hours sleep, I returned to Kennedy for the final countdown in the launch control blockhouse. Gazing at the Space Shuttle five miles away, I listened to the launch director's voice in

my headset. As NASA's director for astrophysics, my role was to provide quick recommendations if major problems occurred during the launch and deployment. After a textbook launch, the telescope deployed, powered up, and communicated with the ground just as we had planned. Everything was, in NASA parlance, "nominal."

However, Would the Telescope Work?

In order to achieve the benefits of being above the atmosphere, the telescope's body must point to a given location in the sky with a stability of .007 arc-seconds. This is equivalent to aiming a laser in Washington, DC and hitting a target in New York City the size of a quarter.

In the late 1980s, the White House decided to open space science cooperation with the Soviet Union. I cochaired the first working group with my Soviet counterparts. When I put up the chart describing the Hubble pointing specification, there was a murmur on the Soviet side. I asked my counterpart what was happening. He said, "It's nothing, just a translation problem." I said, "Please explain." He answered, "Your chart says 0.007 arc-seconds as the pointing stability. We are sure that you really mean seven arc-seconds." It took some time to convince them that we were actually building a system to achieve seven *thousandths* of an arc-second. These highly accomplished space experimenters could not fathom achieving that kind of performance.

What would happen if Hubble's performance was a technically respectable 0.07 arc-seconds? Hubble would be a total loss because the resulting images would scarcely be better that what the best ground-based telescopes would do. We would have squandered $1.7 billion of taxpayer money! There was no way to be certain we would reach this level of performance before our public debut.

Hubble Looks Good, So Off to Japan

With the world watching, we opened the aperture door and let starlight in. I heaved a sigh of relief as a fuzzy spot of light appeared on our monitors. "It works," we shouted. My engineers told me not to worry about fuzziness. We had intentionally launched the telescope slightly out of focus.

With Hubble looking good, I decided to visit my colleagues in Japan. I met with my boss, Len Fisk, just before my departure.

He asked if he should do anything for me while I was gone. I said, "Len, we've just succeeded with what is perhaps the grandest science project in history. Surely, there will be medals in the Rose Garden for all of us." I continued, "Your job is to get George Bush and not Dan Quayle to pin my medal on." He laughed and said that he would do what he could. Looking back, this was pure hubris. I would soon learn that the gods do not like hubris.

My Japanese counterparts knew that I liked to meet in Ryokans (Japanese Inns) where no foreigner had ever been. I had no contact with my headquarters office for a week. As I flew from Narita to St. Louis, I wondered how things had been going in my absence.

"Conscious Expectation of the Unexpected"—An Early Hubble Motto

I entered the St. Louis airport lounge to await my flight back to Washington. I was in good spirits, although feeling like I was on "sake time." I called my secretary to check in. She immediately said, "Have you talked to Dr. Fisk lately?" "No," I answered. She said, "I'll put you right through." I wondered what was so important. Ah, this must be about the medals in the Rose Garden. A surprising few seconds later, I heard Len Fisk saying, "Charlie, where are you?" After I told him that I would be back in DC that evening, he said, "I'm glad to hear that."

He continued, "Charlie, what do you know about spherical aberration?" As I wondered why he might be asking, I replied, "I know that it is a common mistake by amateurs. They sometimes make mirrors with a 'down-edge.' A telescope with a spherically aberrated mirror is useless."

Len then said, "What would you say if I told we launched Hubble with a spherically aberrated mirror?" I answered, "I would say that you are annoyed that I had a good time in Japan, while you had to tend to the Washington bureaucracy. This is a really bad joke."

He persisted, but I remained unconvinced. He finally said, "Okay, put the phone down, but don't hang up. Just find the front page of any major newspaper and bring it back." I returned with the *St. Louis Post-Dispatch* in hand. He then asked me to read the headline to him over the phone. It said, "NATIONAL DISASTER, HUBBLE LAUNCHED WITH FLAWED MIRROR." "Now what do you say," Len asked? I replied, "You guys are really something.

How did you plant a fake newspaper in here?" Later, I named this moment "denial is not a river in Egypt."

Back in Washington, reality sank in. A trivial and obvious error overshadowed the accomplishments of thousands of dedicated people! The following months were to be a kind of living hell for my Hubble team.

The Congressional testimony was brutal. At that time, news of the Savings and Loan scandal was just emerging. Congressional representatives preferred to appear on TV beating up on NASA executives than explaining that crisis. During one session, a member asked me, "Dr. Pellerin, you've told us that the greatest advance of Hubble over prior missions is in the ultraviolet?" "Yes, that's true," I said. I thought he was getting ready to ask me how I knew the mirror was not contaminated. One molecular thickness of oil would have made the mirror black in the ultraviolet. We worried constantly about contamination of the optics.

Instead, the representative looked at me accusingly and said, "Mr. Chairman, the witness is lying. Everyone knows that ultraviolet radiation is invisible." My first thought was to explain that we had detectors that converted ultraviolet radiation into electrical signals. Then I had a better idea. I said, "Sir, x-rays are also invisible to the human eye, yet you can see x-ray images on film." The chairman said, "You are out of order. Let the record end with the member's remarks!"

After the first week of testimony, a friend invited me to a concert at Wolf Trap Park, an outdoor park just outside Washington. The world seemed an okay place after a bottle of wine, a nice dinner, and a beautiful sky. Judy Collins walked over to the microphone and began to sing. No sound came out. She went to another microphone and said, "Aren't you glad that the idiots that built Hubble Space Telescope didn't build this sound system. At least, we have a backup." I felt terrible. Our failure had permeated popular culture.

While I avoided late night television, there was more to come. The movie *Naked Gun 2½* had a bar scene with several paintings in the background. The camera panned over the paintings: the Hindenburg on fire; the Titanic sinking; and the artist's concept of the Hubble Space Telescope on orbit that I had on the wall in my office.

NASA people are proud, and the humiliation of all this began to take a toll. Doug Broome, my brilliant manager of the Hubble flight systems, took the failure very personally. He suddenly contracted

cancer and was dead a few months later. He was a great person; he also had the unusual honor of two NASA Outstanding Leadership Medals. He received one for his work on Apollo and the second for Hubble (before we knew of the mirror flaw).

One of the lessons Len learned from the *Challenger* disaster was to create our own Failure Review Board before someone picked one for us. Len quickly charged the highly respected General Lew Allen, director of NASA's Jet Propulsion Laboratory, to assemble experts and find out what had happened. Len named me as the NASA liaison to the board because I was at that optimal intersection of political visibility and technical understanding of the telescope's systems. Besides, I joined the division in 1982 and the contractor manufactured the mirror in 1977, so I had nothing to do with the flaw. Or did I?

The Failure Review Board Found the Problem

The board met time after time with little progress. Then a member calculated that an unimaginably huge error (centimeters) in adjusting the null corrector used to figure the mirror could cause the flaw. The device was still in bonded storage at the contractor's plant. They measured it and verified the calculation. Great, I thought, I can go back full time to my regular job, leading my division.

However, Lew continued his investigation. He found that there were hints of the mirror flaw in numerous tests. He wondered why smart technical people had not rigorously pursued these hints. He found that the schedule and budget pressures caused them to move relentlessly forward.

Next, he wondered why the NASA scientists and engineers had not addressed these inconsistencies. The board then made a disturbing discovery. The contractor never forwarded these troubling results to NASA. Now, the board's question was, "Why not?"

A Leadership Failure Caused the Flaw

The board finally told Congress that a leadership failure caused the flawed mirror in our $1.7 billion telescope. Lew reported that NASA's management of its contractor had been so hostile that they would not report technical problems if they could rationalize them. They were simply tired of the beatings. This finding astounded me.

During this period, no one in NASA, Congress, or the Administration wanted to talk about Hubble, or a mission to repair it. They just wanted it to go away. Fate placed me in the unique position of being the only person with sufficient motivation and power to mount a Hubble servicing mission.

The studies I had funded when the flaw surfaced were paying off. The error in spacing the null corrector meant we had a near-perfect mirror with the wrong prescription. Scientists from around the world rapidly designed ways to correct the aberrated beam. It only took a few hours with my budget analyst to delay or cancel Division activities yielding the $60 million we needed immediately. I asked the best and brightest at NASA to join me in fixing Hubble, and they all said yes. The mission to repair Hubble in space was underway.

Most of you will never experience a failure as publicly traumatic as the one I just described. The point is that unnoticed social shortfalls destroyed this high-visibility, tightly managed program. This is unfortunately a common problem for teams of technical people. Social shortfalls are the root cause of disasters ranging from Challenger's explosion and Columbia's disintegration to airplane crashes.

Here, however, is very good news. You can use *How NASA Builds Teams* to reduce or remove social context risk from your team. It does not matter whether your team is large or small or whether you are developing new software or drugs, these processes are effective—if you are committed to this work.

An Application Summary for Hubble Trouble

I hope you found my Hubble story interesting. I first related it around a campfire on a White Rim bicycling trip at Moab, Utah. I did not think much of it until a few nights later when my fellow cyclists asked me to tell it again. We all tell an abbreviated version at the start of each workshop. I believe it helps set the stage for everything that follows.

We now explore the dominant driver of team performance, the *context*.