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20 YEARS AFTER STS-107

THE COLUMBIA TRAGEDY AND LESSONS ON SAFETY AND RISK

↑ The STS-107 mission patch featuring the names of the crew members who perished on 1 February 2003 is superimposed on a photo of the sunrise as seen from Space Shuttle Columbia during the STS-107 mission. (Photo credit: NASA)

NASA HISTORY OFFICE
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From the Chief Historian

Flowers frame the names of the Columbia crew carved onto the black granite surface of the Astronaut Memorial Mirror at the Kennedy Space Center Visitor Complex as seen on the first anniversary of the accident. (Photo credit: NASA)

1 FEBRUARY 2003, 8:59AM (CT)—LOSS OF SIGNAL FROM COLUMBIA.

The following hours, days, months, years were painful for NASA. Moving on was difficult. Learning the lessons from the accident was critical. As this year marks the 20th anniversary of the tragedy, we look back in remembrance of the loss of the crew, identify the key lessons learned, and consider how those lessons and their historical context resonate today.

The essays in this issue of *News & Notes* explore the historical context and legacy of the Columbia accident from several perspectives. Earlier this year, I spoke with several NASA leaders to get their thoughts on what they believed to be the most critical points of this history as well as how that history should be applied to NASA's current missions. A few important themes came up consistently in those conversations: the importance of remembering the lessons of the past, the central role of diversity and inclusion to safety culture, a concern about a potential "communication gap" between younger and experienced engineers, and the critical part played by Agency leadership.

Serving as pilot for both STS-92 and STS-112, NASA Deputy Administrator Pam Melroy is no stranger to spaceflight or the Columbia tragedy. In the aftermath of the accident, Melroy was part of the Columbia Reconstruction Team as lead for the crew module and Deputy Project Manager for the Columbia Crew Survival Investigation Team.[1] Melroy remembers the moments after the accident when it became evident that the crew of STS-107 was indeed lost. "There is a mental barrier you cross when you realize there is something that seems so terrible, you can't even think [it] can actually happen."[2]

Melroy points to the importance of the Agency's Diversity, Equity, Inclusion, and Accessibility (DEIA) efforts. Melroy remarks, "the importance to

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↑ Astronaut Pam Melroy spoke to members of the Columbia Reconstruction Team during transfer of debris from the Columbia Debris Hangar to its permanent storage site in the Vehicle Assembly Building in September 2003. More than 83,000 pieces of debris were shipped to Kennedy Space Center (KSC) during search and recovery efforts in East Texas. (Photo credit: NASA)

safety culture [is] that everyone feels safe speaking up and… welcome to have their voices heard.… I think Bob [Cabana] has done a great job, especially with our governance councils, to make sure that people's voices are heard or that he is expecting people to ask hard questions and have that kind of culture in place."[3]

Much like Melroy, NASA Associate Administrator and former astronaut Bob Cabana remembers STS-107 all too well.[4] Cabana came to NASA seven months before the 28 January 1986 Challenger accident—an experience that also left a lasting impact on him. From his time as a test pilot in the Marine Corps, Cabana understood the inherent risks involved in this line of work, that this was "part of our business that we are in…this is gonna happen. But the truth is, it wasn't acceptable. When you go back and read through the Rogers Commission report, it could have definitely been avoided."[5]

Standing 20 years from STS-107, little of the management and leadership structure from 2003 remains at the Agency.

Both Melroy and Cabana noted the importance of maintaining an institutional memory of the accident. Standing 20 years from STS-107, little of the management and leadership structure from 2003 remains at the Agency. Cabana noted a moment from his time as Center Director at Kennedy Space Center in which he asked the audience how many of them were there for the last Shuttle mission, "About a third of the auditorium raised their hands. How do we teach them this lesson?"

Echoing Melroy's comments, Cabana noted the importance of clear channels of open communication and the right to speak up to voice potential concerns:

> It's really important. Every new SES [Senior Executive Staff] that we onboard, I talk to them about the importance of communication, the importance about creating an environment in your meetings that is inclusive, where everybody feels free to contribute without fear, retribution, and how important it is that when you're running a meeting not to tell people what you think, but to get their input first, so that when we make our decisions, we're making our decisions with the best information that we have. We're making informed decisions, and it's really important to have an inclusive, diverse team so you get all the data to make that informed decision.[6]

Talking with NASA leadership about the Columbia tragedy invited me to reconsider a few seminal works on the issues of design and accidents. There exists a vast literature on the topic of design, risk, and characterization of accidents. Three in particular offer analyses and frameworks useful to contextualizing the lessons of STS-107 and

↑ Astronaut Bob Cabana, Director of Flight Crew Operations at Johnson Space Center at the time, spoke on 6 February 2003 at a special memorial ceremony at the Washington National Cathedral, honoring the Space Shuttle Columbia crewmembers. (Photo credit: NASA)

From the Chief Historian (continued)

are reflective of the common themes that emerged in the conversations with leadership.

Professor of Engineering at Duke University, Henry Petroski, argues that "design is Janus-faced, looking always backwards and forwards." In his formulation, the past serves as both a source of inspiration and imperfection to be improved upon. Petroski's key insight is that this "repository of downright failures, monuments to ignorance, excessive optimism, and hubris" offers the engineer a choice: "If heeded, the past thus provides caveats and lessons for future designs. If shunned, it will still haunt the future, always lurking in the shadows of success."[7]

One of most impactful contributions of sociologist Diane Vaughan to the topic is the concept *normalization of deviance*. Here, Vaughan contends that, over time, an unsafe practice becomes "normalized" or accepted as its continued manifestation in performance does not bring about failure. Vaughan began from the premise that "risk is not a fixed attribute of some object," but something "constructed by individuals from past experience and present circumstance" that was then "conferred upon the object or situation." Since risk was filtered through an individual's worldview, understanding it was subject to different experiences, assumptions, and expectations. For Vaughan, the problem is that a "particular object or situation with a readily ascertainable capacity for harm (like a knife) can be interpreted differently by different people." This problem leads ultimately to uncertainty when the risks associated with the technology were "no longer an immediately knowable attribute of the object."[8]

Like "blow by" and erosion of the Solid Rocket Booster (SRB) O-ring leading to the Challenger accident, foam debris from the External Tank was representative of Vaughan's normalization of deviance. Design requirements were violated by debris strikes similar to what was experienced with O-ring failures on the SRB joint. Even though requirements spelled out that, "no debris shall emanate from the critical zone of the External Tank," foam debris persisted throughout the program.[9] In fact, during the launch of STS-112 on 7 October 2002—just months before STS-107—a substantial bipod-foam debris strike occurred. Pam Melroy was the pilot for STS-112 and noted an occurrence from that Shuttle mission:

> During my second flight, a piece of foam hit the skirt of the SRB and dented it. That should have been a red flag. There was just a belief that foam would disintegrate and couldn't damage anything.[10]

Petroski adds an additional layer to Vaughan's thesis pointing to the contention of Phil Sibly and Alastair Walker, who argued that roughly every 30 years, one generation of engineers replaced another. Using the analogy of bridge design, Petroski argues that new designs usually present a novelty and challenge to engineers. But when older designs or technologies become "commonplace," younger engineers consider them "normal technology," forgetting the "assumptions and challenges" at the foundations. In this success paradigm, engineers develop "no great respect or fear of it." What emerges is a communication gap between one generation of engineers and the next. Petroski makes this explicit to the NASA context, noting that at the time of the Columbia accident, a quarter of the NASA workforce

…when older designs or technologies become "commonplace," younger engineers consider them "normal technology" forgetting the "assumptions and challenges" at the foundations.

From the Chief Historian (continued)

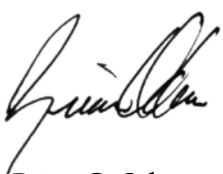
were nearing retirement age and most of the engineers who remembered the hard learned lessons of Challenger had moved on to management positions.[11]

A third, but critically important argument for remembering tragedy was made more recently by Hal Brands and Charles Edel. While their focus is on creating stability in the geopolitical order, Brands and Edel offer lessons equally valuable to NASA's workforce. Exploring the theatrical tragedy in ancient Greece, the authors argue that, for its Greek audiences, "dramatic representations of tragedy were public education" intended "to serve as both a warning and a call to action."[12] Brands and Edel contend that by experiencing the negative lessons of their shared history as a community, "the tragedies pushed the Greeks to grapple with their own frailty and fallibility," forcing "discussions of what was needed to circumvent such a fate."[13]

Each year at the end of January, the Agency recognizes the sacrifices of Apollo 1, Challenger, and Columbia. Reflecting on these three tragedies offers a moment to stop, examine, and refocus our priorities in human spaceflight. As Brands and Edel contend, the Greeks understood that the value of theatrical tragedy was to keep the hard-learned lessons and experiences of the past in the forefront of the viewer's mind—that to forget the painful past only increased the likelihood of its recurrence.

Taken together, these three works offer critical insight into the historical lessons offered by Columbia. The final conversation I had in this series of interviews was with Mike Ciannilli, Program Manager for the Apollo, Challenger, Columbia Lessons Learned Program (ACCLLP) at NASA. While discussing the mission of his critical program, Ciannilli reinforced the message from Melroy and Cabana as well as the purpose of this issue of *News & Notes*:

> If you truly want to plan your course into the future, you have to have a clear understanding of where you've been and that is directly related to Columbia. Understanding the conditions and the circumstances that lead us to losing Columbia, we must authentically and clearly understand what those were. Going forward, NASA has a very exciting and challenging future. But to realize that, we must understand the significant challenges in getting there. When we look back to the past as our roadmap, we can see the missteps that came at a high cost.[14]



Brian C. Odom
Chief Historian

Reflecting on these three tragedies offers a moment to stop, examine, and refocus our priorities in human spaceflight.

Endnotes

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Remembering Columbia

NASA Leaders Reflect on Their Experiences

» Interviews by **Brian Odom**, NASA Chief Historian

IN JANUARY AND FEBRUARY of this year, I discussed the lessons from the loss of Space Shuttle Columbia on 1 February 2003 with several current and former members of NASA's leadership, inviting their perspectives about the value of this history. During our conversations, I asked each of them about their own experiences during the Columbia accident, how those experiences impacted their careers moving forward, and about how the lessons of Columbia might inform our current missions.

Jody Singer
DIRECTOR OF THE MARSHALL SPACE FLIGHT CENTER

Read her NASA biography

Personal Experience

Columbia was my first launch as the Reusable Solid Rocket Motor (RSRM) Project Manager. We had what we thought was a successful launch. The motors had performed as expected. What we didn't realize was that the External Tank debris issue was more than a maintenance issue; it was a flight critical issue. I remember where I was and what I was doing that morning: I was at home, watching the Columbia landing on the TV. I watched in disbelief and listened for news about the fate of the astronaut crew. It seemed immediately that my world turned upside down. I began receiving calls about the accident and began calling my team into work to start the mishap investigation.

Moving Forward

Being new as the RSRM Project Manager, I had to rely heavily on the team, especially the NASA Chief Engineer, Steve Cash, my deputy Rick Burt, and my counterpart at the prime contractor (ATK), Cary Ralston.

From a leadership perspective, Columbia helped reinforce for me the importance of having a team that feels empowered, trusted, and valued; creating an environment where the team feels free to speak up; the importance of knowing that not one person has all the information and expertise to get the best answer, rather it's the combined efforts of a diverse and united team; and the importance of a well-trained team that pays the lessons learned forward.

Lessons for Current Missions

For me [the Columbia accident] reinforces the need to make sure we "pay it forward" to the team so that we don't make the same mistakes. Not forgetting about the past helps remind us of how hard human space exploration can be: we can be more cost efficient, but can't afford to make uninformed decisions. Human spaceflight and what we do is risky, but we can't be so risk-averse that we sit on the ground. What we do is important for our Nation, our economic and technological growth, and for inspiring the next generation. I can't imagine our lives without exploration, science, and the technological development benefits we get from pushing for the impossible. The importance of a clear understanding of roles, responsibilities, and accountability has always been critical, but it is even more critical today as we rely heavily on partners (commercial and international) and as the government is expected to be less involved.

W. Russ DeLoach
NASA CHIEF OF SAFETY AND MISSION ASSURANCE

Read his NASA biography

Personal Experience

I was the Chief of the Shuttle Processing Quality Engineering Branch at the time of the accident. It was a beautiful Saturday morning, and I was coaching a soccer game when I got a call on my Blackberry. One of my folks was on the Shuttle Landing Facility and they told me that Columbia had not arrived as scheduled. It was a most surreal conversation. It was hard to imagine what was going on and where the vehicle was, but my mind did not first go to a catastrophic accident. I guess we wanted to believe there was some strange occurrence that would shortly be understood, and she would be landing soon. Of course, not long after that initial call, it became very clear that the worst had happened.

After the accident, we quickly shifted to a recovery operation, and it was intense.

KSC Safety and Quality personnel were highly desired in the field in East Texas as we had hands-on experience and could recognize the hardware. My role was identifying people with the right expertise and managing rotations to field sites. Getting volunteers was not difficult, everyone wanted to "do something," a way to deal with our grief. But the field work was both physically and emotionally demanding, and people could push themselves too far. Recognizing and managing the stress in others became a major focus of my role in Columbia recovery.

Moving Forward

As I reflect on my experiences in the aftermath of the Columbia mishap, I would say two things stand out as lessons that have affected my approach to work. Firstly, be very careful about what you classify as "routine." This is probably similar to the concept of normalization of deviance, but perhaps more subtle. Over time, as things go right, we can lose appreciation for the difficulty and risk associated with the mission. That is a mindset I am forever more conscious of avoiding. And number two, we have some incredibly talented and passionate people who work for this Agency, and sometimes they need help in not taking on too much. And the greater the pressure, the more important it is for leaders to recognize and manage our workforce's stress.

Lessons for Current Missions

We all know that space flight is hard and brings with it inherent risk. We work every day to make risk-informed decisions and mitigate and accept risks based on the information available. But with the Columbia accident—just like with Challenger before it—we see that it isn't just the technical risk we need to guard against. Our missions are also impacted by human and organizational behavior. The root cause of the incident was a foam strike that breached Columbia's left wing leading edge. The program had seen foam shedding on every Shuttle flight without any major consequences and therefore determined that foam wasn't a problem. Normalization of deviance, a process where a clearly unsafe practice comes to be considered normal if it does not immediately cause a catastrophe, was occurring just as it had on Challenger with the O-rings. As an organization, we were repeating the same behaviors with Columbia as we did with Challenger. We start to think things are acceptable simply because they haven't caused a problem, allowing success to blind us to the need to fully understand anomalies. There were people who recognized that a consequential foam strike occurred, but their concerns were dismissed as acceptable and never surfaced to higher levels of the organization. The same organizational silence factors that doomed Challenger were repeating themselves years later and contributing to the loss of Columbia and her crew. As an agency we must establish a culture of openness where everyone feels safe reporting concerns without fear of reprisal. We must work hard to listen to each other and speak up when we have concerns. And leaders need to guard against their own cognitive biases.

People put more emphases on safety or safe practices when a past experience has impacted them personally. The percentage of NASA's civil servant workforce that did not work here during the Columbia or Challenger accidents is staggering. Over 60% of the current workforce was not here for Columbia and over 90% was not here for Challenger. That means the vast majority of our employees do not have those personal ties to those hard lessons, putting the onus on those of us that were, and on leadership, to keep those lessons alive. Only through our continued sharing of these stories can we prevent history from repeating itself. One way NASA aims to do this is through requiring all NASA civil servants to complete a case study focused on key lessons each year in conjunction with the Day of Remembrance. When you look back at the Challenger and Columbia accidents you can clearly see the similarities in their contributing factors. The NASA Safety Center lays out these lessons and others in the annual Day of Remembrance case studies to keep our workforce vigilant. Safety is NASA's first core value—it is the cornerstone upon which we build mission success. We must all resist complacency. We cannot remain silent if we see something we feel is unsafe. And we have to allow people to come forward with their concerns without fear of repercussion.

From a Safety and Mission Assurance perspective, programmatic changes came about as a result of the Columbia investigation.

NASA implemented the Technical Authority (TA) model to ensure that engineering, health, and safety are able to maintain a level of independence. This creates a healthy tension between the three TAs and Programmatic Authority resulting in a strong system of checks and balances. Technical Authorities also support the Formal Dissent process, which provides a path outside of the program for substantive disagreement to be elevated in certain

Remembering Columbia (continued)

cases all the way to the Administrator if necessary. And of course, the NASA Safety Reporting System, implemented after the Challenger accident, still provides a direct way to report concerns anonymously.

NASA also introduced the Safety Culture model. The model is based on five criteria, or factors, (reporting, just, flexible, learning, and engaged) that when implemented together result in an environment where safety is a priority and everyone works safely, feels comfortable reporting safety concerns, learns from mistakes and successes, and feels confident balancing challenges and risks while keeping safety in the forefront.

We have the opportunity to NOT repeat the mistakes of the past. We can create a safer and more successful future. However, to do so, it takes a great deal of focus, hard work and unwavering commitment on everyone's part.

Ralph Roe
FORMER NASA CHIEF ENGINEER

Read his NASA biography

Personal Experience

At the time of the accident, I was responsible for the Space Shuttle orbiter fleet and a member of the Space Shuttle Program leadership team. The important first-hand experience I would convey to future Program/Project Managers is the environment we were dealing with just prior to the accident is very similar to the environment that every program or project must deal with today.

There was schedule pressure, the future of the Shuttle Program was uncertain at the time, and we were attempting to complete construction of the International Space Station (called Core Complete) by February 2004. This required a very aggressive manifest with little to no margin and we had to report to Headquarters every month on how well we were doing on that schedule. Someone even had the "great idea" of putting countdown clocks on our computers, so whenever your computer went to sleep you would see a countdown to February 2004. That was just a symbol (and a bad idea), but there definitely was schedule pressure. There was budget pressure. The Space Shuttle did not achieve the efficiency first envisioned for a reusable spacecraft, and many in Washington, D.C. felt the Space Shuttle Program was too expensive and should be terminated to free up budget for future programs.

To reduce the cost of the Shuttle Program we spent much of the last half of the 1990s reducing the Shuttle workforce by 50%. We also studied Shuttle privatization, thinking a private company could operate the Shuttle less expensively. Just prior to the accident, we transitioned our prime orbiter contractor, Boeing, from Huntington Beach to Houston, Texas, again to reduce costs. Unfortunately, we only captured about 20% of the Boeing workforce and lost a great deal of experience and expertise.

There were many technical challenges in the Space Shuttle Program. We even coined a term at the time, "Orbiter Scramble," because it seemed our orbiter team was always scrambling to develop flight rationale for technical problems on our next flight, even while we were on the launch pad. The worst part is our normal processes didn't seem to catch the problems, but rather technicians and engineers made "diving catches" and heroic efforts to uncover these technical problems. Every program will have similar schedule and cost pressure and will have to deal with many technical challenges. What is important is how you deal with those pressures. In hindsight, at the time of the Columbia accident our team did not deal with those pressures well, so we want future programs to learn to deal with those pressures better than we did.

Steve Stich,
PROGRAM MANAGER FOR NASA'S COMMERCIAL CREW PROGRAM

Read his NASA biography

Personal Experience

At the time of STS-107 I was working as STS-107 Orbit-1 Flight Director in Mission Operations and Weather Flight Director for launch and landing. I was on the Flight Director console with LeRoy Cain when the accident happened. I knew the crew very well, having worked with them on the mission design and in preparing and training for the mission.

I participated in the accident investigation on a NASA scenario team that worked to determine the cause of the accident. We laid out 10 scenarios that could have been the initiating event for the events that unfolded during Columbia's entry. We methodically attempted to match the data that we had from the recovered debris, the telemetry data in real-time, and the data recovered from the MADS [Modular Auxiliary Data System] recorder. The team was able to determine that failure of the left wing leading edge Reinforced Carbon-Carbon (RCC) thermal protection system (TPS) associated with the debris impact matched all the data.

Moving Forward

Columbia was a life-changing event for me. It was certainly one of the worst days of my life, and absolutely the worst day of my 35-year career at NASA. We had failed the crew as a team and as an organization.

On a personal level as I contemplated the accident cause, I realized that I did not know as much about the Space Shuttle design as I should have in my operational roles in the Mission Control Center (MCC). I began to dig into problems outside my area of expertise to understand the vehicle better in terms of materials, stress analysis, and so on. This allowed me to become a better engineer, manager, and flight director and to gain experience such that I could evaluate on my own whether a risk was reasonable to fly with or whether hardware needed to be replaced, for example. I worked to learn more and more details on each and every problem that we encountered for the rest of my time on the Space Shuttle Program.

I also learned that the Program and Engineering teams needed to give the operations team the best possible vehicle for flight. Although the operations team can remedy certain failures and develop workarounds, there are many elements of the vehicle (e.g., structure, tanks, propellant lines, thermal protection system) that must work as designed. I began to focus more on solving problems before flight versus building contingency procedures for second and third level failures.

I left the operations area in 2008 to join the Space Shuttle Program. I have been in Program or Engineering organizations ever since. I have been in the Commercial Crew Program since late 2015.

Lessons for Current Missions

Human spaceflight requires constant attention to detail. Every aspect of the flight needs to be constantly examined, including in-flight data, post-flight inspections, imagery, and more. We need to continue to dig into items each flight that do not appear to be performing as designed. Loss of foam was occurring on many Shuttle flights, back to STS-1, yet little was done to understand, rectify, or bound the potential damage or in-flight impact.

Sometimes we can see subtle signs of potential issues in the pre-flight testing phase when data is examined very carefully. When we find those items, additional testing, analysis, and in some cases a redesign may need to be performed. There is no substitute for understanding the hardware and systems that we are flying. We need to have a learning culture where we continuously evaluate how the vehicle is performing in flight. Many times, additional analysis and testing may not totally reflect the way that the vehicle is flying. There is no room for complacency and overconfidence in human spaceflight.

Human spaceflight is inherently risky, and it is far from 100% safe even after all the years of U.S. and Russian flights. It is critical to maintain the right skills and experience within the contractor and NASA workforce to verify that the vehicles are flying as designed. Engineers with the right skills and attitude are critical to fly safely. They need to be hungry, dig into data, examine the hardware, and evaluate how the design is performing.

G. Reid Wiseman,
FORMER CHIEF OF THE ASTRONAUT OFFICE

Read his NASA biography

Lessons Learned

To me, we should always demand data, even when it seems obvious what the answer should be. Can foam insulation damage the orbiter? The simple answer seems to be "absolutely not." But without data we should not jump to that conclusion. Additionally, the current review processes with program managers and tech authorities, to include the crew onboard, are absolutely critical and should always be held with complete openness, willingness to listen, and willingness to do the right thing.

Moving Forward

In the Astronaut Office, the Columbia crew and their patch are displayed front-and-center in our conference room. There is not a day that goes by that we don't think of them, the Challenger crew, and the Apollo 1 crew. Whether working on a new vehicle design, sitting in Flight Readiness Reviews, or operating these spacecraft, we are constantly reminded of those who have gone before us and the knowledge we gain from their sacrifice. ■

Columbia's Impacts Today

How the Lessons Learned from the Tragedy Continue to Shape NASA's Choices

» By **Jennifer Ross-Nazzal**, Historian, Johnson Space Center

The STS-107 crew poses for their traditional in-flight crew portrait in the SPACEHAB Research Double Module aboard Space Shuttle Columbia. From the left (top row), wearing blue shirts, are astronauts David M. Brown, mission specialist; William C. McCool, pilot; and Michael P. Anderson, payload commander. From the left (bottom row), wearing red shirts are astronauts Kalpana Chawla, mission specialist; Rick D. Husband, mission commander; Laurel B. Clark, mission specialist; and Ilan Ramon, payload specialist, representing the Israeli Space Agency. On 1 February 2003, the crew was lost with the Space Shuttle Columbia over North Texas. This picture was on a roll of unprocessed film later recovered by searchers from the debris. (Photo credit: NASA)

IN THE AFTERMATH of the Columbia accident, families of the STS-107 crew hoped that NASA would realize valuable lessons from the tragedy and remain vigilant in their responsibility to keep the crew safe so that no other loved ones would have to experience that pain of loss. Rona Ramon, wife of Payload Specialist Ilan Ramon, said, "A lot has to be changed so that it won't happen again. Lessons will be learnt from this for the future."[1]

Since the accident, the Agency retired the Space Shuttle in 2011 and is now preparing to return astronauts to the Moon for the first time since 1972. Even though more than 20 years has passed since this tragedy, a direct link can be drawn between the loss of the Columbia orbiter and its crew to the changes made by Agency management since that time. Leaders from Johnson Space Center (JSC) and Headquarters believe that the hard lessons learned following the accident and the subsequent changes put in place have permanently altered NASA's perspective about flight safety and its Safety organization, reshaped the Agency's communication style, and established the idea of an independent Technical Authority. The shock from the loss of Columbia was so tremendous that it influenced the design of both the next generation of crewed spacecraft, the Orion Multi-Purpose Crew Vehicle (MPCV), and the spacesuits to better protect the astronauts. So much has changed that Nathan Vassberg, Deputy Director of JSC's Safety and Mission Assurance (SMA) Directorate, believes that this "accident had more sticking power than either Apollo 1 or the Challenger."[2] Recently Deputy Administrator Pamela A. Melroy told NPR, "We are very proud of the lessons that we've learned, and we're incorporating them now."[3]

Part of this change can be attributed to the willingness with which NASA's leaders share their memories of the crew, the mission, and the deep scars they carry with them every day with employees who were not at NASA in 2003. This year, employees learned how that loss still haunts some in the workforce. Across the Agency, those who worked on the flight openly shared their recollections of Saturday,

← NASA Associate Administrator Bob Cabana recalled his experiences as Chief of the Flight Crew Operations Directorate during the Space Shuttle Columbia tragedy at the NASA Day of Remembrance Employee Safety Town Hall, on Tuesday, 24 January 2023, at NASA Headquarters. (Photo Credit: NASA/Keegan Barber)

1 February 2003, and the events as they remember them, so that no one will forget the heartbreak. Through tears, Melroy recalled that Saturday morning at Kennedy Space Center when she was serving as a Cape Crusader and waiting to welcome home the STS-107 crew and help them off the Shuttle, and the moment she first realized they weren't coming home. Serving as Chief of the Flight Crew Operations Directorate at the time, Bob Cabana, also waiting on the runway in Florida, had the difficult job of informing the families that their loved ones had died.[4] Former Chief Engineer Ralph Roe said, "If you're blinded by the successes that you have, you don't think critically enough about issues. That will stay with me forever," when talking about the lessons acquired from the event.[5] Others have wondered what else they could have asked about the foam strike that might have made a difference. The vulnerability of these individuals and the raw emotion with which they recount these memories is one way the Agency emphasizes the importance of doing everything possible to ensure everyone understands the need for flight safety.

Beyond hearing first-hand experiences of this fateful day, the decisions made and their repercussions pertaining to the Columbia accident remain front and center in the minds of employees through presentations at the NASA Centers and Headquarters, NASA's annual Day of Remembrance, and employee training. SATERN, NASA's online learning portal, offers an hour-long class on the accident, detailing the timeline of events and the changes made as a result. The Day of Remembrance is held every year across the Agency to remember the three flight crews who lost their lives in spacecraft accidents. Cabana emphasized its importance this year when he spoke at the Kennedy Space Center Visitor Complex. "Why do we have a NASA Day of Remembrance?" he asked. "It's so we do not forget the hard lessons learned from Apollo, Challenger, and Columbia … it's so important that [the workforce] learn these lessons so they are not repeated again."[6] The Apollo, Challenger, Columbia Lessons Learned Program, established in 2016 to share "the invaluable lessons of NASA's past to help ensure future success" is another way the Agency is schooling its workforce in the accidents and their consequences.[7] But, talks, classes, and remembrances are just a few of the changes since the accident.

NASA's Safety Program has changed since 2003, when the Columbia Accident Investigation Board (CAIB) described the organization's "flawed safety culture" as "broken."[8] JSC SMA Director Willie Lyles and Deputy Director Vassberg found perceptions of the program have changed across the Agency. People used to see that function as an obstacle to launch; Safety halted the flow of preparation for liftoff as "a traffic cop" might stop cars on the freeway. Today, the Safety organization is a full partner with the space

"If you're blinded by the successes that you have, you don't think critically enough about issues. That will stay with me forever,"

–Ralph Roe, Former Chief Engineer

programs and a trusted adviser when it comes to flying in space. Once viewed as an annoyance, something they had to deal with, program managers today see Safety as their partner, an entity that can help accomplish the mission.[9]

The CAIB Report criticized NASA for organizational barriers that stifled differences of opinion during the STS-107 flight and made it difficult for employees to draw attention to the risks that they saw. Since the release of that report, leadership across the Agency has made a point of stressing that everyone, even new employees and interns, has perspectives that are valuable. Across NASA, employees are urged to speak up if they see something that is not safe. Within meetings, leaders poll team members and ask for other ideas and thoughts on issues. People are encouraged to speak up and share their opinions, and diverse solutions are encouraged. Leadership is encouraged to be approachable and to include everyone. Management, JSC Engineering Director Julie Kramer White says, has an obligation to create an environment conducive to speaking up as well as raising a workforce that is willing to say when there is a problem. This is something that is important to her, and she has shared copies of her talk on "Combating Organizational Silence in Human Spaceflight" across the Center.[10]

One of the most significant changes attributed to the aftermath of the Columbia accident is the creation of a Technical Authority at NASA. The concept was put forward by the CAIB. NASA's Technical Authority, originally its Engineering organization, was later expanded to include two other organizations: Safety and Health/

↑ The redesigned launch and entry suit for the Artemis program, the Orion Crew Survival System, prioritizes crew protection. (Photo credit: NASA)

Medical. The board asserted that there was a need for an independent organization of engineering experts with an understanding of the design and development of the vehicle and its systems to maintain the technical standards for the program. These engineering experts, not the program managers, would review any flight waivers brought forward that were associated with the technical standards and would determine if those deviations were reasonable. In the case of "an anomalous event," Engineering, Safety, and Health/Medical would provide an independent perspective from the program in determining forward action. Technical staff also would sign off on the launch vehicle certification. The primary responsibility of Engineering and the other authorities is technical excellence and characterizing risk, not being overly influenced by schedules outlined by the program or bowing to cost pressures.[11]

Beyond the organizational transformations mentioned above, Kramer White noted that the 2003 accident impacted decisions about the MPCV. In the design phase for Orion there were discussions about a top-mounted capsule vs. a side-mounted vehicle like the Space Shuttle and the possibility of damage from debris on launch. NASA specifically chose a front-mounted capsule because of the "difficulty in protecting a side-mounted vehicle from debris being shed" off the stack. To protect the Orion crew module from debris and the environment, the spacecraft is also launched under an aerodynamic shroud.[12]

Also, the new Orion spacesuit might look like the old launch and entry suit from the Shuttle flights—it's orange—but that's the only similarity. Dustin Gohmert, Project Manager for Orion Crew Survival Systems, attributes the design and development of the Orion Crew Survival System spacesuit to the knowledge gained from the 2003 tragedy. *Loss of Signal: Aeromedical Lessons Learned from the STS-107 Columbia Space Shuttle Mishap*, a book created to share the aeromedical aspects of the accident and the investigation, shaped how engineers thought about protecting the crew.

The Columbia crew suffered from hypoxia and injuries from the acceleration they experienced when the Orbiter tumbled. Spacesuit engineers knew they could solve those issues and set

"I can't overstate the influence that the Columbia accident had on the architecture that we evolved to… It was, without question, the driving factor in the design and the decisions we made."

–Dustin Gohmert, Project Manager for Orion Crew Survival Systems

about doing so. When the crew flew home, their visors were open, not closed. Space Shuttle astronauts usually flew home with their visors open because closing them for extended durations created a potential flammable environment, as suit gas vented out into the crew cabin. (Breathing in 100% oxygen, the crew would metabolize very little O_2, which would eventually create an oxygen-rich cabin, similar to what caused the Apollo 1 fire.) Orion crews will fly home with their visors closed thanks to a closed-loop Environmental Control Life Support System that recirculates the oxygen-rich air in the suits, allowing the crew to metabolize every drop without releasing it into the cabin. In this process, the CO_2 is removed and the air recirculated. The helmets worn by the crew have also been redesigned because the bubble helmet the Shuttle crews wore caused crew injuries. A redesigned seat and restraints also help to protect the astronauts. All of these changes came about from the lessons gleaned from the STS-107 aeromedical report. "I can't overstate the influence that the Columbia accident had on the architecture that we evolved to.… It was, without question, the driving factor in the design and the decisions we made," Gohmert said.[13]

As the recent anniversary made clear, many continue to ask what NASA has learned from the Columbia accident and if it is still relevant to those working on the Artemis Program. The trauma of that event has resulted in changes, many at the direction of the CAIB, and others advocated for by those who lived through the shock and resulting aftereffects of the disaster. Management continues to urge the workforce not to become complacent as they did in the years after the Challenger accident. The opportunity to design, develop, and test a new vehicle has also led to higher expectations to protect the crew and the vehicle. Across the Agency, leaders have prioritized improved communication, challenging employees to speak up and to put safety first. ■

DIVE DEEPER with NASA History Online Resources

- Remembering Columbia STS-107 Mission website
- The CAIB Report
- Ralph Roe's Oral History Interview

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How the STS-107 Accident Enabled a Path for Human Spaceflight Beyond Low-Earth Orbit[1]

» By **Stephen Garber**, Historian, NASA Headquarters

THE COLUMBIA SPACE SHUTTLE accident on 1 February 2003 presented the George W. Bush administration with difficult choices. Could NASA safely resume Shuttle flights to the International Space Station? If so, for how long? With two highly visible Shuttle tragedies and only three operational vehicles remaining, administration officials concluded on the day of the accident that major decisions about the space program could be delayed no longer.

The STS-107 accident had deep technical and organizational culture roots. On the technical side, shedding foam from the External Tank had punctured a hole in a key spot on one of Columbia's wings, leading to the destruction of the vehicle on reentry. While technicians and engineers were aware of this problem, there was simply no definitive way to stop all future foam shedding; instead, NASA's solution was limited to devising a better system for observing foam strikes on ascent. An equally vexing issue was the "normalization of deviance" (a term coined by sociologist Diane Vaughan to describe the organizational culture that permitted the Challenger accident in 1986) in which personnel knew about previous foam strikes but assumed they were tolerable because none of these occurrences produced catastrophic effects before STS-107.

Given this situation, many observers inside and outside the Washington Beltway believed that NASA's very existence was in peril. It wasn't immediately clear that NASA could return the Shuttle Program to safe operations. If NASA couldn't do this, then it had no human spaceflight program, which many saw (and still see) as its raison d'être.

This close-up shows Space Shuttle Columbia as it lifted off from Launch Pad 39A on mission STS-107 on 16 January 2003. A piece of insulative foam from the External Tank struck the leading edge of the left wing (shown here) upon liftoff, leading to the loss of the vehicle and its crew on reentry on 1 February. (Photo credit: NASA)

Soon after the accident, a handful of White House staffers who were knowledgeable about NASA and human spaceflight began meeting informally as the Columbia Accident Coordinating Group. A key factor, if not saving grace, in their deliberations to chart a way forward for NASA was that both President George W. Bush and Vice President Dick Cheney had spoken out publicly immediately after

…many observers inside and outside the Washington Beltway believed that NASA's very existence was in peril. It wasn't immediately clear that NASA could return the Shuttle Program to safe operations.

spaceflight to honor the memory of the seven lost crew members. Such firm presidential support became a touchstone for these staffers whenever other colleagues skeptically questioned the value of human spaceflight.

These staffers invited Office of Management and Budget (OMB) colleagues to join their debates, forming a slightly larger so-called Splinter Group that deliberately did not include any NASA personnel. In May 2003, this group issued a white paper decrying the lack of a "compelling vision" for NASA for decades. The paper also called for strong presidential leadership to reverse the situation and chart a bold new direction for NASA.

In the spring of 2003, Steve Isakowitz (NASA's comptroller, a confidante of Administrator Sean O'Keefe, and a former OMB official) began asking within NASA what kind of relevant long-range planning had been done already. It turned out that NASA had been supporting studies and honing plans for several years in preparation for an opportunity to propose a new mission for the space program.

As early as April 1999, NASA Administrator Daniel Goldin had established the Decadal Planning Team (DPT) to provide a forum for future Agency leaders to begin considering goals more ambitious than sending humans on missions to near-Earth destinations and robotic spacecraft to far-off destinations, with no relation between the two. Goldin charged the DPT with devising a long-term strategy that would integrate the entire range of the Agency's capabilities, in science and engineering and robotic and human spaceflight, to reach destinations beyond low-Earth orbit (LEO).

As early as April 1999, NASA Administrator Daniel Goldin had established the Decadal Planning Team (DPT) to provide a forum for future Agency leaders to begin considering goals more ambitious than sending humans on missions to near-Earth destinations and robotic spacecraft to far-off destinations, with no relation between the two.

Isakowitz conferred with Gary Martin, the leader of the NASA Exploration Team (NEXT), the follow-on effort to the DPT, to find out more. Isakowitz also talked with Goldin's successor, Administrator O'Keefe, about how such strategic planning might fit into that year's federal budget cycle for NASA. Also in May 2003, Isakowitz and Martin gave a joint presentation to O'Keefe entitled "New Directions: Long-Term Goals for Human Space Flight," in which they discussed sending astronauts beyond LEO, a goal O'Keefe supported in principle.

The next month, DPT/NEXT team members held a retreat that became known as the Three Teams Review. The first team looked at sending robotic spacecraft and then astronauts to the Moon as a steppingstone for sending humans to Mars. The second team examined the possibilities for having astronauts assemble large telescopes in space and then travel to Mars (sending only robotic spacecraft to the Moon.) Members of the third team focused exclusively on robotic exploration of space past LEO, but didn't get much traction among their colleagues, understanding that human spaceflight was key to generating public enthusiasm for NASA and thus Congressional funding and White House support.

Meanwhile, the Splinter Group expanded to include NASA staff, and became known as the Rump Group. Early on, its members coalesced around a few core assumptions: NASA should return the Shuttle to safe flight operations, use it to complete assembly of the International Space Station (ISS), and then retire the Shuttle. Additionally, the administration should not raid the budgets of other NASA programs to pay for additional human spaceflight efforts.

In July, the Rump Group produced a white paper that posed several fundamental questions. What would be the final ISS configuration? When could the ISS reasonably be considered complete? What new human-rated launch vehicle would be developed to replace the Shuttle and how long would it take to develop? Relatedly, should the United States maintain an independent, continuous human spaceflight capability (or would we rely on Russia to launch astronauts to the ISS)? More ambitiously, should NASA pursue human spaceflight beyond LEO?

In August 2003, the Columbia Accident Investigation Board (CAIB) issued its much anticipated, multi-volume report. The clearly written report focused not only on technical details, but also on important policy issues. Specifically, the CAIB report pointedly noted that since the end of the Apollo program, NASA had lacked a compelling mission that engaged the public, Congress, or the White House. Technical experts generally concurred that in 2003, the Shuttle fleet was old and needed replacement. Yet previous attempts to replace the Shuttle represented a national failure of leadership or as the CAIB report bluntly stated, a "lack of vision." This dearth of top national leadership on space policy meant that NASA had been severely underfunded for its challenging goals, echoing the Splinter Group's sentiments. The report was a wake-up call to anybody who still thought that NASA could continue to muddle through with the Shuttle program indefinitely.

The CAIB report was a wake-up call to anybody who still thought that NASA could continue to muddle through with the Shuttle program indefinitely.

The sausage-making of the interagency policy process to decide upon a new charge for NASA began in earnest shortly afterwards. Fall 2003 brought many meetings of relevant staffers throughout the Bush administration, as well as Deputies Committee (Deputy

President George W. Bush announces his administration's Vision for Space Exploration policy in the NASA Headquarters auditorium on 14 January 2004. (Photo credit: White House/Eric Draper)

Cabinet officials such as the Deputy Secretary of Defense, Deputy Secretary of State, etc.) meetings. Other senior White House personnel such as Bush's science advisor, domestic policy advisor, and the deputy national security advisor weighed in on space policy in ways that were virtually unprecedented. Two key staff from the National Security Council and the Office of Science and Technology Policy collaborated tightly with key OMB staffers, as well as high-level NASA officials such as Isakowitz, O'Keefe, and John Schumacher, O'Keefe's chief of staff. These and other NASA officials drew heavily from the work of the DPT and NEXT teams. The high-level staff work culminated with a briefing to President Bush on December 19, 2003.

On 14 January 2004, Bush made an unusual presidential appearance at NASA Headquarters to announce the new Vision for Space Exploration (VSE), which included specific timelines for new programs, as well as a broader call for moving beyond LEO. The VSE called for safely returning the Shuttle to orbit, using it to complete ISS assembly by 2010, and then retiring the Shuttle. It also called for NASA to develop a new Crew Exploration Vehicle for astronauts to travel to the ISS, the Moon, and beyond. The VSE's timetable aimed to put astronauts' boots on the lunar surface by 2020. In a more sweeping fashion, Bush's public VSE announcement proposed that sending humans back to the Moon would serve as a proving ground for putting astronauts on Mars, while letting robotic spacecraft lead the way. Much has been written about the human desire to go in person to the Red Planet but suffice to say this steppingstones approach clearly reflected the DPT and NEXT teams' work.

Virtually all the staff and top leaders who helped create the VSE were also keenly aware of the seeming historical precedent of the ill-fated Space Exploration Initiative (SEI) proposed in 1989 by Bush's father, President George H. W. Bush. SEI called for humans to return to the Moon (after Apollo) and then to go to Mars, but the proposal was basically dead on arrival after its enormous price tag became public. The VSE crafters consciously avoided what they saw as the policy errors of 15 years earlier. Overall, the VSE was big on presidential public support, but only called for a relatively small budget increase for NASA to make it happen.

Nevertheless, when the Bush administration initiated interagency discussions in 2003 to consider a new spaceflight strategy, NASA was prepared with technical and policy options, as well as a team of individuals who had spent years preparing for the moment. Although elements of the VSE policy differed from the plans developed by the DPT and NEXT teams, the benefits of preparation were unmistakable.

In less than one year, NASA had gone from seemingly routinely flying the Shuttle, to a major human spaceflight accident that claimed the lives of seven astronauts (as well as two debris search specialists working for the CAIB), to a major new national space policy designed to inspire and carry NASA forward for decades. Key decisions, such as setting a termination date for Shuttle flights and initiating the development of technologies for deep space exploration, heralded a paradigm shift, allowing both NASA and the U.S. space community to move beyond the infrastructure, technologies, and institutional arrangements that had sustained LEO operations for more than two decades.

While the bureaucratic machinery of our nation's capital often churns slowly, this time the process moved quite expeditiously. The tragic Columbia accident clearly spurred action that created the VSE, which led in turn to the Constellation and then Artemis programs. To paraphrase an experienced Washington hand's comment in an entirely different context, never allow a crisis to go to waste, as it's an opportunity to do bold new things.[2] ■

Endnotes

1 This article is adapted from Glen R. Asner and Stephen J. Garber's Origins of 21st Century Space Travel: A History of NASA's Decadal Planning Team and the Vision for Space Exploration, 1999-2004 (NASA SP-2019-4415), especially Chapter 5, "The Columbia Accident and Its Aftermath."

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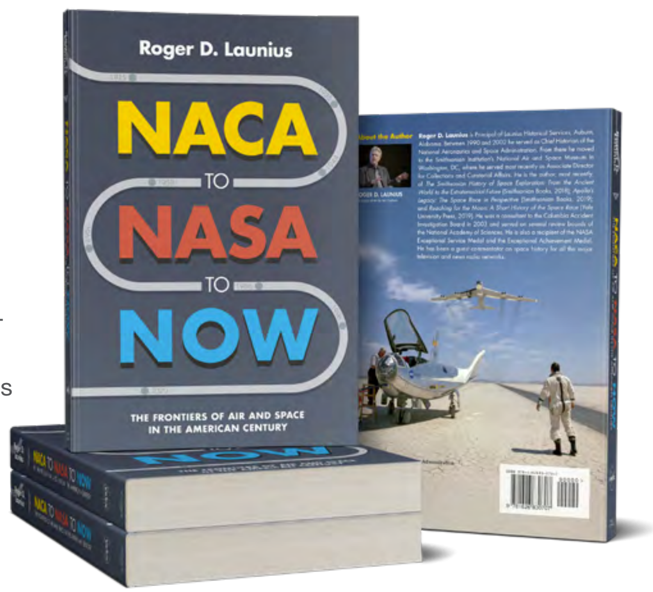

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Langley Research Center: Key Player in Shuttle Return to Flight Effort

» Submitted by **Rob Wyman**, History and Archives Program Manager, Langley Research Center. Adapted from a 2005 Langley Fact Sheet

↑ One of Langley's aerospace engineers inspects a Shuttle scale model inside Langley's 20-Inch Mach 6 Wind Tunnel on 12 February 2003. Inserted into a hypersonic air stream, the model provided surface temperatures and heating rates. (Photo credit: NASA/LaRC)

NASA'S LANGLEY RESEARCH Center, located in Hampton, Virginia, contributed key engineering support to the Agency's massive Space Shuttle Return to Flight (RTF) effort, which culminated in the successful launch of Shuttle Discovery in July of 2005.

One of NASA's four research centers, Langley had played a critical role in the development of the Space Shuttle in the 1960s, 1970s, and early 1980s, including running a series of last-moment confidence-building tests of the glue that held tiles to the surface of the Orbiter in the months leading to the first Shuttle flight in 1981.

After the Columbia tragedy in February of 2003, Langley immediately began to lend its expertise to help the NASA Space Shuttle Program Office understand what happened and how to avoid a similar tragedy in the future. Langley wind tunnel and computer-based studies of Orbiter aero-thermodynamics (aero-heating), for example, were especially helpful to understanding the condition of Columbia during its ill-fated atmospheric reentry.

Langley wind tunnel and computer-based studies of Orbiter aero-thermodynamics… were especially helpful to understanding the condition of Columbia during its ill-fated atmospheric reentry.

Focus on Thermal Protection

Many of Langley's technical discipline areas, including aerodynamics, aero-thermodynamics, structures and materials, systems analysis, and engineering, were tapped to safely return the Shuttle to flight.

These technical strengths were primarily focused on achieving a better understanding of the Shuttle's thermal protection system (TPS)—what can make the thermal protection system fail, how to inspect the thermal protection system without harming it, how to repair the thermal protection system on orbit, and when it was safe to fly even with minor damage.

Inspecting Without Harming

The Columbia Accident Investigation Board specifically called for developing a non-destructive evaluation (NDE) inspection plan for reinforced carbon-carbon (RCC) areas of the Shuttle, to include the Orbiter's wing leading edge.

NDE produces critical information concerning the condition of a structure by using methods that can see beneath the surface without harming it, as opposed to destructive testing methods where the structure is damaged in testing and no longer usable.

NDE methods pioneered by Langley were adopted for ground tests of RCC insulation material on each Orbiter between flights.

Researchers at Langley also helped with the development of a new NDE testing method known as Terahertz imaging used to detect voids and other flaws in the spray-on foam insulation on the External Tank to prevent the materials' failure during flight. The system provided high-resolution, three-dimensional information in real time on the foam area being tested.

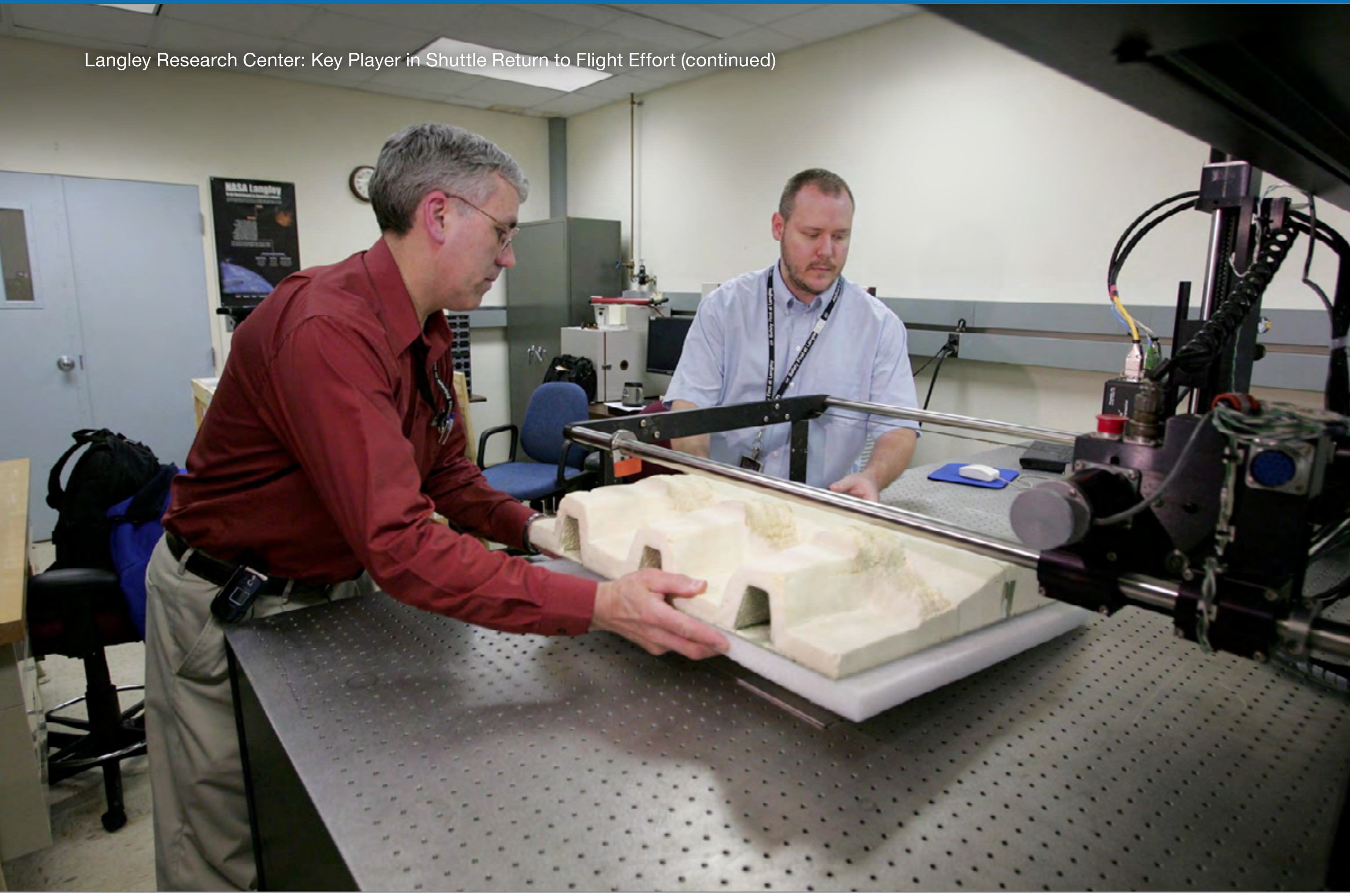
Assessing Damage Effects at Reentry

NASA Langley used hypersonic wind tunnels in combination with advanced state-of-the-art computational fluid dynamics to assess the effects of damage to the Shuttle's thermal protection system (TPS), designed to protect the vehicle from the extremely high temperatures encountered during reentry into the Earth's atmosphere.

Studying the effects of TPS damage included assessing the localized heating environment directly around the damage site and determining the impact the local damage would have on the global heating environment over the Shuttle's entire TPS.

↑ A researcher places a sample of foam like that on the Shuttle External (fuel) Tank into a crushing device to determine how the foam reacts when it strikes something at high speed, as happened during the Columbia mission. (Photo credit: NASA/LaRC)

↑ A bit of precisely sized and shaped tape is placed on the surface of a wind tunnel model for studies of aerodynamic heating during Shuttle reentry, simulating the effects of an on-orbit "plug" repair. (Photo credit: NASA/LaRC)



↑ Langley researchers demonstrated non-destructive methods for detection of flaws in the Shuttle External Tank foam. (Photo credit: NASA/LaRC)

Researchers developed a database to evaluate possible changes in the shape of the Shuttle surface due to TPS damage and their effects on reentry heating. This database, developed through extensive wind tunnel testing and computational analyses, included a close look at both vehicle surface cavities and surface bumps. The database was instrumental in helping to determine if TPS damage sustained during ascent or while in orbit required repair prior to the Shuttle returning to Earth.

Contributions, In Short

NASA Langley:

- Contributed to a better understanding of the material properties of the foam that fell from the Shuttle's External (fuel) Tank.
- Contributed new ways of detecting problems in the thermal protection system for both the External Tank and the Shuttle Orbiter using advanced nondestructive examination techniques.
- Developed physics-based models describing the damage caused by debris striking the Orbiter's tiles and wing leading edge.
- Developed concepts to inspect and repair the reinforced carbon-carbon panels on the Orbiter wing leading edge and supported efforts to repair tile damage.
- Ran wind tunnel tests to ensure that minor damage (cavities) and repairs to tiles or the wing leading edge would not cause a heating problem during reentry.

In all, more than 200 Langley personnel's efforts to find the cause of the Columbia accident played an important role in the Agency's successful efforts to return the Shuttles to flight. ■

Lessons from Columbia

Building a Knowledge Sharing Culture[1]

» By **Tiffany L. Smith**, Chief Knowledge Officer and Director, APPEL Knowledge Services, NASA Headquarters

On 22 January 2003, the crew of STS-107 captured this sunrise from the crew cabin during Flight Day 7. (Photo credit: NASA)

THE LESSONS NASA LEARNED from the loss of Columbia and its crew were profound. Documentation, insights, and reflections from the accident are available via the NASA History Office[2] and in a comprehensive new website from the Office of Safety and Mission Assurance's Apollo, Challenger, and Columbia Lessons Learned Program.[3] Although these lessons are often encapsulated in specific, actionable nuggets of information, the lessons that most inform our culture tend to be unwritten. After Columbia, much closer scrutiny was applied to NASA's organizational culture, the echoes of which continue to resonate and shape the Agency's ways of working and learning today.

While mourning the Columbia tragedy, NASA was prompted to reconsider its previously accepted organizational practices, a necessary introspection that was urged by the Columbia Accident Investigation Board (CAIB). Chartered in the first two hours after loss of signal,[4] the 13-member CAIB worked for almost seven months with more than 120 staff and 400 NASA engineers and reviewed thousands of documents and other inputs to analyze the factors that led to the accident.[5] The CAIB intentionally expanded its purview beyond technical cause to make assessments on organizational culture, including historical factors, decision-making processes, and unintended consequences of organizational and management practices.[6] Many of the Agency's challenges had been acknowledged prior to the STS-107 Columbia flight but were not prioritized or resolved, while others were not sufficiently understood.[7]

The CAIB identified four problematic cultural elements that they linked to the Columbia accident: the assumption that prior success could be taken as evidence to expect continued success; organizational issues that inhibited candid communication; institutionally siloed management practices; and informal authority structures that worked outside the formal system.[8] The CAIB compared these with best practices and made recommendations to correct the challenges they observed. Many of these recommendations have proven evergreen and remain in place as priorities for the Agency 20 years later. The establishment of NASA's Technical Authorities,[9] the creation of the Office of the Chief Engineer's NASA Engineering and Safety Center[10] as a source for independent assessment and expert knowledge, and the Office of Safety and Mission Assurance's leadership to address organizational silence and reinforce safety culture are traceable to the CAIB report.

The CAIB also identified challenges with how NASA learned and applied its lessons,[11] citing a 2001 report by the General Accounting Office (GAO).[12] At this time, NASA's approach to lessons learned concentrated on the use of information technology systems to collect and store lessons in a semi-structured format. While new technologies suggested new opportunities, the GAO subtitled one section of a later report, "Information Technology is Important, but Should Not Be the Only Mechanism for Knowledge Sharing."[13] The Aerospace Safety Advisory Panel reinforced the need for a more comprehensive strategy in 2011 with a recommendation for the Agency to create a Chief Knowledge Officer to serve as a focal point and champion for knowledge sharing practices.[14] Both my predecessors in the Agency Chief Knowledge Officer role noted the importance of taking a federated approach to this responsibility, recognizing that NASA needed to manage local knowledge in its own context, while building capacity to share critical knowledge across the Agency as appropriate.[15] NASA has also expanded the lessons learned construct in recent years to include processes related to team review, recording, disseminating, and application of these lessons.[16]

> …NASA needed to manage local knowledge in its own context, while building capacity to share critical knowledge across the Agency…

Space Shuttle Columbia was lit up at Launch Pad 39A on the night of 5 March 1981 as preparations for its maiden voyage, the STS-1 mission, were being made. (Photo credit: NASA)

In addition to lessons learned, oral histories, classroom discussions, mentoring, and other knowledge sharing activities are crucial to NASA, because much of what engineers and project teams must learn and apply on the job is impossible to capture in a database.[17] As Steven R. Hirshorn, Chief Engineer for Aeronautics at NASA Headquarters, writes, engineering leaders at NASA need to know the "systems engineering process, oversee the process, and be an advocate for its value to the project. The Chief Engineer must also be able to use their experience and judgment to implement it appropriately for their project."[18] Competencies like these are crucial to any field, but the lessons of Columbia remind us that even those with the greatest technical acumen need to have a supporting culture to apply and share their knowledge effectively.

Bryan O'Connor, Amy Edmondson, Mike Ryschkewitsch, and Robin Dillon (left to right) share insight into organizational silence on a panel at Goddard Space Flight Center on 31 July 2012. (Photo Credit: NASA/Goddard Space Flight Center)

When tragedies occur, a healthy organization does not normalize the accident or shame the participants: it seeks to understand why the accident occurred and, if possible, to prevent it from happening again. The cultural lessons from Columbia continue to guide how we share knowledge and how we apply our expertise to our missions. As members of an organization that is committed to learning and improving, NASA's people must combine the facts we know, the lessons we learn as a team, and the common values we practice together. In this way, NASA's knowledge and organizational culture requires continued vigilance and maintenance. We must do this not only when it is easy, but when it is hard.

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1 Thank you to Stephen J. Angelillo, Michael Bell, Steven R. Hirshorn, Kevin Gilligan, and Zachary Pirtle for sharing their insights at different stages of this article's development, and thank you to the NASA History Division for the kind invitation to participate in this issue.

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A Safety Lesson from an Early NACA Leader

» By **James Anderson**, Historian, Ames Research Center

A November 1941 portrait of Smith DeFrance, Engineer-in-Charge at Ames Aeronautical Laboratory, the same year that the first wind tunnel began operating at Ames. (Image credit: NACA)

A **PLANE CRASH** at Langley Memorial Aeronautical Laboratory in August 1924 killed one NACA engineer and seriously injured the 28-year-old pilot, Smith DeFrance, who lost his left eye and spent months recovering in Walter Reed Hospital. DeFrance had been piloting a Curtiss Jenny while his colleague observed from the rear seat. Both men worked at the Langley Laboratory in Virginia, where DeFrance was the assistant head of the flight research section. In that role, DeFrance helped define what it meant to be an experimental test pilot. He had earned a Silver Star flying biplanes in combat during World War I, but in the aftermath of the 1924 crash, DeFrance pledged to his wife that he would never fly again.[1] It was a personal decision that still has a familiar resonance almost 100 years later. Since then, there have been significant shifts in how organizations conceptualize matters of safety and how practices are implemented to address safety concerns. And while those procedures and frameworks probably seem more sophisticated today, the importance of sharing stories that capture our personal experiences with tragedy is evident in the recollections of people who worked with individuals like DeFrance. DeFrance's experience gave him an enduring authority that transcended any specific policy or procedure.

Eight years before the fatal crash, in the very first annual report of the National Advisory Committee for Aeronautics (NACA), the committee acknowledged a need to address safety concerns, specifically, the causes of accidents. Following a list of problems that the committee had identified as needing immediate attention, such as developing a practical form for determining an airplane's stability mathematically "without necessarily requiring wind-tunnel tests,"[2] problems not exclusively aeronautical in nature were considered. The lengthiest entry by far, causes of accidents, was saved for last:

> While conditions have changed decidedly from the early days of aeronautics in this country, there is still evidence of carelessness in the design and operation of aeroplanes. It would appear as coming within the province of this committee that legislation should be enacted toward obtaining control of this feature at an early date. However, any such legislation should be most carefully considered and the views of those interested should be obtained. This is particularly necessary, as already a number of attempts have been made toward legislation in different States, with the result that in one State, at least, experimental work is practically prohibited, not because inventors and constructors can not comply with the law, but because the operation of the law requires facilities which do not exist in the State in which the laws have been passed. With a view toward determining the requirements of such legislation, it is proposed that a beginning be made by requesting that all accidents be reported to the advisory committee on forms to be published by the committee, embodying a set of categorical questions, the answers to which may lead to a determination of the principal causes of accidents. In cases where such accidents result in the maiming or killing of spectators or flyers, such

↑ The first two Curtiss Jennies used in service at Langley Memorial Aeronautical Laboratory were borrowed from the Army Air Service and began supporting NACA test flights at the laboratory in 1919. (Image credit: NACA)

> questions should be answered by the investigating authorities. The word "request" is used in view of the possible conflicts of State and Federal authority and jurisdiction; and whereas it is very probable that both State and Federal authorities would be willing and glad to cooperate in this work in response to a request, it is not clear that such cooperation would follow legislation, unless carefully worked out.[3]

This challenge and the potential conflicts over jurisdiction inherent in federalism proved to be troublesome to the newly established NACA, at least superficially. In the next annual report, a single sentence seemed to close out the issue: "Although this problem is a serious one, the committee has not been able to inaugurate the work proposed."[4] The item no longer appeared in subsequent NACA annual reports. That does not mean that safety was no longer important to the NACA, only that the form in which the NACA addressed safety concerns in its reports became dispersed across specific examples rather than encapsulated in one targeted effort. Key members of the NACA were, in fact, intimately involved with the burgeoning regulatory challenges facing civil and military aviation in its early years.

This was not the first time that federalism and the issue of conflicting jurisdictions had arisen with respect to safety or transportation. Congress had already passed legislation to regulate steamboats and the railroads in response to public safety concerns related to those modes of transportation that crossed state lines. In terms of aviation and the extension of its regulatory concerns to an international context—and the NACA's involvement tackling those concerns and coordinating across civil, military, and industrial stakeholders—a recent book by Sean Seyer skillfully recounts what had been a previously neglected time and context in the history of aviation policy.[5] In spite of regulatory and legal hurdles, however, much of the work the NACA undertook over its 43 years had direct benefits to safety even if "safety" was not overtly touted as the driving force. It's difficult to argue with the obvious benefits of not crashing. The fundamental and applied research that the NACA conducted improved survivability from accidents through advancements in areas such as fire prevention, passenger and pilot restraints, and aircraft aerodynamic stability.

DeFrance, meanwhile, was not directly involved in the policy and regulatory discussions that some of the NACA committee members undertook in the committee's early years. He was focused on his work as an NACA employee at the Langley facilities, where by the late 1930s he was overseeing its four largest wind tunnels and leading the design efforts for facilities that would begin construction in 1940 at Moffett Field in California. Also in 1940, the same year that he was appointed Engineer-in-Charge and the Moffett Field facilities were officially named Ames Aeronautical Laboratory, DeFrance was still honoring his pledge not to fly again and travelled to Ames by train. Rarely making the long journey back to Washington, DC, he led Ames for the next 25 years, continuing on through Ames' transition to a NASA research center, until his retirement in 1965.

DeFrance's 25 years at the helm left an impression on the Ames workforce. In a story told on several occasions years after his retirement, some of DeFrance's colleagues recalled that he was present in the control room as a wind tunnel at Ames powered on for the first time.[6] When he asked what a nearby switch was for, one of the engineers responded that it was for an emergency shutoff, so DeFrance reached over and engaged

A Safety Lesson from an Early NACA Leader (continued)

it. At first baffling those present, the act quickly earned their appreciation and respect for his somewhat dramatic insistence on testing such an important feature in an era when the action was not a required step to take, much less document.

Today, there is arguably less attention paid to the influence of any one individual on an entire center or agency as in the early NACA days. That does not mean that such influence should be discounted. Everyone in the workforce faces daily safety considerations, usually more aligned with occupational safety and ergonomics than the kind of safety measures that prevent catastrophe. While there's almost never a literal emergency shutoff switch within our immediate grasp, when our colleagues tell personal, relatable stories that deliver a message that resonates, the abstract aspects of safety become actionable. Perhaps Smith DeFrance still has something to teach us. Ask yourself: What figurative emergency shutoff is within your grasp that you have not tested yet?

The first operational wind tunnel at Ames on 10 March 1941, three days before its fan was powered on and then promptly subjected to DeFrance's impromptu emergency shut off check. (Image credit: NACA)

Endnotes

1 This accident is often cited as a defining moment for DeFrance, but the details are difficult to pin down. *The New York Times* reported the crash the day after on 21 August 1924, noting that it was Steven Bromley, Jr. who had died and that DeFrance had suffered what were "probably fatal injuries." Elizabeth Muenger's *Searching the Horizon: A History of Ames Research Center 1940–1976* (NASA SP-4304), recounts the incident with an unnamed Bromely as a "newcomer, in the copilot's seat, [who] froze at the controls while De France was beginning a landing approach" (p. 14). While these details are not explicitly cited, they most likely come from the story being retold among colleagues over the following years, captured in the interviews Muenger conducted as part of the book's research. In the first history of Ames, *Adventures in Research: A History of Ames Research Center 1940–1965* (NASA SP-4302), Edwin Hartman noted DeFrance's loss of an eye in the crash, but did not give a detailed description of the accident nor mention the loss of life. And in *Model Research: The National Advisory Committee for Aeronautics, 1915–1958* (SP-4103), Alex Roland wrote in a footnote that after the loss of the eye in the crash, DeFrance "carried the scars, both physical and emotional, through the rest of his days" (p. 364). Like Muenger's account, this assertion does not appear to be directly rooted in specific primary documentation, but has emerged as something commonly known enough that it has become part of the retellings.

2 *First Annual Report of the National Advisory Committee for Aeronautics, 1915* (Washington, DC: Government Printing Office, 1916), p. 13.

3 Ibid., p. 17.

4 *Second Annual Report of the National Advisory Committee for Aeronautics, 1916* (Washington, DC: Government Printing Office, 1917), p. 15.

5 Seyer, Sean. *Sovereign Skies: The Origins of American Civil Aviation Policy*. Johns Hopkins University Press: 2021.

6 Two versions of the story have some endearing differences. The more detailed account, told shortly after DeFrance's retirement appears in *Adventures in Research* (p. 35), where the emergency shutoff is described as a red button in the control room of the 7-by-10 foot #1, the first operational wind tunnel at Ames, which powered up on 13 March 1941. The second account appears in *Atmosphere of Freedom: Sixty Years at the NASA Ames Research Center* (p. 24) and is attributed to an interview conducted with DeFrance's colleague Walter Vincenti in 1999, 14 years after DeFrance had passed away. That account implies that the tunnel in question was the 12-foot Pressure Tunnel, and instead of a red button, it was a red lever. In spite of those differences, the point of the story remains the same.

Learning from NASA's Launch Failures

» By **Robert Arrighi**, Historian, Glenn Research Center

↑ Joe Nieberding and Larry Ross (left) discuss the Centaur Program at Glenn Research Center in October 2013. (Photo credit: NASA)

THE CENTAUR UPPER-STAGE rocket is one of the greatest achievements of the U.S. space program. Centaurs have sent scores of probes, satellites, and observatories into space over the past 60 years for both the government and private industry, including many high-profile NASA missions such as Surveyor, Viking, Voyager, and Cassini-Huygens. Despite the program's remarkable success rate, there have been painful setbacks along the way. Examples include the 1970 failure of a shroud to jettison properly resulting in the loss of the one-of-a-kind Orbiting Astronomical Observatory-B; and a lightning strike 49 seconds after liftoff in 1987 that prevented a costly Navy communications satellite from reaching orbit.

Mission failures result in not only tremendous financial losses and impacts to upcoming launch schedules, but also a feeling of apprehension among teams that spent years preparing the launch vehicle and payload for the mission and the resulting disruption of their personal lives. Although these failures are extremely difficult to accept, they do offer excellent opportunities to learn and improve operations for future endeavors. In the mid-2000s, retired NASA managers Joe Nieberding and Larry Ross decided to collect and analyze data from past Centaur failures in an effort to provide lessons learned for current and future engineers.

Joe Nieberding and Larry Ross decided to collect and analyze data from past Centaur failures in an effort to provide lessons learned for current and future engineers.

Ross and Nieberding began their NASA careers in the mid-1960s working on the Centaur Program at the Lewis Research Center (today, NASA Glenn). The Center was responsible for integrating the payload into the launch vehicle, establishing the correct flight trajectories, and preparing the vehicle for launch. Ross contributed to the vehicle's first missions sending Surveyor spacecraft to the Moon and helped transition the program to subsequent assignments. Nieberding specialized in developing flight trajectories and integrating payloads into the vehicle. As a member of the launch team, he was involved in 65 launches from Cape Canaveral.

By the mid-1970s, Ross was managing all of Lewis' launch vehicle activities. He subsequently served as Deputy Director and Center Director for the entire Center in the early 1990s. In 1987 Nieberding was named head of the new group that analyzed a range of technologies and opportunities for future space missions, including the use of Russian rockets to service the planned space station.[1] The men retired in 1995 and 2000, respectively, but remained active with consulting and review board work.

The loss of Space Shuttle Columbia in February 2003 spurred a series of events that led to the termination of Shuttle activities and the introduction of a new effort to return to the Moon. The program, referred to as Constellation, included the development of a new family of Ares launch vehicles—"I" designated for humans and "V" for cargo.

As a member of the Ares-I non-advocate review board, Nieberding was asked to brief the panel in September 2006 on his experiences with launch vehicle failures. The presentation was well-received but contained only a portion of the materials that had been gathered. Nieberding and Ross created a formal partnership and began formulating plans to present the information as a class for young NASA engineers with little hands-on experience. There had been a significant erosion of NASA's vast expendable launch vehicle expertise since the agency Agency transitioned those activities to private industry in the 1980s and 1990s. Ross and Nieberding could discuss actual events, many in which they participated.

The pair worked with the Glenn History Office and Records Management team to locate Centaur failure reports, film footage, and other factual information to bolster their presentation. In addition, they interviewed fellow subject matter experts and retirees.

The resulting class, which came to be known as "Mission Success First: Lessons Learned," is structured along the lines of the Harvard Business School's case study approach. After some preliminary background information, they drill down on a series of case studies. For each, they describe the incident, examine the causes of that specific failure, and then offer a set of lessons learned that can be applied to a range of activities. The ability of Nieberding and Ross to blend the analysis with humor and rare video footage made the class an immediate success.

Scott Graham, who managed Glenn's Ares work, arranged for Nieberding and Ross to present their materials to his team in January 2007. Glenn's training office sponsored several follow-on classes. The audience soon included representatives from other NASA Centers who arranged for additional presentations at their sites. Nieberding's participation in the Agency's annual Safety and Mission Assurance meetings led to more invitations. By 2009 the class was incorporated into the NASA's Academy of Program/Project & Engineering Leadership (APPEL) where it became one of their highest rated offerings.

Nieberding and Ross continued their engagements even after the cancelation of Ares-I in 2010. At the behest of NASA Headquarters, they presented to launch vehicle upstarts including Blue Origin and Space-X, as well as legacy firms such as United Launch Alliance (the current manufacturer of Centaur) and Boeing. The course was also conducted for international audiences in seven countries.

Over the years, Ross and Nieberding integrated more and more new case studies into their program, some of which were suggested by class participants. These included different types of failures such as a B-2 stealth bomber crash and the Interstate 35 bridge collapse. The information from more than 50 failures was collected in a database so that the case material could be individualized for different audiences, which now includes non-aerospace organizations such as Sandia National Laboratories and Disney.

From this large body of information, Nieberding and Ross were able to identify trends that transcended time, location, and even type of activity.

From this large body of information, Nieberding and Ross were able to identify trends that transcended time, location, and even type of activity. Human error was the root cause of almost every case, whether it was poor design, communication breakdowns, procedural errors, or insufficient testing. Nieberding recalls a number of

(continued on page 30) »

1 See, "Nieberding's Missions to Post-Soviet Russia," *NASA History News & Notes* (Fall 2020) Vol. 37, no. 3.

News from NASA's Centers

NASA Headquarters

Washington, DC

» By **Michele Ostovar,** Editor

In late January, the NASA History Office was pleased to welcome back Travis Frederick as our intern for the spring term. Travis, a Ph.D. candidate in security studies at Princeton University and a fellow at the Kennan Institute, previously served in our office in the Spring 2021 term. Travis became interested in becoming a NASA intern in 2015 when he met the NASA Russia Representative while working as a State Department intern at the U.S. Embassy in Moscow. His Ph.D. research focuses on how history, memory, and identity became part of Russia's national security strategy during the post-Soviet memory wars. Over his internship, he will be assisting with preparations for the upcoming *NASA's Discovery Program* book while doing a comparative study of U.S. and Soviet approaches to planetary science for his independent research project.

February saw the much-anticipated release of the newest title in the NASA History Series, *NACA to NASA to Now: The Frontiers of Air and Space in the American Century* by former NASA Chief Historian Roger D. Launius. This concise history of the Agency and its predecessor, the National Advisory Committee for Aeronautics (NACA) illustrates the political, economic, managerial, international, and cultural contexts in which the events of flight have unfolded, and it will undoubtedly serve as an excellent resource for a wide audience to become acquainted with NASA's heritage.

Production work continues on three additional publications that are scheduled to be published this year, including *The Aeronautics and Space Report of the President: Fiscal Years 2021 and 2022 Activities*, *A Wartime Necessity: The National Advisory Committee for Aeronautics (NACA) and Other National Aeronautical Research Organizations' Efforts at Innovation during World War II*, edited by Alex M Spencer, and *NASA's Discovery Program: The First Twenty Years of Competitive Planetary Exploration* by Susan M. Niebur with David W. Brown (editor).

CONGRATULATIONS TO NASA HISTORIAN, JENNIFER ROSS-NAZZAL!

The NASA History Office's own Dr. Jennifer Ross-Nazzal has received the **2023 Liz Carpenter Award** for her book, *Making Space for Women: Stories from Trailblazing Women of NASA's Johnson Space Center*! This award, given annually by the Texas State Historical Association, goes to the best scholarly book covering the history of women and Texas.

Making Space for Women features the stories of 21 women who worked at Johnson Space Center as astronauts, scientists, engineers, secretaries, trainers, managers, and more. Their narratives discuss the changes they experienced in their careers as the workforce became more diverse. Ross-Nazzal has served as the Historian at NASA's Johnson Space Center since 2002, researching and writing on a variety of subjects including women's history.

Armstrong Flight Research Center (AFRC)

Edwards Air Force Base, California

» By **Christian Gelzer**, Historian

Christian Gelzer has been working diligently to transfer AFRC history Web pages to the Agency's new website, due to be released this spring. Additionally, to help reduce the Center's holdings and spare anyone from having to move the Center history office's nearly 100 boxes of publications in the future, he spent a day distributing NASA

News from NASA's Centers (continued)

publications to Center employees and to anyone else who was interested.

Following a request from an engineer, Gelzer is preparing a series of talks to NASA Center engineers about X-planes, the AFRC's role with them, and what the projects accomplished. With the continued retirement of engineers with experience with the X-planes in the 1970s and 1980s, a significant proportion of the current engineering workforce at Armstrong have been with the Agency for less than five years and are eager to learn more about these experimental aircraft.

ERIK CONWAY NAMED 2022 AAAS FELLOW

In an announcement in January 2023, NASA-JPL Historian Erik Conway was one of only four individuals with NASA affiliations named as 2022 fellows by the American Association for the Advancement of Science (AAAS), receiving this prestigious nod in the Section on History and Philosophy of Science. Conway has served as the historian at NASA's Jet Propulsion Laboratory since 2004, focusing on science and technology. The author of histories of atmospheric science, supersonic transportation, aviation infrastructure, Mars exploration, and climate change denial, he most recently co-authored the book ***A History of Near-Earth Objects Research***, published in 2022. Congratulations Erik on being recognized with this distinction!

Learning from NASA's Launch Failures (continued)

↑ Larry Ross, Ann Over, Joe Nieberding, and Randy Over (left to right) pose for a photo at a June 2022 class for the European Space Agency held in Noordwijk, Netherlands.

occasions in which attendees contacted their teams during class intermissions to ensure that some technical aspect was checked. In one instance, the Ares-I team incorporated a pump test into their pre-launch procedures after learning that a failed boost pump caused the loss of the first Titan-Centaur mission in 1974.

After 16 years and 127 classes conducted on four continents, Ross and Nieberding will be retiring from their secondary career after a May 2023 class at Kennedy Space Center. The Mission Success First course, however, will carry on, with additional cases and fresh insight provided by Ann and Randy Over. The former has 36 years of microgravity and spaceflight systems experience at NASA Glenn, and the latter was chief engineer at the Ohio Department of Transportation. They will present their first class in June 2023 in the Netherlands.

Other Aerospace History News

Applications Open for 2023 Fellowships in Aerospace History

The Fellowships in Aerospace History are offered annually by NASA to support significant scholarly research projects in aerospace history. These fellowships grant the opportunity to engage in significant and sustained advanced research in all aspects of the history of aerospace from the earliest human interest in flight to the present, including cultural and intellectual history; economic history; history of law and public policy; and the history of science, engineering, and management. NASA provides funds to the History of Science Society (HSS) to allow us to award a fellowship. Representatives from the American Historical Association (AHA), HSS, and Society for the History of Technology (SHOT) comprise the review committee. Three fellowships will be offered for the 2022–23 term; applications will be entered into consideration for all three fellowships:

- AHA Fellowship in Aerospace History
- AHA Fellowship in the History of Space Technology
- HSS Fellowship in Aerospace History

Eligibility

Applicants must possess a PhD in history or in a closely related field or be enrolled as a student (having completed all coursework) in a doctoral degree granting program. Preference will be given to scholars at early stages in their careers. **Stipends may be awarded only to US citizens or permanent residents.**

Fellowship Term

The fellowship term is for a period of at least six months, but not more than nine months, and should commence no later than January of the fellowship term. The fellow will be expected to devote the term largely to the proposed research project. Residency is not required, but office space may be provided by the Kluge Center at the Library of Congress upon request for a minimum of three months. Fellows are encouraged to take advantage of resources at the National Archives, the National Academies of Science, the Library of Congress, the Smithsonian Air and Space Museum, NASA Headquarters, and other collections in the Washington, DC, area.

Other Requirements

The fellow will be expected to write a report and present a public lecture on the fellowship experience. If the fellow is in residency in Washington, DC, a presentation at NASA Headquarters is encouraged. The fellow shall provide to the NASA History Office a copy of any publications that might emerge from the research undertaken during the fellowship year.

Stipend

The stipend is US$21,890 for a six- to nine-month fellowship, which includes travel expenses. The fellowship income is classified as stipendiary—there are no provisions for paying fringe benefits or withholding taxes—and will be disbursed in equal payments over the term of the fellowship. Funds may not be used to support tuition or fees. A fellow may not hold other major fellowships or grants during the fellowship term, except sabbatical and supplemental grants from their own institutions, and small grants from other sources for specific research expenses. Sources of anticipated support must be listed in the application form.

To Apply

Log into your MY AHA account and click "Available Application Forms" in the AHA Awards, Grants, and Jobs section. If you don't have an account, create one. The applicant must submit a completed application, CV, a specific and detailed research proposal that will be the basis of the fellow's research during the term and can also include additional writing samples. Two to four letters of recommendation that address your historical competence; your ability to apply historical concepts and methods to aerospace science, technology, management, or policy; and your ability to communicate both orally and in writing are also required. **Completed applications are due April 1.**

Please contact awards@historians.org with any questions.

Other Aerospace History News (continued)

Space Archives and Special Collection Database

» By **Scott Sacknoff**, Chair, SPACE 3.0 Foundation

The SPACE 3.0 Foundation has sponsored a graduate student to build a database of space-related archives and special collections to assist current and future researchers in discovering sources of materials and how they can access them. This spreadsheet will be made available for free via a link from the SpaceCommerce.org and SpaceHistory101.com websites.

An initial passthrough has been completed, and we are now seeking input to identify collections and other categories of useful information. The current list of archives identified can be reviewed in the linked PDF. If there are others you think should be included, please either send an email to info@spacecommerce.org or fill out and send us the linked Excel data entry form.

Fields Currently Being Collected

- Organization
- Collection Name
- Materials Held
- Description of Collection Holdings
- Collection Amount/Size
- Access Restrictions
- Address / Country / Contact Phone Number / Contact Email Address
- Link to Collection Website

If you have any questions or other input, please contact Scott Sacknoff.

In NASA InSight's second full selfie on Mars, made up of 14 images taken in the spring of 2019, a thin coating of dust covers the spacecraft. InSight, a mission of the Discovery Program, recently concluded in December 2022. Photo credit: NASA/JPL-Caltech.

Call for Papers for Discovery@30, New Frontiers@20: A Symposium on the History of NASA's Discovery and New Frontiers Programs

» By **Brian Odom**, NASA Chief Historian

Dates: 18–19 January 2024
Location: Washington, DC

Congress approved NASA's Discovery Program in 1993, initiating a new era of lower-cost, competed missions to explore the solar system. Like NASA's older Explorer program of astronomy and astrophysics missions, these missions were to be developed and led by principal investigators. In 2002, based on the model of Discovery but recognizing a need for medium-class science missions to tackle questions identified in the decadal survey, NASA initiated the New Frontiers Program. Over the past 30 years, missions from these two programs have transformed our understanding of our solar system and have accomplished historic firsts. They have also redefined the role of science and scientists in the development of planetary science missions, even as this willingness to experiment with innovative management approaches created a tension with an often risk-averse NASA.

The NASA History Office and the Smithsonian's National Air and Space Museum invite proposals for papers to be presented at a two-day symposium to be held 18–19 January 2024 in Washington, DC. We welcome diverse voices and perspectives to examine the history of the Discovery and New Frontiers Programs, their successes and failures, and their impact on knowledge and the practice of planetary science. The symposium will be a combination of panel discussions, keynote talks, and group discussion. The intention is to publish an anthology of selected papers.

Visit the Call for Papers web page to see a list of potential topics for papers.

Submission Procedure

If you wish to present a paper, please send the title, an abstract of no more than 400 words, and a short biography or curriculum vitae, including affiliation, by 1 May 2023 to Dr. Brian C. Odom, NASA's Chief Historian. Questions about the symposium are also welcome.

Apollo Astronaut Walter Cunningham Dies at 90

» Reprinted from NASA Press Release 23-001 on 3 January 2023


NASA astronaut Walter Cunningham, Apollo 7 lunar module pilot, was photographed during the mission. (Photo credit: NASA)

FORMER ASTRONAUT Walter Cunningham, who flew into space on Apollo 7, the first flight with crew in NASA's Apollo Program, died early Tuesday morning [3 January] in Houston. He was 90 years old.

"Walt Cunningham was a fighter pilot, physicist, and an entrepreneur—but, above all, he was an explorer. On Apollo 7, the first launch of a crewed Apollo mission, Walt and his crewmates made history, paving the way for the Artemis Generation we see today," said NASA Administrator Bill Nelson. "NASA will always remember his contributions to our nation's space program and sends our condolences to the Cunningham family."

Cunningham was born 16 March 1932, in Creston, Iowa. He graduated from Venice High School, in Venice, California, before going on to receive a Bachelor of Arts with honors in physics in 1960 and a Master of Arts with distinction in physics in 1961 from the University of California at Los Angeles. He then completed a doctorate in physics with exception of thesis at the Advanced Management Program in the Harvard Graduate School of Business in 1974.

> "Walt Cunningham was a fighter pilot, physicist, and an entrepreneur—but, above all, he was an explorer. On Apollo 7, the first launch of a crewed Apollo mission, Walt and his crewmates made history, paving the way for the Artemis Generation we see today."
>
> —Administrator Bill Nelson

The Cunningham family offered the following statement: "We would like to express our immense pride in the life that he lived, and our deep gratitude for the man that he was—a patriot, an explorer, pilot, astronaut, husband, brother, and father. The world has lost another true hero, and we will miss him dearly."

He joined the Navy in 1951 and served on active duty with the U.S. Marine

Apollo Astronaut Walter Cunningham Dies at 90 (continued)

A memorial wreath was placed in the Heroes and Legends exhibit at the Kennedy Space Center Visitor Complex in Florida following the 9 January 2023 ceremony honoring the memory of Walter Cunningham. (Photo credit: NASA/Cory Huston)

Corps, retiring with the rank of colonel. He flew 54 missions as a night fighter pilot in Korea. He worked as a scientist for the Rand Corporation for three years. While with Rand, he worked on classified defense studies and problems related to the Earth's magnetosphere. Cunningham had accumulated more than 4,500 hours of flying time in 40 different aircraft, including more than 3,400 in jet aircraft.

Cunningham was selected as an astronaut in 1963 as part of NASA's third astronaut class.

"On behalf of NASA's Johnson Space Center, we are beholden to Walt's service to our nation and dedication to the advancement of human space exploration," said Vanessa Wyche, Center director. "Walt's accomplished legacy will continue to serve as an inspiration to us all."

Prior to his assignment to the Apollo 7 crew, Cunningham was on the prime crew for Apollo 2 until it was canceled, and he was the backup lunar module pilot for Apollo 1.

Cunningham was designated the lunar module pilot for the 11-day flight of Apollo 7, which launched on 11 October 1968, and was the first human flight test of the Apollo spacecraft. With Walter M. Schirra, Jr. and Donn F. Eisele, he tested maneuvers necessary for docking and lunar orbit rendezvous using the second stage of their Saturn IB rocket. The crew successfully completed eight tests, igniting the service module engine, measuring the accuracy of performance of all spacecraft systems, and providing the first live television transmission of onboard crew activities. The 263-hour, 4.5-million-mile flight splashed down 22 October 1968 in the Atlantic Ocean.

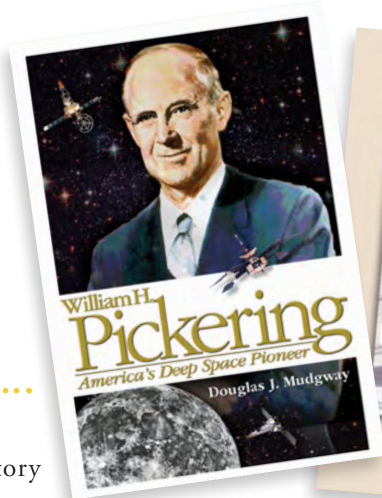
Cunningham's last assignment at NASA Johnson was chief of the Skylab branch of the Flight Crew Directorate. In this capacity, he was responsible for the operational inputs for five major pieces of manned space hardware, two different launch vehicles and 56 major experiments that comprised the Skylab Program.

Cunningham retired from NASA in 1971 and would go on to lead multiple technical and financial organizations. He served in senior leadership roles with Century Development Corp., Hydrotech Development Company, and 3D International. Cunningham also was a longtime investor and entrepreneur, organizing small businesses and private investment firms. He also was a frequent keynote speaker and radio talk show host.

His numerous awards include the NASA Exceptional Service Medal and NASA Distinguished Service Medal. For his service he was inducted into the Astronaut Hall of Fame, International Space Hall of Fame, Iowa Aviation Hall of Fame, San Diego Air and Space Museum Hall of Fame, and Houston Hall of Fame. Cunningham and the Apollo 7 crew also earned an Emmy in the form of the National Academy of Television Arts and Sciences Special Trustee Award. ■

Remembering Douglas Mudgway, Engineer and Author

» Adapted from Douglas Mudgway's obituary



DOUGLAS JAMES MUDGWAY, born in Auckland, New Zealand, passed away on 20 December 2022, at the age of 99. Mudgway graduated from the University of New Zealand in 1945 with a degree in physics and mathematics, and after working for the New Zealand Department of Scientific and Industrial Research, moved to Australia to work as a scientist on radar for the guided missile test range at Woomera, dividing his time between there and in England at the Royal Aircraft Establishment. In 1962 he was hired by NASA to work as a development engineer at the Jet Propulsion Laboratory (JPL) in Pasadena, California, and moved with his wife and three children to the United States.

↓ The 210' Dish Antenna at Goldstone, California, used to track Pioneer spacecraft, as seen in 1972. (Photo credit: NASA)

He wrote extensively on his experiences with NASA's solar system exploration and was the author of two books on the history of deep space technology...

At JPL, Mudgway was the Deep Space Tracking and Data Acquisition Manager of the Surveyor Moon landing spacecraft (1966), the Viking Mars landers (1976), and for the Galileo mission to Jupiter from its inception in 1978 until his retirement in 1991. He was awarded the NASA Exceptional Service Medal for his work on Viking in 1978, and received a second award, the Exceptional Achievement Medal for his contribution to the Galileo mission in 1991.

Since retiring to Sonoma, California, Douglas Mudgway continued his involvement with the NASA Space Program as an independent consultant. He wrote extensively on his experiences with NASA's solar system exploration and was the author of two books on the history of deep space technology, *Uplink-Downlink: A History of the NASA Deep Space Network from 1957–1997*, published as part of the NASA History Series in 2002, and *Big Dish: Building America's Deep Space Connection to the Planets*, published in 2005. He also authored a biography of deep space pioneer William H. Pickering, former JPL Director, that was published in 2007. In 2008, this book was selected by the American Institute of Aeronautics and Astronautics for Best History Manuscript dealing with the impact of space technology or science on society.

He is survived by his three adult children and their spouses, seven grandchildren and two great grandchildren. He will be remembered fondly by his many colleagues and friends. ■

Upcoming Meetings

22–26 MARCH 2023
American Society for Environmental History Annual Meeting
Boston, Massachusetts
https://www.aseh.org/events

28–30 MARCH 2023
International Astronautical Federation Spring Meetings 2023
Paris, France
https://www.iafastro.org/events/iaf-spring-meetings/iaf-spring-meetings-2023.html

30 MARCH–2 APRIL 2023
Organization of American Historians Annual Meeting
Los Angeles, California
https://www.oah.org/meetings-events/oah23

12–15 APRIL 2023
National Council on Public History Annual Meeting
Atlanta, Georgia
https://ncph.org/conference/2023-annual-meeting/

19–21 APRIL 2023
2023 Forum on Philosophy, Engineering, and Technology
Delft, Netherlands
https://www.fpet2023.org/

1–2 JUNE 2023
Society for History in the Federal Government Annual Meeting
Washington, DC
https://shfg.wildapricot.org/2023-annual-meeting-cfp

7–9 JUNE 2023
Policy History Conference
Columbus, Ohio
https://jph.asu.edu/2023-about

12–16 JUNE 2023
2023 AIAA Aviation and Aeronautics Forum and Exposition
San Diego, California (and online)
https://www.aiaa.org/aviation

15–17 JUNE 2023
Society for Historians of American Foreign Relations (SHAFR) Annual Meeting
Arlington, Virginia
https://shafr.org/shafr2023

22–29 JULY 2023
ARCHIVES * RECORDS 2023 (Joint Annual Meeting of the Council of State Archivists and the Society of American Archivists)
Washington, DC
https://www2.archivists.org/am2023

17–19 JULY 2023
5th Annual John Glenn Memorial Symposium
Cleveland, Ohio
https://astronautical.org/events/john-glenn-memorial-symposium/

24-30 JULY 2023
Experimental Aircraft Association (EAA) AirVenture
Oshkosh, Wisconsin
https://www.eaa.org/airventure/

2–6 OCTOBER 2023
International Astronautical Congress
Baku, Azerbaijan
https://www.iafastro.org/events/iac/iac-2023/

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The Space Shuttle Columbia Memorial is seen after a wreath laying ceremony on 31 January 2014 at Arlington National Cemetery. Photo credit: (NASA/Bill Ingalls).

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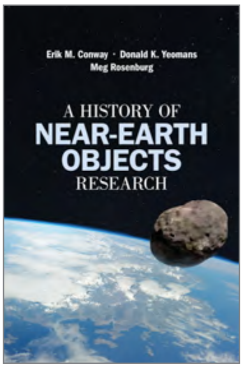

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