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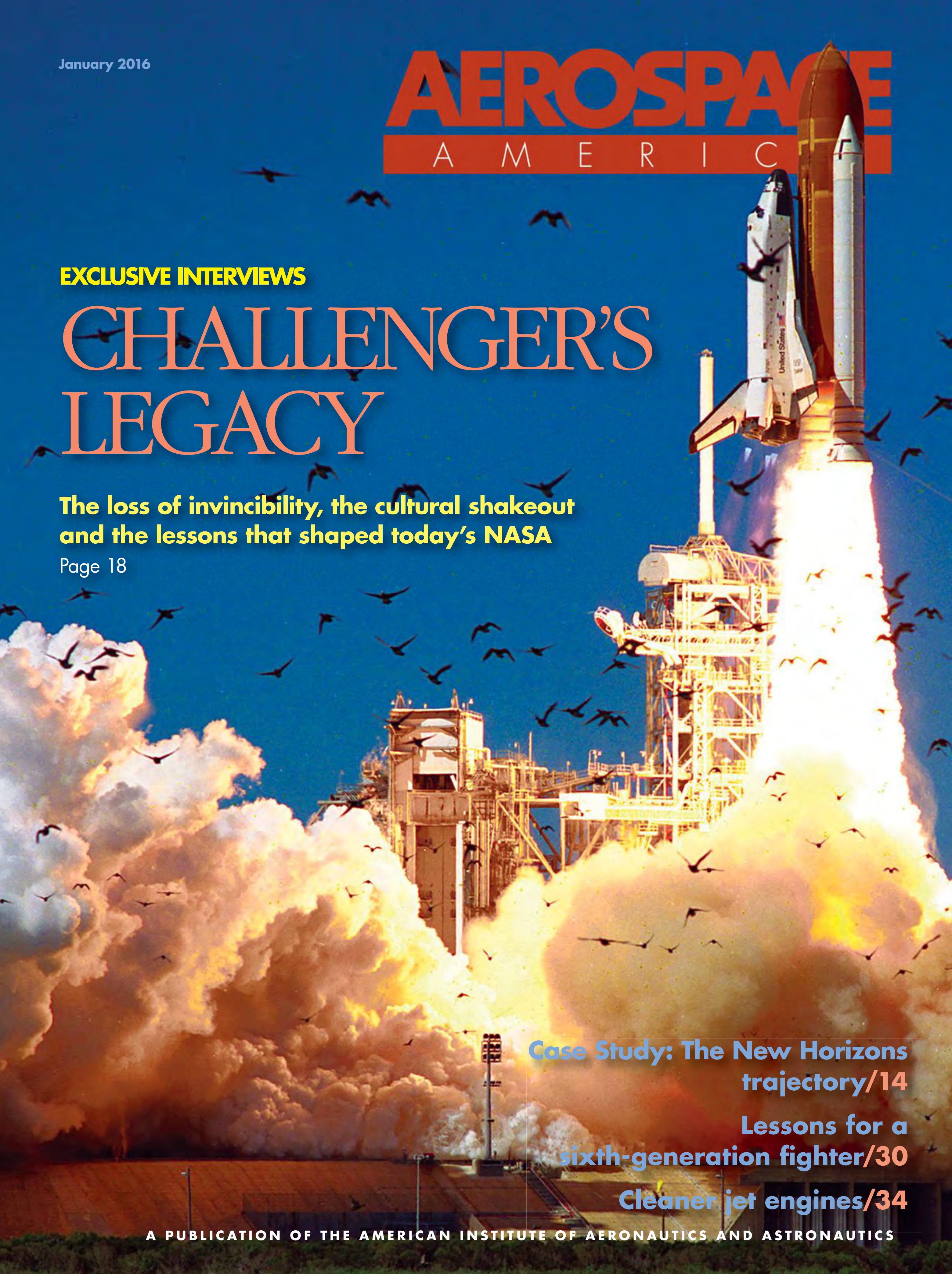

EXCLUSIVE INTERVIEWS

CHALLENGER'S LEGACY

The loss of invincibility, the cultural shakeout and the lessons that shaped today's NASA

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Challenger's Legacy

NASA

Humanity's determination to go to space for adventure, commerce and exploration has never been stronger, but many of those who will open up this frontier have no direct memory of an unusually cold Florida morning that changed NASA forever. On Jan. 28, 1986, the space shuttle Challenger rose and exploded in front of a live cable TV audience and school children who were watching via a special satellite feed. The crew of seven was killed, including history teacher Christa McAuliffe. The sense of invincibility that had grown at NASA was shattered. Debra Werner asked some of the people connected to the mission to recall that day, its lessons and how NASA summoned the courage to fly again 33 months later.

by Debra Werner
werner.debra@gmail.com

David Hilmers *flew on the STS-26 Discovery mission in October 1988, the first flight after the Challenger disaster.*

DAVID HILMERS

I was in training for another mission, a very difficult one to launch a vehicle upper stage, called the Centaur, from the shuttle. There were a lot of potential difficulties because it was a liquid [fueled] upper stage and it had its own set-up fuel tanks that were difficult to stabilize. There were a lot of areas where failure scenarios were a little more probable than we like. It was going to require that we launch for the first time at 109 percent of rated thrust. We were discussing flight rules. We stopped the meeting to turn on the video from the Cape. We were all struck by the icicles on the tank and the knowledge that we had never launched in that kind of extreme cold before. There was an uneasiness in the air. As we watched the tragedy unfold, people didn't say anything. The meeting just stopped and we filed out. I was in a daze. I remember going home that night, going to my piano and playing Pachelbel's Canon over and over again with a lot of tears and sadness.

It was the first time we had lost a crew in space. That feel of invulnerability went away. It really sobered us to the care that we have to take. We couldn't expect to let problems slide and hope that they would go away or somehow get fixed. We looked at every document and every part of the space shuttle. We made an enormous number of changes. It set the groundwork for all the successful shuttle missions [to follow until] Columbia, and that was perhaps due to a separate problem. That's a pretty good safety record. We lost my friends and we lost a vehicle but it wasn't in vain.

"It was the first time we had lost a crew in space. That feel of invulnerability went away. It really sobered us to the care that we have to take."

Return-to-flight mission>> It was a privilege to represent NASA and the country [aboard Discovery STS-26] in getting our space program back on its feet. There was also a burden to bear, constant questioning and a lot of pressure on us to be good representatives of NASA for that mission. It was worth that effort and certainly one of the highlights of my career at NASA.

John B. Charles *has been at NASA Johnson Space Center since 1983, helping to improve human spaceflight safety.*

JOHN B. CHARLES

I came to the Johnson Space Center in 1983 as a post doctoral fellow. In 1986, I was a civil servant scientist. I recall being off site at a meeting early in the morning, then walking in the front door of building 37, which was where the life sciences offices largely were and still are. I was in the conference room watching the launch on television. Typically with rocket launches, after blast off people get up and walk away. People were walking out of the conference room. It was [just under] two minutes into the flight and this thing happened. Most people didn't notice. A few of us who were paying attention noticed, but didn't understand what was going on. As you recall, the commentator didn't say anything for a while. We kept saying that doesn't look right. Is that supposed to happen like that? And then the commentator said major malfunction. The rest is a bit of a blur.

Faulty suspect>> In the absence of any definitive information, I assumed like everybody else that it was the turbopumps because I had heard the turbopumps were the engineers' biggest concern on those Space Shuttle Main Engines. And of course, it wasn't the turbopumps. They kept working right up until the vehicle disintegrated. After that, we had to try to understand what happened to the crew members. How they died was our main concern because we are supposed to be thinking of ways to protect them.

One of my dominant recollections is the absence of information. Even as the inspection and recoveries were taking place and review boards were doing their work, there was not that much information shared. Then, within days or weeks, it became clear we were going to resume the shuttle program. That really seemed to help us refocus on crew safety.

NASA "decided the shuttle program needed to be refocused on things that truly justified putting people in space and it was not like a trucking company."

Clearer priorities emerge>> Management decided the shuttle program needed to be refocused on things that truly justified putting people in space and it was not like a trucking company. That led to interest in the Extended

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Duration Orbiter, which was going to fly shuttle missions up to 30 days as mini space-station missions to do the research that needed to be done in spaceflight to begin to understand the effect of spaceflight on astronauts in preparation for the space station. Before Challenger, medical research was largely the domain of payload specialists. Toward the end of the pre-Challenger era, the real astronauts kept saying, "Medical experiments? We'll let the payload specialists do those. We are the pilots. You don't ask the pilot on Southwest Airlines to do medical experiments do you? Go bother the payload specialists." After Challenger, with the demise of the payload specialist program at least for a little while, there was also the realization that we're all in this together. The medical research we were doing couldn't have helped the people on Challenger and it could not have prevented Challenger, but it can help us understand the medical problems of spaceflight and can help prevent future problems. So the astronauts to their credit became more enthusiastic or at least less reluctant to participate in medical investigations we developed [for the proposed] Extended Duration Orbiter Medical Project, which never happened, obviously, but shuttle flights became longer, 17-day flights.

New appreciation for medical concerns>> We formed a new healthier, happier relationship with the astronaut office. They were much more supportive, much more willing to participate in the medical investigations. It also helped us to focus our medical investigation on things relevant to crew safety, health and performance and not simply things that we thought were interesting. Internally we'd always been focused on the things that were relevant, but it helped us refocus on what relevant meant.

End of a cringe-inducing term>> After Challenger astronauts began wearing new spacesuits, because it may not have helped the people on Challenger but it made NASA focus on what else could go wrong. Up until that time, a lot of very smart people believed the shuttle was an operational vehicle, even though the folks who were flying it and managing it cringed at that description. Challenger gave NASA the opportunity to focus more on crew safety issues and explore other things that could have go wrong. It was a bit of a new golden age in terms of crew safety research, risk-reduction research.

Rob Kelso *began working in NASA Space Shuttle Flight Operations in 1981 and in 1988 became a shuttle flight director. Today, he runs the Pacific International Space Center for Exploration Systems at the University of Hawaii.*


ROB KELSO

I was in the customer support room, a room for senior business managers that had spacecraft or payloads on shuttle missions. In the customer support room, you can have TVs on because you are not actively monitoring the ascent. I noticed several things. When the shuttle broke apart, just before solid rocket booster separation, it was clear that a major problem had happened by all of us watching on [NASA satellite] TV. But in the control room, it took a number of seconds for that to dawn on people because when the breakup began, all the pieces were still relatively close together so the tracking radars tracked it as one group until it began to disperse.

The people who were standing at the Cape in the viewing area and the people who were watching it on TV, had an earlier sense of the disaster than the people who were sitting in the mission control room because the data appeared to be normal. When that happened, we felt shock, the sick feeling in your stomach. We had never lost anyone in flight before. We lost a crew on Apollo 1 on the pad, but never during dynamic phases of flight or on orbit. The other thing I remember is that there was no indication anything was going wrong with the vehicle until the breakup. Obviously when you look at the very minute data there were signs, but it wasn't evident to anyone in my area until it happened.

Wringing value from down time>> It was hard to recover after that. We were down for years. I remember Tommy Holloway [then NASA's top flight director] telling my flight director class, "When we start flying again, you are going to be extremely busy. While we are not flying,

"After Challenger, people asked, 'Do we really want to fly these big [Centaur] hydrogen and oxygen tanks in the shuttle?' It was pretty dangerous. That program was canceled.

this is your golden time to get all of your studying done and visit all the contractors." He was right. That downtime was our time to get smart, educated and prepared as flight directors.

Rethinking shuttle's purpose>> For about a year before the accident, I had been working [on the] Shuttle Centaur [rocket program] to launch the Ulysses and Galileo missions from the shuttle. We had two crews assigned and we were beginning to do training, procedures development and testing. After Challenger, people asked, "Do we really want to fly these big [Centaur] hydrogen and oxygen tanks in the shuttle?" It was pretty dangerous. That program was canceled. [The Ulysses solar probe and the Galileo Jupiter probe were launched from shuttle orbiters using solid rockets.] Challenger changed the role of the shuttle. It was no longer the National Space Transportation System. We were directed not to fly commercial payloads anymore. We were directed to off-ramp the Defense Department program. The Teacher in Space program went away. It changed the whole complexion of the shuttle program. That didn't show for a number of years because we had flight commitments. We had to fly those out.

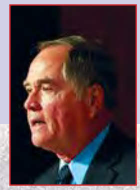
Much needed changes>> Obviously there are positive things [that resulted]: management change and an understanding that there was a lot of pressure to launch that led to unacceptable risk.

It also raised the question, "Do we really want to fly Centaur's big hydrogen and oxygen tanks on the shuttle?" We never really sat back as a community and said, "Does this make sense?" On Return to Launch Site abort, we would be too heavy. We would have to dump hydrogen and oxygen. We were already mounting drain pipes and valves to dump propellant out of the Centaur during RTLS [meaning a return-to-launch-site emergency]. After the accident, people said, "What were we thinking?"

We are ingrained in flight control that failure is not an option, but we do learn from failure. We adopt new values on how we assess risk. Flight directors are trained to assess risk versus risk and risk versus gain: doing something versus doing nothing. One of the great outcomes from Challenger from a flight control perspective is that up until that point, we were so busy we never had captured the rationale for all the risk–based decisions in our mission rule book.

New rules>> After Challenger there was enough downtime to go through every flight rule. If we lose a fuel cell, do we continue to fly? Do we come down? What if we lose a star tracker? We debated all those rules and captured the rationale for our decisions. In many cases, rules were changed in that reassessment and a risk review.

Bob Crippen, *a four-time shuttle astronaut and the shuttle operations deputy director from 1986 to 1989 at the Kennedy Space Center.*


BOB CRIPPEN

I had been assigned to be commander of the shuttle's first flight out of Vandenberg Air Force Base. My crew and I were training in Los Alamos on one of the payloads we were supposed to carry. We knew the launch was coming up so [we] asked for a TV to watch the launch. At the time, people thought launches were commonplace enough that right after liftoff they cut away from the launch. We were walking out of the room, griping and complaining about the media coverage when somebody said, "Hey, wait'" because the coverage went back after the explosion. So that's when we saw it. It was heartbreaking. Most of us had good friends on there. The commander of the flight was Dick Scobee, who had been my pilot on my third flight. We said we'd better get back to Houston. It was one of the quietest flights I can remember.

"That night when it was so cold, people at the contractor were saying it was too cold for solid rockets to fly. Marshall Space Flight Center knew that. Johnson Space Center did not know that."

Figuring out what went wrong>> I personally was involved in the investigation. We found out the cause, that the culprit was the solid rocket motor. My buddy Dick Truly had been an astronaut and gone back to the Navy. He got called to come back and take over the Office of Spaceflight. There were a lot of management changes at the top level. That occurred very quickly. He asked me to come help deal with some of the investigation and the Rogers Commission in Washington, which I did. As part of my task, we reorganized the shuttle management. I had made a recommendation that we ought to have more operational people in program management and Richard said, "If you believe that, you'll hang up your flying boots and come help us run the program." That's what I ended up doing. Arnie Aldrich was the director of the shuttle program. One of our recommendations was to be more centered at NASA headquarters. Arnie went to Washington. Dick Kohrs was one of his deputies for engineering in Houston, and I became one of his deputies at the Kennedy Space Center for operations.

Returning to flight>> We set about one of the hardest jobs I've ever worked on, getting the shuttle back flying again. All of us who had been involved with the vehicle knew it had a lot of weaknesses that needed to be corrected. Not just the solid rocket motors. We set about trying to do that. After a couple of years, we accomplished what we set out to do. We had a lot more people telling us why we couldn't fly than why we could, but I felt pretty good when my buddy [astronaut] Rick Hauck [who commanded STS-26] lifted off on the return-to-flight mission.

One thing I was concerned about in particular was the wheels and brakes. They were too weak for the design and the weight of the vehicle. We set about revamping all that along with a large number of other modifications. We went over the entire vehicle, all the failure mode analysis and critical items list.

Improving communications>> One thing that came out of the Challenger investigation was that between Marshall [Space Flight Center] and Johnson and NASA headquarters the communication was poor. Some people knew stuff at one place that people at another place didn't know. That night when it was so cold, people at the contractor were saying it was too cold for solid rockets to fly. Marshall Space Flight Center knew that. Johnson Space Center did not know that. One of the things we worked hard to do was improve communication. If somebody was concerned about something, we needed to hear about it across the program, not just at one particular center. We worked hard at that. When we started back flying again in 1988, it was worth all the effort. I personally and a lot of other people believe the good friends we lost on the Challenger would have wanted that. They would not have wanted that to end the program.

Steve Cash, *a solid rocket motor expert who participated in the post-accident redesign effort and who is now director of safety and mission assurance at Marshall Space Flight Center.*


STEVE CASH

We were in a crowded conference room watching the launch. Everything seemed to be going as expected. Then you had this tragic event. It was unreal. It was a shock. We knew it was going to change how we did business for the rest of our lives.

Learning to listen>> Before Challenger, we all were worried about our little area of the world. I was worried about hold-down studs because that's what I worked on. After Challenger, we realized that we were all in this together. We learned a little bit more about teaming within the center and with the other centers. We built bigger teams and better teams. We opened up communications lines like we never had before. It changed how we looked at problems. We started to realize somebody at JSC looking at one of the problems or issues we had at Marshall may have a good solution. We need to be willing to listen to those other people out there. It was one of those [changes] that evolved. In the early '90s, I was working on the solid rocket motor team, I had moved in to the chief engineer's office at the time and supported the reusable solid rocket motor full time for that area. I started to see a big difference in the relationship that I had with Kennedy Space Center and Johnson Space Center and with our contractors. We started doing more things together. We started meeting more face-to-face rather than being on teleconferences all the time. We got to know people firsthand. I could feel comfortable calling guys down at the Cape. We even began to do details between our office, the Reusable Solid Rocket Motor office and the Kennedy Space Center Launch Operations office. We were starting to exchange ideas and exchange workforce. Several of our team members went to Johnson Space Center for six-month rotations with the shuttle program manager's office. We sent several of our team members to headquarters to work there. It became important to us to reach out and become more of a team.

"Systems engineering 101">> It was a natural output of spending more time looking at our designs and how they affect the other elements. We realized everything we did affected every other element. It was Systems Engineering 101, understanding the space shuttle vehicle as a system. To be successful, we all had to be successful. You couldn't just have a successful booster flight. If you lose an engine, it's just as detrimental. As you started to look deeper at your own systems, it led you to other systems outside the motor project and you started building those relationships with other engineers across the country. We started teaming much better.

Participating in the redesign effort>> We had six trailers full of folks working redesign efforts. I was in charge of the transient pressure test article [TPTA]. It was a full-scale test article but it only had two Reusable Solid Rocket Motor segments and two domes. What we would do in that TPTA is put slabs of propellant in and simulate the rise rate with the correct temperature and pressure. Then we put flaws in our joint design. We tested our

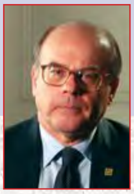
"Before Challenger, we all were worried about our little area of the world. I was worried about hold-down studs because that's what I worked on. After Challenger, we realized that we were all in this together."

joints to see that they could withstand flaws. It made it much safer. We were able to start taking more risk in our test program after Challenger. We were capable of running full-scale tests with full-scale pressure with the right loading to demonstrate that our designs were good. That was something we had never done before. We had never done a full-scale flaw program before Challenger. It really changed how we saw the motor. That's the reason the Shuttle Solid Rocket Motor is the safest solid rocket motor today. We even did a full-scale solid rocket motor test, full burn over two minutes out at Utah in the test stand, a static test called PVM-1 [Production Verification Motor-1]. We actually scarred the metal in the crevice joint to get gas to the O-ring to show that the O-ring would seal. We did a lot of things differently after Challenger.

We might put a cut in an O-ring to see how the joint responded. When you did that, you would guarantee gas to your secondary O-ring, that was one of the things we had never done. We had a lot of comfort before Challenger because we had two O-rings. So if one fails, you have the second one. But if you are never able to test that, then you are not sure the design is acting the way you think it should. That was a change in how we did business: that full-scale flaw testing.

It's like everything else. You learn from your mistakes. Challenger was a terrible thing. We lost seven of our very good friends. But it did force us to go back to look at how we designed things and how we tested them to make sure they actually performed the way we thought they would. That is probably one of the biggest things that came out of Challenger: how we changed our test program.

Tommaso Sgobba, *who was an aeronautical engineer before becoming chief of the European Space Agency's independent safety office in 2007.*


TOMMASO SGOBBA

I was recruited by ESA two and a half years after the accident. There were a lot of reverberations inside ESA, which had technical implications and organizational implications. At the time of the accident, the ESA safety organization was at the division level, which is a layer below department and department is a layer below directorate. Because of the accident, the ESA Product Assurance and Safety Division was promoted to the level of department. The idea was to create a centralized function that would have an oversight on all projects.

"Before the Challenger disaster, managers had no idea what a decision meant in terms of risk."

Quantifying risk>> One aspect that changed was how a manager decided to take a risk. Before the Challenger disaster, managers had no idea what a decision meant in terms of risk. NASA [after the accident] recruited experts in probabilistic risk assessment from the nuclear industry. The idea was to quantify the project's various risk factors. That analysis showed that space debris was one of the five top-level risks for the shuttle. Later it was found to be the top-level risk for the space station.

One of the things that people criticized after the accident was the so-called normalization of the anomalies. That means that anomalies occurred in the past but there were no consequences, therefore these things were considered acceptable or "normal." This happened for the Challenger because the seals eroded on earlier flights but nothing had happened. The same thing happened with the shedding of foam that years later led to the Columbia disaster.

Unsolved management conundrum>> The big issue at the core of the Challenger disaster is still unsolved: how to separate the safety responsibility from the project manager's responsibility. The project manager is tasked with flying a complex machine and achieving the mission within certain cost constraints Congress has allocated to the project. If a safety manager raises a problem, there is always someone else arguing that the problem is not as risky as the safety manager believes. These problems are never black and white. The project manager also has to consider a myriad of constraints like launch windows. If you do not launch, the rocket will be on the ground. Other customers are waiting to launch. Money will be lost. All this together creates a situation in which managers tend to believe what they unconsciously want very much to believe. Sometimes they are right. Sometimes they are just lucky.

There was only one tiny part of the shuttle program in which safety responsibility was separated from the project manager's responsibility. This was for the shuttle payloads. In the early days, the shuttle was meant to replace all expendable rockets for launching satellites. Payloads were typically developed outside the shuttle program. The shuttle program established rather conservative rules, and payloads had to meet those rules or they did not fly. NASA exercised this authority, through the payload safety review panel chairman reporting to the program manager, rather strongly and successfully. Harold Battaglia, one of the early payload safety review panel chairs, was a living legend in this respect.

Rhea Seddon, *a veteran of three space shuttle flights, who together with Challenger crew member Judith Resnik was part of the first astronaut cadre to include women*.


RHEA SEDDON

I remember it quite clearly. I was at an off-site building for a meeting. We turned on the television to watch the launch. It was such a beautiful, clear day. We had heard all the news about the ice. I think everyone was afraid that icicles would break off and go up in the engines. So as soon as the launch got off the ground we were in our usual state of elation. Then something happened. We saw the boosters come off and realized it was too soon. For some reason the tank and shuttle were still flying. Then it became obvious that big chunks of stuff were falling in the ocean. I immediately went back to the space center. It was a bad day. A lot of sadness, worry and activity trying to figure out what we had to do next.

Not unbreakable>> There were a number of things. First, it became a reality that we could lose a vehicle in space. We had dodged bullets in the past and thought we were unbreakable and safe. We realized that we weren't.

Planning for the unthinkable>> Secondly, we realized we didn't have plans in case this happened. We had to quickly figure out: Where are the crew members' families? Who do the spouses want here with them? How do we get them back to Houston? Are their kids all here or are they back home with the neighbors? It was a very difficult time to go through the recovery and the Rogers Commission. We all tried to do everything we could to help the families who were going through untold horror, too much publicity and difficult times. Then we all had to make an assessment of whether we were willing to stay [in the astronaut corps] or not. By the time it was clear we were going to continue to fly space shuttle and the redesign of the boosters had been completed, my husband [former astronaut Robert "Hoot" Gibson] and I both had flight assignments. We were committed to those flights and those crews that we had been training with. So it was a fairly easy decision for us. I don't think either of us thought spaceflight was completely safe. So we made the assessment that we would stay. But we had friends who decided it was time to move on. Some had spouses that didn't want to face that.

"There was a big turnover of leadership ... I think the changes were for the better, but it was a terrible time to go through."

There was a big turnover of leadership. That always brings change and new says of doing things. A lot of us wondered what the new NASA was going to be like. We were encouraged by things like the Family Support Plan for astronauts and their families. We had good leadership. We had found the problem and it wasn't unsolvable. It allowed us the time to look at other systems and the reliability of those. We got through it. I think the changes were for the better, but it was a terrible time to go through.

June Scobee Rodgers, *wife of Challenger Commander Dick Scobee, founding chair of the Challenger Center for Space Science Education, which established an international network of Challenger Learning Centers, and author of "Silver Linings: My Life Before and After Challenger 7."*


JUNE SCOBEE RODGERS

I need to go back to the first time Dick Scobee flew in space. He flew as a pilot on [Challenger's 1984] STS-41-C [mission]. When he came back from that important flight, he whisked me aside and said I want to tell you first what it was like. So off we went to our favorite restaurant. The stars in his eyes were as bright as those in the sky as he talked about the mission. It was the first time they repaired a satellite in space. Toward the end of his discussion, I said, "Didn't it make you mad that President Reagan mentioned every person's name on the crew during his phone call to you all but he forgot your name?" Dick said, "Oh no June, what was important was the mission."

Now to move forward, he is the commander of 51-L [Challenger's 1986 mission]. At first it was a five-person crew and then they added a teacher. I was ecstatic. I was a college professor. His dream was to be an astronaut, mine was to be a teacher. I grew to know and love Christa and worked with her on her assignments. She was a history teacher and a little uncomfortable with the science. We worked through it. She was in my home regularly. Their mission became known as the Teacher in Space mission. I was thrilled to be a part of all of it. Dick and I had been married 26 years. We married as teenagers, worked to help each other through college, careers and two wonderful children. Then he's at the top of his goal in life, being a commander of a space mission, and I'm so excited because it involves education. We [were] standing with all the families when we lost the Challenger and we lost that beloved crew. It was the most painful time in our lives. It was stunning, numbing shock. Our personal grieving became much more public. We were at Johnson Space Center a few days later for a memorial service for the crew when President

Reagan spoke. I was sitting next to Nancy Reagan when the missing-man formation flew over. So many times before with my military husband, we had seen that formation for friends who had died. The idea behind it is that one pilot flies out of the formation straight toward the heavens in honor of the person who has died and those remaining will continue the mission. I looked to those planes and said I cannot help NASA with their mission but I can continue that education mission. I brought the families together soon after that. By April, we had formed our nonprofit foundation. They elected me chairman. It was a struggle for a couple of years, but there were just enough people who joined our effort. The best person of all was then-Vice President George H.W. Bush.

"I was sitting next to Nancy Reagan when the missing-man formation flew over. So many times before with my military husband, we had seen that formation for friends who had died."

I wanted to create something like a computer game but instead of one student sitting at a computer, there are people working at different stations, a navigation station, a physician station, technology station, all these different areas and they have to communicate. We built the first one in Houston. It's tremendously rewarding to know we have reached millions of youngsters and made a difference in the lives of some. In a way, I think we are filling the inspiration gap until we have astronauts flying to Mars. It's a marvelous tribute to the Challenger crew and their mission, but even more so to the teachers who work every single day who make learning exciting. Since the first center opened in 1988, Challenger Center has educated more than 4.4 million students. There are more than 40 Challenger Learning Centers around the globe serving hundreds of thousands of kids each year.

Allan McDonald, *Morton Thiokol's top official at Cape Canaveral for the Challenger launch, and author of the book "Truth, Lies and O-Rings: Inside the Space Shuttle Challenger Disaster."*.

ALLAN MCDONALD

As horrible as that day was, which it was, it was most horrible for me because we tried to stop the launch the night before. After hearing the forecast, our engineers in Utah worried whether the O-ring seals would operate properly. The projected temperatures were a long way from the temperatures we had flown the shuttle in before. Because of that concern, the engineers contacted me. I was the senior Morton Thiokol person at Cape Canaveral. They asked me to get actual weather forecasts at the launch site so they could calculate the temperature of the hardware. I agreed to do that. I told them that when I provided that information, I wanted them to get all the engineers together, assess the impact of the temperature and have the vice president of engineering make a specific recommendation on the lowest temperature that would be safe to launch.

Fateful conference call >> I arranged a meeting with the NASA folks at Kennedy Space Center and tied in the engineering folks in Huntsville, Alabama, at the Marshall Space Flight Center on a conference call with our engineers. The Morton Thiokol engineers presented what they knew and didn't know. Bob Lund, Morton Thiokol's vice president of engineering, concluded by saying he would not recommend launching the shuttle in temperatures below 53 degrees Fahrenheit, which I fully agreed with. NASA management really surprised me by challenging the basis for our recommendation. I had been in the program for about two years, and in previous flight readiness reviews, I was always challenged as [to] why I felt it was absolutely safe to fly. We always delivered some hardware that had some very minor defects. In the past, I always had to prove to them beyond a shadow of a doubt that the defect did not compromise shuttle safety.

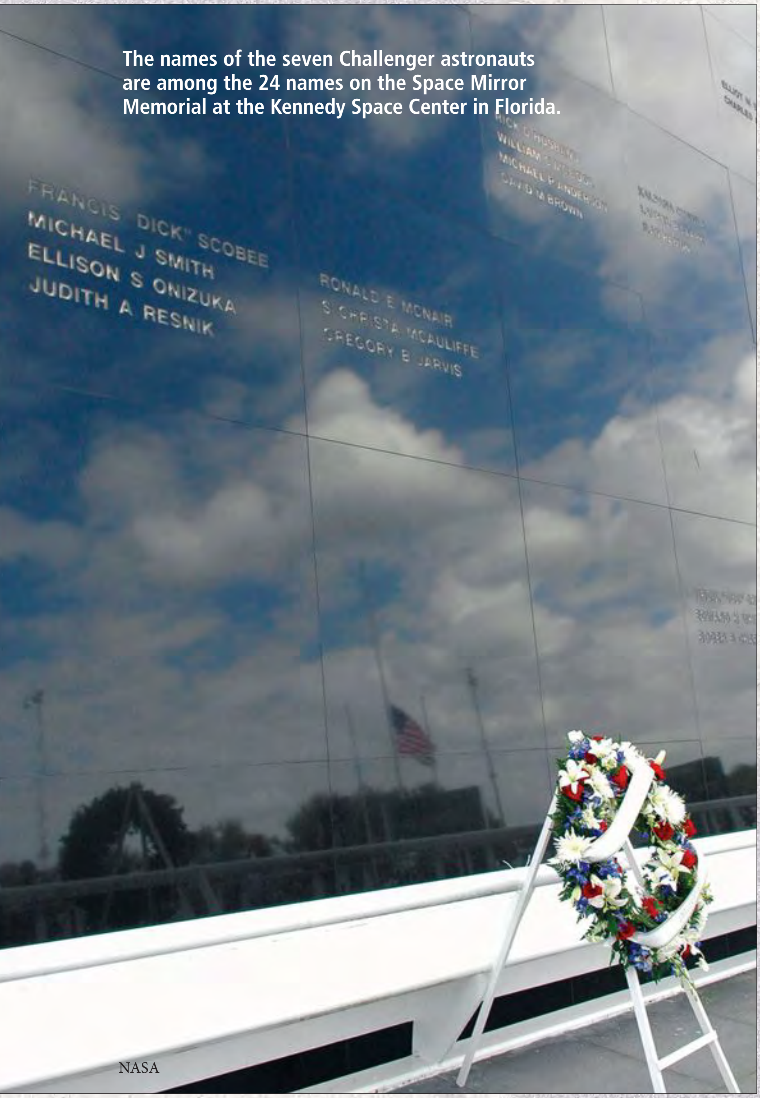
NASA's eagerness to fly >> We recommended against flying and they would not accept our recommendation because it was based on a qualitative observation. We didn't have any good test data or analysis that said it would not be okay to fly at those temperatures. Our recommendation was based on an experience.

Sooty O-rings >> After a flight one year earlier in January of 1985, when we pulled apart boosters that had flown, we saw soot trapped between two O-rings. We have two O-rings in the Solid Rocket Boosters for redundancy because that's a critical function. We had never seen that soot before and couldn't understand what was unique about that flight. We concluded that it was the temperature. The flight was preceded by the three coldest days in Florida history. Now, NASA was challenging the Morton Thiokol position that it was unsafe to fly.

My boss, Joe Kilminster, said [during the telephone conference], "We'd like to take some time off on a caucus to make sure we presented everything we had." They allowed him to do that. He asked for five minutes. It was a half hour before he came back on. This time Joe Kilminster said they revisited all the data and concluded that its okay to proceed with the launch as planned. He didn't give any specific temperature, which also took me aback. [Kilminster told the Rogers Commission that he changed his mind after analyzing the potential for erosion in the primary O-ring seal and concluding that "we were in the condition of having a safe position for recommending a flight."]

Refusal to sign off on flight >> I refused to sign [the launch recommendation], which I said in my book was the smartest thing I ever did in my life. As a result, my boss had to sign it. I was so upset by all that, I argued for over a half hour. I told the NASA folks that I didn't care who made the decision, I didn't care if it was the CEO, I said they couldn't accept it because "you know and I know those motors have never been qualified to the environment you are asking us to fly in. As far as I am concerned, they are supposed to be qualified from 40 to 90 degrees. I know they were never tested there but there was analysis done at 40 that said they'd be okay."

They just stared at me. I said, "If I were the launch director, I would cancel this launch for three reasons. The first one is this discussion on the affect of temperature on the capability of the O-rings. Also, I talked to our head of space services. He is in contact with our ships at sea to retrieve these boosters. They are in a survival mode. They are in seas over 30 feet with winds over 50 knots gusting to 70. They won't be in the recovery area in the morning. The third reason was I heard NASA's comments about freeze protection."



The names of the seven Challenger astronauts are among the 24 names on the Space Mirror Memorial at the Kennedy Space Center in Florida.

NASA

NASA had all these water systems at various levels on the fixed surface structure. When they are building up the shuttle and payload and checking it out, they have no freeze protection. They were just going to leave the spigots open so water could drip and the pipes wouldn't break. I said, "If it gets as cold as projected, there is going to be ice all over that place tomorrow morning. It's got to be a big debris issue and may change acoustics. I don't know. I'm making a recommendation not to launch not based on what I know, but based on what I do not know."

They never argued with me. They said, "We'll take those comments in an advisory capacity, Al. These are not your responsibility."

Then I said, "I'll tell you something, I hope nothing happens tomorrow, but if it does, I'm not going to be the person to stand before a board of inquiry and explain why I gave you permission to launch my boosters in an environment I knew they weren't qualified in." That ended the conversation that night.

When I went out there the next morning, the temperature was about 22 degrees. I sat down at my console and put on my headset. The first thing I did was panned the camera on the launch pad. I couldn't believe all the ice. Icicles were hanging on the boosters, hanging on the orbiter, hanging on the surface structure. I thought, "They obviously are not going to launch this. No way." NASA sent an ice team to knock it all down. They did that the best they could and eventually NASA resumed the count.

I didn't find out until later, that ice team also made some temperature measurements on the vehicle and the structure, including the boosters, tank and orbiter. For some strange reason, they reported temperatures of 7 to 9 degrees Fahrenheit at the aft field joint of the right hand booster. That was not reported to the Mission Management Team because the ice team's primary assessment was for the ice on the tank. When the Challenger launched, I figured that if it failed because the O-rings did not work properly, the whole thing would blow up before it cleared the tower. That did not happen. It failed 73 seconds later.

It was horrible. I remember hearing people sobbing in the background because they knew this was not survivable. I kept hearing the Capsule Communicator saying RTLS, Return to Launch Site, and nothing of course coming back.

I thought this whole explosion occurred from a tank or engine failure. The only things that kept flying were the solid rocket boosters. I didn't find out otherwise until I went to the Marshall Space Flight Center the next day as part of the failure analysis team.

Jim Kingsbury, who was the head of science and engineering at Marshall, called and said he'd just reviewed some films and saw fire coming out of the side of the solid rocket booster. I walked in the conference room and told him he didn't know what the hell he was looking at because solid rockets don't go flying around with fire coming out of the side of them. They blow up.

[In a film of the launch from a NASA camera] we saw a puff of smoke coming out at 6/10th of a second after ignition, which indicated it failed at exactly the time we thought it would. Then I knew this whole failure was caused by an O-ring failure in the manner we thought might well happen because of cold temperatures.

One of the hardest things I ever did in my life was to call home and tell my wife about it. My youngest daughter, Megan, who was four then, answered the phone. When she heard my voice, she said, "When is the space shuttle going up, daddy?" I couldn't believe she hadn't seen this but was thankful she didn't. She knew I always came home when the space shuttle went up. I couldn't answer her.

It was a horrible time from then on because I got so involved in the accident and found the problem. Within two or three days, I presented the problem to NASA in detail. It was very clear they didn't want to hear it. I understood that. They were under a lot of pressure to keep the shuttle program going and show they could actually make two shuttle flights a month in a couple of years, which was the goal. They just got blinded by the fact that we didn't have absolute proof that it would fail. We certainly had absolute proof that it wasn't safe.

Looking back on that, the thing that bothers me today more than the fact that it was a bad decision to launch in the first place, was people trying to cover it up later. That to me was a bigger error. When you are under a tremendous amount of pressure and making a big decision in a short period of time, that's tough for anybody. But when you decide to cover it up, that is a decision one makes after thinking it through. To me that's more disingenuous than just making a bad mistake.

It was a very difficult time because then I had to tell a Presidential Commission that what they heard from NASA wasn't true. [EDITOR'S NOTE: When the Rogers Commission convened, NASA officials said they did not know what caused the accident and had no reason to suspect the solid rocket booster joints.]

Rogers Commission learning of O-ring problem>> In his book, "What Do You Care What Other People Think," Dr. Richard Feynman [winner of the Nobel prize in physics and member of the Rogers Commission] said the strangest thing that ever happened was when this fellow McDonald was in a meeting of the Presidential Commission he wasn't suppose to be in and he walked out of the audience and told the commission what they heard from NASA wasn't true. Chairman Rogers was so shocked he asked McDonald to repeat it.

I feel good about that part of it, but my testimony ruined a lot of peoples' lives, both at my company and within NASA. A lot of their friends still have great animosity towards me. The broader spectrum of people was thankful I did what I did.

Immediately after Challenger, when the shuttle began flying again, NASA made a few great improvements. At the time of Challenger, the Mission Management Team was in a separate room and it was 100 percent NASA people. After Challenger, a senior representative from each of the major suppliers became part of that Mission Management Team. If I had been sitting with the Mission Management team that morning, they would have known of my concerns.

"We recommended against flying and they would not accept our recommendation because it was based on a qualitative observation. We didn't have any good test data or analysis that said it would not be okay to fly at those temperatures."

Marshall-Johnson rivalry>> NASA also recognized it had some intimidating managers and tried to create an environment where people feel comfortable throwing on the table anything that bothered them. They told NASA managers, "There may be one person in the room who thought of something that nobody else did and it may be extremely important. If they don't feel comfortable putting in on the table, you've lost it."

I headed up the solid rocket booster redesign [at Thiokol]. I'm proud how well it came out. At the end of the shuttle program, it was the safest piece of hardware on the shuttle.

For at least the first three flights after [Challenger], communications were very open. People were willing to say anything. I saw a huge change for the good. There also was a lot more communication between the NASA centers and between the agency and the contractors.

Immediately after the Challenger accident, I heard people at Johnson directed a lot of anger at Marshall. Marshall and Johnson were competing with each other for a share of the shuttle program and a share of the work. That led to people failing to share information. If that competition had not been there, the Marshall folks would have told the Mission Management Team about their discussion with Thiokol. That might have made the mission management team cancel the launch.