National Aeronautics and Space Administration

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FALL | 2010

Inside

NASA AND SPACEX WORK TOGETHER

SHAPING THE SHUTTLE

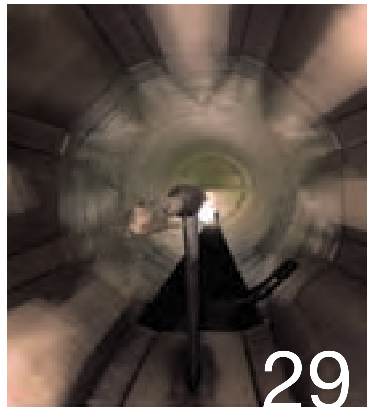
PEER ASSIST: LEARNING BEFORE DOING

Photo Credit: NASA/Bill Ingalls

ON THE COVER

Contrails are seen as workers leave the Launch Control Center at Kennedy Space Center after the launch of Space Shuttle *Discovery* and the start of the STS-131 mission. After its nearly thirty-year history of human spaceflight achievements, the Space Shuttle is nearing its final planned launch.

Contents



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INSIGHTS

STORIES

ask

Issue No. 40

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The Academy of Program/Project and Engineering Leadership (APPEL) and *ASK Magazine* help NASA managers and project teams accomplish today's missions and meet tomorrow's challenges by sponsoring knowledge-sharing events and publications, providing performance enhancement services and tools, supporting career development programs, and creating opportunities for project management and engineering collaboration with universities, professional associations, industry partners, and other government agencies.

ASK Magazine grew out of the Academy and its Knowledge Sharing Initiative, designed for program/project managers and engineers to share expertise and lessons learned with fellow practitioners across the Agency. Reflecting the Academy's responsibility for project management and engineering development and the challenges of NASA's new mission, *ASK* includes articles about meeting the technical and managerial demands of complex projects, as well as insights into organizational knowledge, learning, collaboration, performance measurement and evaluation, and scheduling. We at APPEL Knowledge Sharing believe that stories recounting the real-life experiences of practitioners communicate important practical wisdom and best practices that readers can apply to their own projects and environments. By telling their stories, NASA managers, scientists, and engineers share valuable experience-based knowledge and foster a community of reflective practitioners. The stories that appear in *ASK* are written by the "best of the best" project managers and engineers, primarily from NASA, but also from other government agencies, academia, and industry. Who better than a project manager or engineer to help a colleague address a critical issue on a project? Big projects, small projects—they're all here in *ASK*.

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In This Issue

Spaceflight is hard, Wayne Hale reminds us in the interview in this issue of *ASK*. His discussion of a long career devoted to the Space Shuttle touches on the sources of the shuttle program's many successes and its few painful failures. A couple of other articles here ("From Sketch Pad to Launchpad" and "Shaping the Shuttle") look back at the beginning of the thirty-year program, detailing the knowledge, flexibility, and commitment that went into designing the world's first (and still only) reusable spacecraft.

Some of that knowledge came from imaginative and often daring earlier work. The X-15 program, which began in the fifties, provided essential understanding of thermal protection during high-speed reentry and proved that an aircraft-like spacecraft could glide safely to an unpowered landing. (See Kerry Ellis's "X-15: Pushing the Envelope.") The data generated by wind-tunnel experiments that began at Ames Research Center before NASA was established, described in Jack Boyd's "The Freedom to Learn," has served the space program from Mercury to Apollo to shuttle and remains relevant to future flights to other planets.

Technical challenges make spaceflight hard, but what Ed Hoffman describes as "adaptive challenges" (in "From the Academy Director") are at least as important and are tougher in some ways. Technical problems can be clearly defined; potential solutions can be designed and tested. Adaptive challenges are harder to pin down and responses to them involve difficult social, organizational, and political change. The *Challenger* and *Columbia* accidents may have been partly due to what we might call "mis-adaptation"—a cultural shift toward arrogance and complacency that failed to take technical problems seriously enough.

Today's adaptive challenges at NASA call for new ways of working toward new goals. One early example of success in achieving one of those goals—collaborating with entrepreneurial private industry on future space-transportation technology—is described in "NASA and SpaceX Work Together." A shared passion for space exploration underlies the cooperation between two very different organizations.

In some cases, adaptation may mean a return to past practices. Both the X-15 article and "Freedom to Learn" describe a time when it was more possible to take risks, to explore radical ideas, to try and fail than has been the case at NASA in recent decades. As Laurence Prusak says in "The Knowledge Notebook," being allowed and even encouraged to fail is one of the keys to innovation—the kind of innovation the agency is being asked to achieve in the coming years.

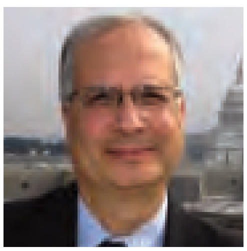
Of course, achieving these ambitious goals also depends on maintaining and improving fundamental practices for managing and carrying out projects. Jeff Cline's MIDAS article attributes the success of that software development program to clarity about requirements and extensive communication. Haley Stephenson's report on the Academy's second Knowledge Forum and Kent Greenes's description of peer assists deal with the issue of giving project teams the knowledge they need to carry out their tasks. And Joseph Horvath ("Case Study: Making Compliance Comprehensible") shows how even documentation required by regulatory agencies can be used to improve how work is done.

Don Cohen
Managing Editor

From the Academy Director

Change Management and Adaptive Challenges

BY ED HOFFMAN



What do we mean when we talk about change management?

Change is an inevitable part of the life of an organization. Regardless of why it happens, it is always difficult and painful for many people.

One metaphor that's helpful for understanding change in an organizational context comes from evolutionary biology. In *The Practice of Adaptive Leadership*, Ronald Heifetz, Marty Linsky, and Alexander Grashow recall that humans have been practicing adaptation for millennia:

> Our early ancestors' process of adaptation to new possibilities and challenges has continued over the course of written history with the growth and variation in scope, structure, governance, strategy, and coordination of political and commercial enterprise. So has the evolution in understanding the practice of managing those processes, including in our lifetimes what we call adaptive leadership.

They go on to define adaptive leadership as "the practice of mobilizing people to tackle tough challenges and thrive," noting that they use the term "thrive" as an evolutionary biologist would when describing the three characteristics of a successful adaptation:

1. It preserves the DNA essential for the species' continued survival;
2. It discards (re-regulates or rearranges) the DNA that no longer serves the species' current needs; and
3. It creates new DNA arrangements that give species the ability to flourish in new ways and in more challenging environments.

This concept of *thriving* is the essence of change management in organizations. Core values and practices remain intact, while the organization modifies or closes out activities that no longer match current needs and develops new ones to meet current and anticipated future needs.

Heifetz, Linsky, and Grashow suggest that organizations typically encounter one of two types of issues: technical problems and adaptive challenges. When a technical problem arises, the problem definition is clear, the solution arrived at is clear, and the process of solving the problem takes place through established lines of authority. Adaptive challenges are altogether different. Both the problem definition and the solution require learning, and the primary decision-making needed to meet the challenge takes place at the stakeholder level.

NASA currently faces an adaptive challenge. It has faced them before, and it has thrived. Doing so again will require learning across the enterprise.

Like the transition from Apollo to shuttle, the current adaptive challenge is the result of changes in the political, social, economic, and technological context in which the agency operates. As a government organization, the agency's mission has always been shaped by stakeholders in the White House and Congress in response to the world around us. This is as true now as it was in the age of the "space race" between the Soviet Union and the United States. As the new national space policy notes, the space age began as a race between two superpowers for security and prestige. Today, the benefits of space activities are ubiquitous in everyday life, and the space community includes increasing numbers of nations and organizations around the globe.

A new challenge is here. It's time to thrive.

NASA + SpaceX Work Together

BY ANDREW CHAMBERS AND DAN RASKY

A sample of PICA-X heat-shield material subjected to temperatures of up to 1,850°C (3,360°F) at the Arc Jet Complex at NASA Ames Research Center, Moffett Field, California. The NASA-originated PICA material holds the record for high-speed reentry into the earth's atmosphere. The SpaceX-developed and -manufactured PICA-X variants meet or exceed the performance of the original material, and will protect the Dragon spacecraft on its return to Earth.

Photo Credit: SpaceX

Inspecting the carbon-composite carrier structure for the first Dragon spacecraft heat shield, fresh from its mold. At nearly 4 m (13 ft.) in diameter, the structure supports the PICA-X tiles that protect the spacecraft during reentry.

Photo Credit: SpaceX/Roger Gilbertson

NASA is committed to working with private industry to develop the next generation of space-transportation technologies. The agency's Commercial Crew and Cargo program manages Commercial Orbital Transportation Services (COTS) partnership agreements that provide financial and technical resources to organizations committed to developing reliable and economical new launch vehicles and spacecraft. SpaceX is one of these partners. Successful NASA–SpaceX collaboration has created the heat shield for the firm's Dragon spacecraft.

The PICA Heat Shield

The NASA 2007 Government Invention of the Year, a lightweight heat-shield material developed at Ames Research Center, was the basis of the Phenolic Impregnated Carbon Ablator (PICA) heat shield that protected Stardust from temperatures as high as 2,500°C as the spacecraft reentered Earth's atmosphere at more than 28,000 mph—faster than any previous manmade object. PICA was the ideal choice for the Stardust mission to collect samples from comets; other thermal-protection materials able to withstand those temperatures would have been too heavy.

The Stardust success led to serious consideration of PICA for other NASA programs. The designers of the Orion crew capsule tested the material extensively, designing and building a full-scale engineering prototype heat shield for Orion. Uncertainties about the potential risks of a multi-tile PICA heat shield (the much smaller Stardust shield was a single piece) led the Orion team to select the Apollo heritage Avcoat thermal-protection system for Orion. But their thorough research on PICA proved a valuable resource for other programs.

One is Mars Science Laboratory (MSL). The size of the science lab lander and the speed of Mars entry and descent mean that thermal-protection material used on earlier, smaller landers would not work for MSL. Christine Szalai and her colleagues at Jet Propulsion Laboratory, Ames, and Lockheed Martin have successfully designed, fabricated, and flight certified a multi-tile PICA heat shield for the science lab that is currently waiting for its 2011 flight to Mars.

Given PICA's light weight and high performance, and the potential to benefit from knowledge gained on Orion and MSL, SpaceX chose PICA for its Dragon spacecraft, a pressurized capsule designed to carry cargo and eventually astronauts to and from low-Earth orbit. The company asked experts at Ames to provide support for the development of a 3.6-meter PICA shield for Dragon, and NASA made its expertise and specialized facilities available to SpaceX. SpaceX undertook the design and manufacture of the reentry heat shield; it brought speed and efficiency that allowed the heat shield to be designed, developed, and qualified in less than four years.

Two Cultures, One Goal

This is where we met. Andrew Chambers was SpaceX project lead for the heat shield. NASA sent Dan Rasky, one of the original developers of the material, to spend most of 2008 working half time at SpaceX's Los Angeles facility. With his own desk, phone, and SpaceX badge, he was very much a member of the firm's thermal-protection system team. Having started his career at a small, entrepreneurial aerospace company, Rasky found working at SpaceX to be like coming home, but he still experienced some culture shock after twenty years at NASA.

The speed of decision making was the most dramatic difference. At one meeting of the dozen team members and SpaceX Chief Executive Officer and Chief Technical Officer Elon Musk, Musk turned to Rasky during the discussion of options for producing PICA and asked, "Dan, what do you think?" When Rasky described his preference and the reasons for it, Musk said, "OK. That's what we're going to do."

At NASA, his proposed solution would have led to a series of studies and additional meetings before a decision was made. But on-the-spot executive decisions that would be difficult at a government agency or large corporation readily happen at a small private company. Rasky found that kind of decisiveness exhilarating and a little alarming—what if he was wrong?

Chambers had seen that sort of initial reaction before, from colleagues who joined SpaceX from other, traditional aerospace companies. But his team's ability to make these decisions and execute them efficiently is the key to rapid development. At SpaceX, most processes are developed and performed in house, making design iteration highly efficient. In the time others take to determine the scope of their trade studies, the SpaceX team will build and test the required prototypes. Additionally, an integrated thermal-protection system team that brought together the required specialist areas, including aerodynamic predictions, structural analysis, and materials performance, allowed smart choices to be made and a "sparse matrix engineering" approach (not filling in all the blanks before proceeding) to be taken when developing prototypes. It's the prototype that tells you whether your decisions were sound. If it fails to meet expectations, it provides data needed to make a better choice next time.

The speed of the process was enhanced by having many of NASA's technical experts only a phone call away. Additionally, an efficient procurement system allowed even exotic materials to be

Test placement of the PICA-X tiles on the first Dragon flight's heat-shield carrier structure. During reentry the lightweight tiles withstand temperatures as high as 2,000°C (3,620°F).

Photo Credit: SpaceX/Roger Gilbertson

Protected by a PICA-X heat shield in this artist's rendition, the Dragon spacecraft reenters the earth's atmosphere at around 7 kilometers per second (15,660 mph), heating the exterior of the spacecraft as high as 2,000°C (3,620°F).

N+S

Image Credit: SpaceX

delivered in just a couple of days and used for the next prototype.

The small size of the SpaceX PICA team—five engineers and six or seven technicians—also contributed to speed. Group members all worked at the same site and could easily meet to hash out problems, exchange information, and make decisions.

SpaceX has the advantage of speed and the freedom to innovate; NASA brings a breadth of experience and technical expertise to the table. It was NASA, after all, that carried out the research to develop the phenolic impregnated carbon material in the first place. NASA has unmatched experience in how materials and spacecraft actually behave in flight. And NASA has special facilities that small entrepreneurial companies could not readily afford. So, for instance, SpaceX makes use of the arc-jet facilities at Ames that offer the only way to test the Dragon shield material at the requisite high temperatures.

When different organizations try to work together—and especially organizations with different cultures—they sometimes run into trouble. Failure to understand one another's values and ways of working can get in the way. A sense of ownership of a project or a technology can interfere with knowledge sharing and cooperation. NASA and SpaceX have not experienced any of those problems in the PICA heat-shield work. Part of the success of the collaboration is due to the two organizations' shared engineering language and shared enthusiasm for the virtues and potential of PICA. Part of it is undoubtedly due to the shared greater goal of new capabilities for successful spaceflight—the ultimate aim of the COTS partnerships.

Mutual Benefits

The benefits SpaceX has derived from this collaboration are clear. They were able to take advantage of the extraordinary capabilities of PICA and the knowledge developed about it in the course of several NASA programs. And they got access to NASA's testing facilities.

But NASA benefited, too. For one thing, the knowledge flow goes both ways. What SpaceX has learned about designing, testing, and manufacturing large PICA heat shields is also available for NASA to apply to current and future programs. In addition, NASA can learn from SpaceX's work practices. Although the agency will never operate like a small, entrepreneurial firm, its own innovative work could benefit from a version of SpaceX's sparse matrix engineering and rapid prototyping.

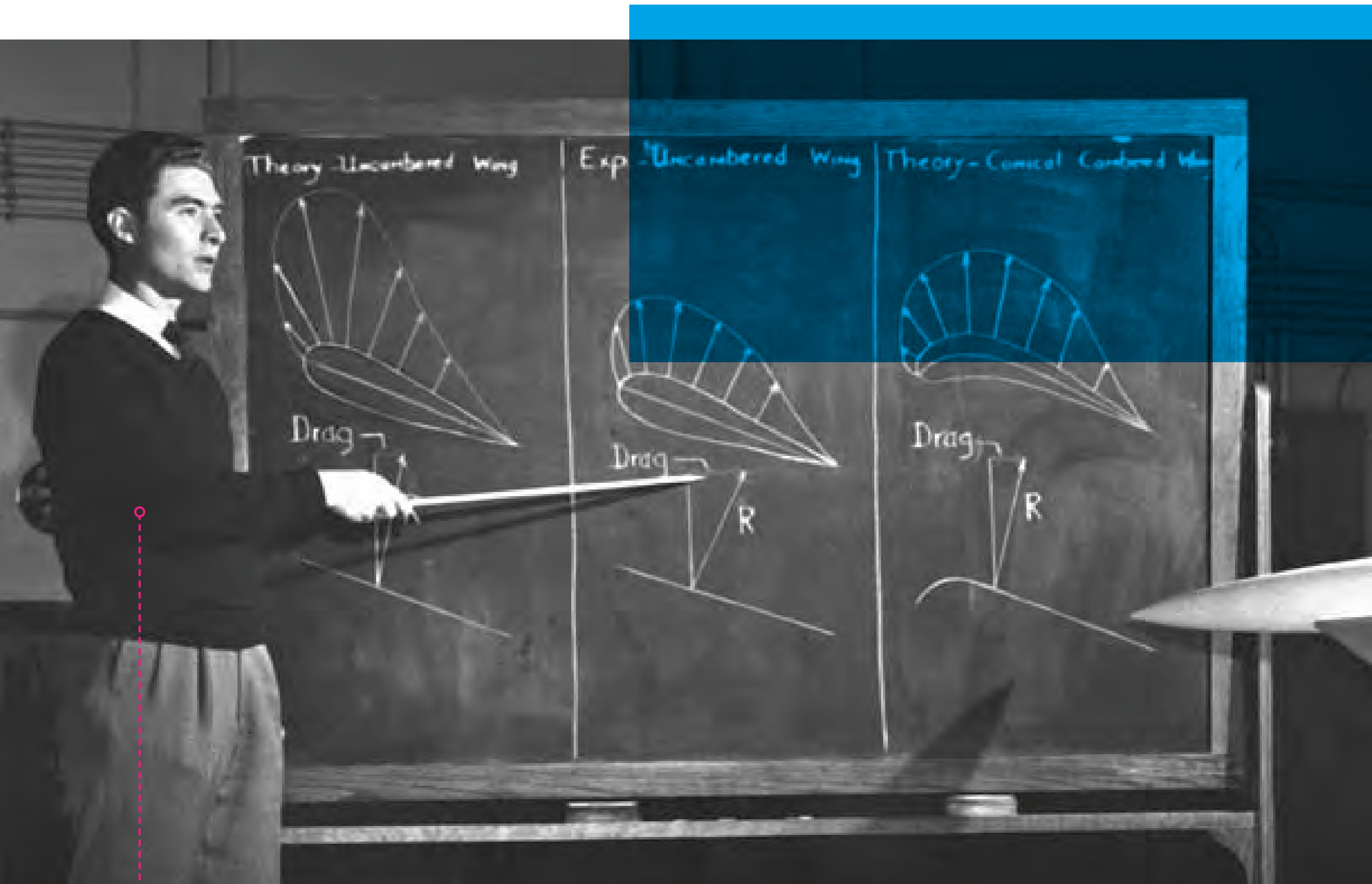
The ultimate mutual benefit will emerge when the Dragon spacecraft delivers cargo and crews to the International Space Station and returns safely to Earth, protected by its PICA heat shield. ●

ANDREW CHAMBERS started his career in the propulsion department of SpaceX in 2004. He initially worked on the development of various liquid rocket engines, including those that will lift the Dragon spacecraft. Over the past four years, he has developed the reentry heat shield for this capsule.

DAN RASKY is the director for the Emerging Commercial Space Office at Ames Research Center and a senior scientist with NASA. He is a co-founder and director of the Space Portal, whose mission is to "be a friendly front door for emerging and nontraditional space companies."

The Freedom to Learn

BY JACK BOYD



In 1944, I went to Virginia Tech to get my bachelor's degree in aeronautical engineering. In those days, we finished college in three years because the war was on, which was nice because you got in and out pretty fast. Langley Field sent interviewers out to our campus to talk to people, but I had been in Virginia all my life, and I wanted to see California. I told the recruiter I didn't want to go to Langley; I wanted to go to Ames. A few weeks later I got a telegram from Langley that said, we've talked to Ames, and here's your offer: $2,644 per year, take it or leave it. I took it.

Jack Boyd explains the efficiencies of conical camber in 1957.

Photo Credit: NASA

Ames sent me an offer but they didn't say where I was going to work. The lady who talked to me said, "I see you have one course in college in compressible flow aerodynamics [which is like high-speed aeronautics] and we have a little supersonic wind tunnel, so we're going to assign you to this 1-foot-by-3-foot supersonic wind tunnel."

There were fantastic people in that facility, people like R.T. Jones, who developed the sweptback wing; Harvey Allen, who developed the blunt-body concept; Walter Vincente, a really outstanding high-speed aero man; Milt Van Dyke; and Dean Chapman. I didn't realize it at the time, but I worked with eight or ten of the best-known aerodynamicists in the world. As the years wore on, they became the leaders of the aerospace world.

They told me they were going to let me do a bit of research on sweptback wings, which were kind of new in 1947. At the time, we had to design our models, decide what we wanted them to look like, take the result to the machine shop to get them built, take them to the wind tunnel to test them, and then write a report on the results. You did the whole thing from start to finish.

Learning the Job

I felt intimidated when I started, but everyone encouraged me. It was a very open-minded society in those days, an innovative society. If you had an idea and it had relevance to anything at all, they'd let you pursue it as far as you wanted to take it.

R.T. Jones told me to start reading everything I could find about aerodynamics. For the first three or four months, I just read and talked to people. They didn't really give me a job. Then one day they told me I'd been around long enough and knew enough about aerodynamics, so I should design a sweptback wing, put pressure taps in it, and test it to obtain detailed pressure forces on the wing. They threw me in to the middle of it, but all the experts around me could answer almost any question. The group I was in had only ten or twelve engineers, so it wasn't hard to know who to go to, especially with R.T. Jones and Harvey Allen there to help. And I was one of only two or three new employees that year, so they focused on us new employees.

The team in the little wind tunnel was only about twenty people in total: the branch chief and a number of researchers and mechanics. And we had maybe four to six "computers"—the computers were young ladies who sat in a room with a calculator and reduced the data for you. A lot of the engineers in those days literally married their computers. I did not. During all this exciting activity, I had time to meet and marry a beautiful lady, Winnie, and we have five children and nine grandchildren.

The center directors were very close friends of each other and frequently gave each other advice. I remember a visit from the Langley center director who advised us, "If you've got a good idea, go try it. If it fails, so it fails; just try another one." Innovation was really the name of the game.

Photo Credit: NACA

Interior view of Schlieren setup in the 1-foot-by-3-foot supersonic wind tunnel at the NACA Ames Aeronautical Laboratory, Moffett Field, California.

H. Julian Allen stands beside the observation window of the 8-foot-by-7-foot test section of the NACA Ames Unitary Plan Wind Tunnel. Allen is best known for his "blunt-body theory" of aerodynamics, a design technique for alleviating severe reentry heating problems.

The bright people at Ames kept us from failing very often. Being among those folks was probably the thing that got me a really good start. Every day six or eight of us would go to lunch together and talk about our work. Harvey Allen had dinner functions and cocktail parties at his home in Palo Alto, and he'd invite the younger engineers to mix with the older ones. The girlfriends some of us had didn't want to go. They found out the first time that all we talked about was work.

Sharing What We Learned

We were part of a very open society at Ames, with many open discussions, and all the data we obtained was free to the aerospace industry. They would use the data we got out of the supersonic and subsonic wind tunnels to help design their own aircraft. We also held National Advisory Committee for Aeronautics (NACA) conferences. Each year there was a conference at one of the centers: Langley, Ames, or Lewis. People from academia and the aerospace industry, both military and civil, would attend, and we would present our results from the past year. People including Theodore von Karman, Jimmy Doolittle, Hugh Dryden, Allen, and Jones would come to these meetings—all the bigwigs of the aerospace world. Those conferences, held every year, were key to transmitting NACA information to the industry, as were the NACA reports.

When NACA became NASA, the way we shared things changed some, and I don't think deliberately. In the days up until 1958, NACA developed technical and aerospace data

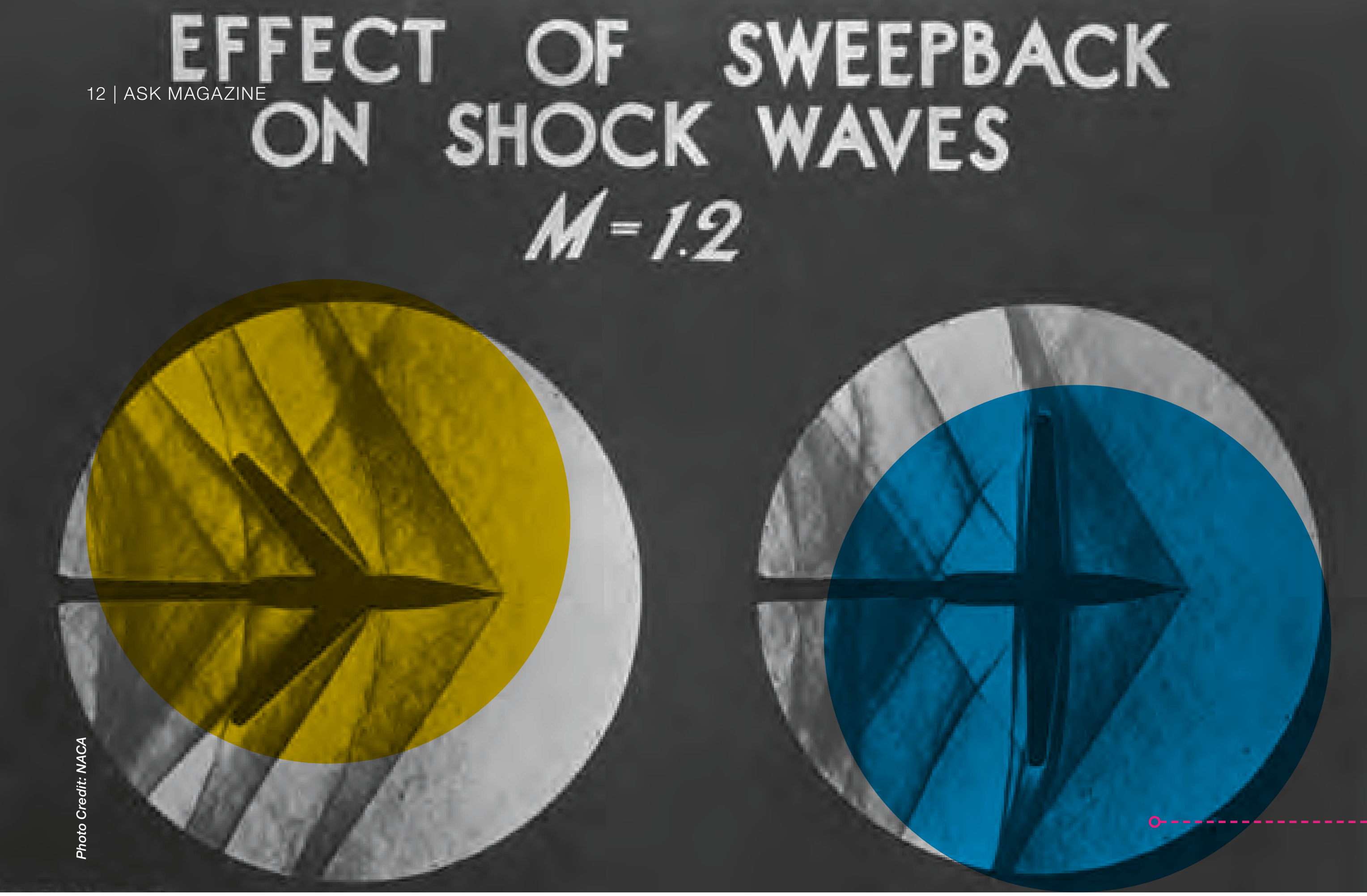


Photo Credit: NACA

for industry, and industry was the user of the data. When we became NASA, we became the users of some of the technology ourselves and managers of big projects like Mercury, Gemini, Apollo, and so on. It changed a little bit in how we transmitted the information out.

Innovation from Aeronautics to Astronautics

The air speeds at which we were working in those days were Mach numbers of 0.2 to 2.0, twice the speed of sound. We were making wings more slender and in sharper shapes to go faster more efficiently. In the fifties we at Ames began to think about space thanks to Harvey Allen, who started us thinking this way. He told us that if we were really going to go into space, we'd be orbiting the earth, for example, at 17,000 miles an hour, so we would need to make a blunt body shape to slow down a vehicle when it comes in so it wouldn't burn up.

That got us thinking about other kinds of things that would be interesting to work on. For example, if we went to Mars and Venus, where the atmospheric gases are different, certainly the aerodynamics would be different, too.

I came across a guy called Zdenek Kopal, who was a famous astronomer who worked at an observatory in the Pyrenees mountains in Spain. We invited him to Ames for a lecture, and he began talking to us about planetary astronomy and gas mixtures on other planets. We were aerodynamicists; we knew nothing about planets. But Kopal and Carl Sagan said carbon dioxide and nitrogen were probably prevalent gases on Mars and Venus. We had a facility here called a free-flight range, which allows you to fire a model into a mixture and take data from it; unlike a wind tunnel, it could be filled with a variety of gas mixtures. We thought we'd fill one of these ranges with a variety of carbon dioxide and nitrogen mixtures and fly different shapes into them to see what the aerodynamics looked like. We got some interesting results. There were differences, not only in the aerodynamics but also in the heating. That got us started down that path of being interested in planetary entry vehicles.

Had we not started doing this work at NACA before 1958 because we were curious, I think we would never have gotten to the moon when we did. We had a jump-start on the technology we were going to need. Langley, Lewis, and Ames people were working on the technology that led to the application of the lifting-body studies—which looked at the feasibility of maneuvering and landing an aerodynamic craft designed for reentry from space—to Gemini, Mercury, Apollo, and, later, the Space Shuttle. We were not only curious, we had the freedom to pursue that curiosity. In order to fill one of the ranges with gas mixtures, we just asked the guy at the range and he said, "Hey, that sounds like a great idea, go do it." Our center director was very safety conscious and he made sure it was safe. Many other people did much more detailed research after that; we just started it here.

Simply starting somewhere and sharing what you learn from the experience allows others to take what you learned and keep expanding on it. You never know where things can end up, The NACA credo.

Schlieren photograph of the flow around airplane models showing the effect of sweptback wings on shock waves at Mach 1.2.

like landing on the moon. Curiosity can lead to innovation, and continuous learning, even unconventionally, can help keep that curiosity strong.

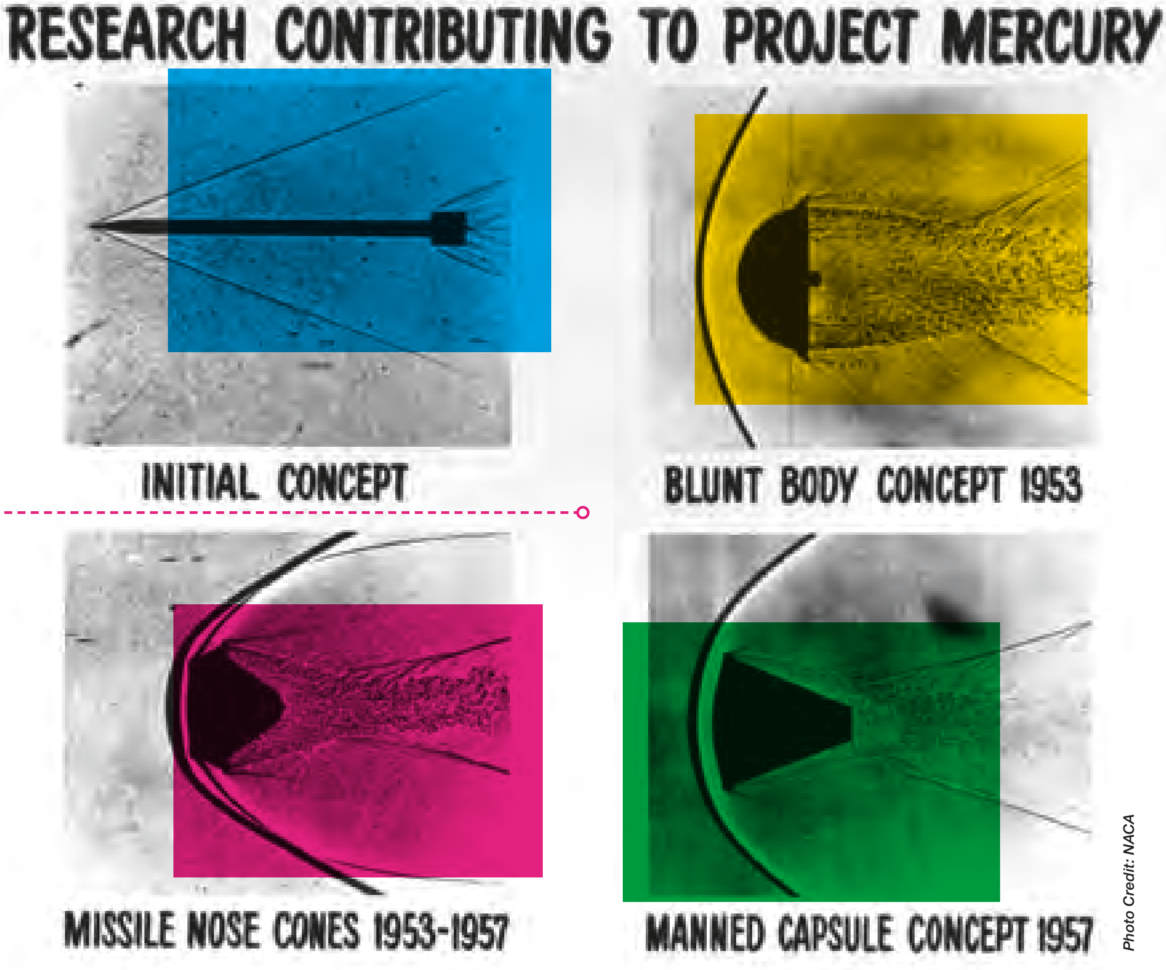
Continuing Education and Future Innovation

I left NASA in '85 and went to the University of Texas as assistant to the chancellor for research and was able to teach as an adjunct professor at the Austin, El Paso, and Pan American campuses. I came back to Ames in '93, and that's when we started the Aerospace Encounter, an educational program designed to inspire students in fourth through sixth grades about science, technology, engineering, and math. It is still operating today.

The kids cannot run the wind tunnel we use to house the program, but they can use computer workstations to operate a model wind tunnel and see what a big wind tunnel really looks like. We also have a computer program that lets them design their own airplanes. They pick an engine, a body shape, wing type, and a destination—like flying from San Francisco to London—and try to optimize how to do it. If they don't have the right thrust or number of engines, their design can't make it, of course, from San Francisco to London. So they have to redesign it. When they create a design that works, the computer alerts them to their success, and they can print out their design and take it away with them.

The kids taught us something we knew early on: they were unconstrained in their thinking. For example, they would design an aircraft that looked like a blimp with little wings on it.

Photo Credit: NACA



These four shadowgraph images represent early reentry vehicle concepts.

Photo Credit: NACA

It wouldn't go anywhere at high speeds because the drag was too high, but their minds were open to almost anything.

I talk to students a lot. I've got an arrow chart explaining that it's going to be up to them what we do in the next fifty years. That chart says we're going to explore the moon, we're going to explore Mars, we're going to explore the solar system. And then there's the end of the arrow. My grandson asked, "What are you going to put in that arrow, sir?"

I said, "I don't know. What do you think?"

He said, "Why don't you put the words 'quantum gravity machine?' I think Einstein was wrong. We can go faster than the speed of light, and I'm going to prove it, and that's what I'm going to call it: quantum gravity machine."

It's been two years now, and so far I've seen no sign of the machine, but he's still working at it. If we're going to pursue human exploration of Mars using current chemical propulsion, it would take nine months to get there and nine months to get back. That's just unacceptable. With my grandson's quantum gravity machine, it would take about 4.5 minutes to get to Mars.

I like to talk to children because they're open to almost anything. They don't care what kind of questions they ask you. They aren't inhibited. They've taught me to keep my mind more open. The mind closes as you get older; you get your own set of ideas and believe you must be right. You're not quite as open to learning new things. With Aerospace Encounter, you're constantly surprised by the questions kids ask, which is part of why it's so great.

The average age at Ames was about 27 years old when I started. Now it's around 50 years old. So we really need to get the young blood flowing here. But we need to do it while preserving the history that has come before.

Preserving and communicating NASA history keeps us from making the same mistakes twice, hopefully. It also sets a shining example of what this country can do when it puts its mind to it. I don't mean just landing on the moon; I mean the whole spectrum of things we've done. Look at what NASA has accomplished and think about how the first airplane flew in 1903. Just over one hundred years later, look what we've done. We've gone to the moon, we've gone to Mars robotically, we've flown out of the solar system, beyond planets, over to Pluto. These are remarkable things. We need to pass on what we've learned from it all so we can keep doing remarkable things in the future. The kids are our future. They will develop the innovative technology that will permit us to further explore our solar system and beyond.

JACK BOYD serves as senior advisor to the Ames Research Center director and as the senior advisor for history and the center ombuds. He first reported to work at Moffett Field, the home of Ames, sixty-three years ago.

The view from the cockpit of the B-52 carrier aircraft.

Photo Credit: NASA

X-15: PUSHING THE ENVELOPE

BY KERRY ELLIS

Breaking the sound barrier took guts, curiosity, optimism, and some serious risk taking. Equipped with slide rules and other fifties technology, the army, navy, and North American Aviation teamed up with the National Advisory Committee for Aeronautics (NACA) to create an aircraft that could outfly all others. Through a series of experimental aircraft, NACA—later NASA—pursued supersonic and hypersonic flight with record-breaking results. The lessons learned during this ambitious research program contributed to many other NASA programs.

During 199 flights between 1959 and 1968, the X-15 achieved many firsts and set a slew of world records, some of which still stand. Those achievements required a high level of risk and included failures along the way. But the program's ability to build, test, fly, and repeat in quick succession made every new plane better than the one before. With the freedom to rapidly churn through data and rebuild when necessary, the team achieved more than anyone imagined possible.

Building a Rocket Plane

The X-15 was created to explore hypersonic (generally defined as five times the speed of sound) aerodynamic performance, research structural behavior during high temperatures and pressure, study stability and control during exit from and reentry of the atmosphere, and examine pilot performance and physiology. What the program discovered directly contributed to Mercury, Gemini, Apollo, and the Space Shuttle.

Its immediate predecessor, the X-2, had been designed to achieve Mach 3. Pilot Milburn "Mel" Apt managed to push the plane to Mach 3.196 before turning back to Edwards Air Force Base to land; the roll he initiated to make the turn caused an adverse yaw problem previously experienced by Chuck Yeager in the X-1. The plane tumbled out of control, and Mel died in the accident. Making the leap from the tragic final flight of the X-2 to a plane intended to double the X-2's design speed was risky. But the tragedy made the X-15 team work hard to ensure pilot safety.

To solve the yaw problem, the team developed a wedge-shaped tail: narrow at the front and wide at the back. This helped keep the air streams apart longer at hypersonic speeds, which gave the plane exceptional directional stability. The wedge tail is now a commonly accepted shape for hypersonic control surfaces, but the X-15 was the first to employ it on a manned aircraft.

To barrel through the air at six times the speed of sound and reenter the atmosphere from the edge of space, the X-15 body needed to survive extreme stress and heat. Engineers used Inconel-X, a heat-resistant nickel-chrome alloy, and titanium for the structure—achieving the first use of a reusable superalloy structure capable of withstanding hypersonic reentry. In the process, the team developed new fabrication techniques for machining, forming, welding, and heat-treating Inconel-X and titanium.

Heating at hypersonic speeds presented other design challenges as well. Since metal expands at high temperatures, slots were built into the sides of the plane to accommodate a few inches of expansion. "It expanded just like an oilcan," pilot Maj. Gen. Joe Engle said. "It sounded like someone banging on the side of a plane with a sledgehammer, and the old guys wouldn't warn you about it."

Early inertial systems affected how the X-15 was eventually flown. The systems relied on gyros, whose axes would be thrown

The X-15 mockup as it was inspected in December 1956.

Photo Credit: U.S. Air Force

off kilter during hypersonic acceleration. This effect prevented pilots from knowing how high or how fast they were flying. To accurately measure thrust energy, the team decided to time how long the engine burned. A stopwatch in the cockpit told pilots when to shut off the engines in order to complete a planned flight path with precision. Burning the engine for one second too long could mean an extra 280 mph and 35,000 ft. of altitude, something pilot Maj. Gen. Bob White experienced firsthand.

Piloting Through Near Space

Engle described the X-15 team as one that worked together in perfect harmony: "If I didn't look at badges, I would not know who anybody worked for on that program; it was that kind of operation." The pilots who undertook the flight risks were key members of that team.

To keep pilots safe from the immense heat and pressure experienced during flight, engineers developed nitrogen cabin air-conditioning for the cockpit. This also helped counteract potential flammability should the engine malfunction. While filling the cockpit with oxygen was an option, the potential for an explosion if it interacted with the engine's flammable propellant was too high a risk. To prevent blackouts from high g-forces and ensure the pilots could breathe within the nitrogen-filled environment, the X-15 team developed an early pressure suit, also pressurized and cooled with nitrogen. The only breathable oxygen available was in the suit's faceplate.

Each flight lasted about eight to ten minutes. Around eighty seconds after the X-15 was launched from under the wing of a B-52, pilots would shut down the engines. The rest of the flight was unpowered, and the pilot was essentially guiding a high-speed glider. Precision piloting was critical. If the engine was cut one second too late, or if the pitch was off by one degree, pilots could end up thousands of miles off track. With the only navigation available being line of sight from the X-15's two small windows, a few ground stations, and non-hypersonic chase planes, overshooting the course meant emergency landing decisions had to be made and communicated quickly. And if one of the windows glazed or cracked from the heat of flight—a problem that often occurred—pilots were reduced to tracking on only one side of the plane. This made the stopwatch in the cockpit very important for accurate energy management and flight-path positioning.

Eight pilots were given the title of astronaut for flying more than 50 miles above the earth's surface. One, Captain Joe Walker, set an aircraft altitude record of 67 miles above Earth. When they were flying in near space, "Airplane attitude didn't make much difference," Engle said. "You could fly sideways or backwards over the top. But it was very important once you started back down and got into sensible atmosphere to be lined up both in pitch and yaw for reentry." At the wrong angle, the plane could skip up during reentry, which happened to pilot Neil Armstrong during

A HEART-POUNDING EXPERIENCE

A major concern when NASA began to explore human spaceflight further was the physiological responses of those chosen to fly the missions. Heart rates for pilots were very high, and data from X-15 pilots directly influenced the decision to fly men into space. Below is Walter C. Williams' account of how the heart-rate issue was finally resolved.

We were working hard on Project Mercury. We were getting ready to fire Alan Shepard on the first ballistic flight. Prior to that, we had a little hearing before the President's Scientific Advisory Committee. It had two types of members: engineering types and aeromedical types.

We had a terrible time with the doctors; that's the only way to describe it. They thought we ought to fly seventy-five more chimps before we flew a man. I'm serious! We had the data from this one chimpanzee, which showed very high pulse rates, and they were concerned that this might kill a man or you'd pass out or what have you. And so we had quite a go-around on that.

Meanwhile, the X-15 was flying out here and the pilots were being monitored and, yes indeed, they had high pulse rates due to stress; their highest rates were usually before launch or landing. So I sent out for that data and brought it in and for a while I thought they were going to cancel the X-15 instead of clearing us to fly Project Mercury!

So Don Flickinger, the senior research aeromedical doctor, and one who had been closely following the X-15 program, got one of the doctors on the committee and Joe Walker in a three-way conversation (the data we had involved Joe Walker). The doctor began questioning Joe about this and that, then saying, "These pulse rates are pretty high—over 150. How did you feel?"

Joe responded, "Oh, I felt all right. Now wait a gosh-damn minute. Are you trying to ask me whether or not I fainted?"

The doctor said, "Well, yes. Did you faint?"

Joe replied, "Hell, no! I didn't faint!"

The doctor continued, "Well, I don't know … people can pass out and not realize it."

Joe retorted, "Look, what I did one second depended on what I had done the second before, and I'm here talking to you!"

Scott Crossfield sits in a thermal-vacuum chamber during tests of a prototype XMC-2 pressure suit. Production versions of this suit were used for thirty-six early X-15 flights.

Photo Credit: Boeing


Photo Credit: NASA

The X-15 research aircraft during its first powered flight on Sept. 17, 1959.


Joe Engle during the X-15 program.

Photo Credit: NASA

one flight. "He ended up getting down to Burbank, turning around, and barely made it in to the dry lake bed, landing south to north instead of north to south like usual," described Engle. "It was the longest flight in duration we had in the X-15."

Training was key. Laying a foundation for later space programs, the X-15 program relied on a ground simulator to help pilots grow familiar with the minute controls and precise timing required for hypersonic flight.

Paving the Way for Human Spaceflight

The pilots and engineers on X-15 worked together to discover the magic altitude where flying with reaction controls—rocket thrusters on the nose and wings—would work best. "Engineers asked us to find out where that magic altitude was," said Engle. "We made some errors coming back in—sometimes getting a bit of roll. We learned that a blended, adapted flight-control system, using both reaction controls and aerodynamic surfaces, is necessary for an entry from space back into the atmosphere. The same flight-control system developed on X-15 was used on Space Shuttle."

The way the Space Shuttle lands was directly influenced by the X-15's unpowered landings. "Early in the design phase of shuttle, there was a very strong feeling that we really shouldn't be landing something with as low a lift-to-drag ratio as the Space Shuttle unpowered," explained Engle. "In fact, one of the early design proposals had air-breathing engines that would fit into the aft end of the payload bay. They would have taken up a quarter to a third of the payload bay in volume, not to say how much it was going to weigh, for the engines to be on a mechanism to fold out after you went supersonic, start up the engines, then fly it in like a conventional airliner. That plus the fuel." Being able to demonstrate safe, accurate, unpowered landings with the X-15 proved to shuttle developers that a conventional powered landing was unnecessary.

Pressure suits developed for the X-15 provided insight into how full-pressure suits restricted the reach and energy envelope—how much and with what effort suited pilots could move—which paid off later in the design of spacesuits. "There was considerable discussion with Wright Field concerning use of a partial-pressure suit, which was developed, versus a full-pressure suit, which had to be developed," said Walter C. Williams, chairman of the X-15 Flight Test Steering Committee. "It was felt important to develop a full-pressure suit. … This suit became the foundation on which suit technology was built for use in the space programs."

The X-15 program also demonstrated the first application of hypersonic theory and wind-tunnel testing to an actual flight vehicle, which helped provide confidence in the wind-tunnel studies later done for the shuttle.

Pushing the Envelope

The X-15 program, and its team, achieved so much in so little time due in large part to their skill and willingness in taking measured risks, pushing the envelope of what could be done with high-speed flight. The results of their collaboration paved the way for human deep-space exploration, influencing Mercury, Gemini, Apollo, and the Space Shuttle. Risk-taking was vital for the team's leaps in innovation.

"There is a very fine line between stopping progress and being reckless," said Harrison Storms, chief engineer at North American Aviation during the X-15 program. "The necessary ingredient in … solving a sticky problem is attitude and approach. [It's] what I refer to as 'thoughtful courage.' If you don't have that, you will very easily fall into the habit of fearful safety and end up with a very long and tedious-type solution at the hands of some committee. This can very well end up giving a test program a disease commonly referred to as 'cancelitis,' which results in little or no progress and only creates another 'Hangar Queen.'" ●

FROM SKETCH PAD TO LAUNCHPAD

BY HALEY STEPHENSON

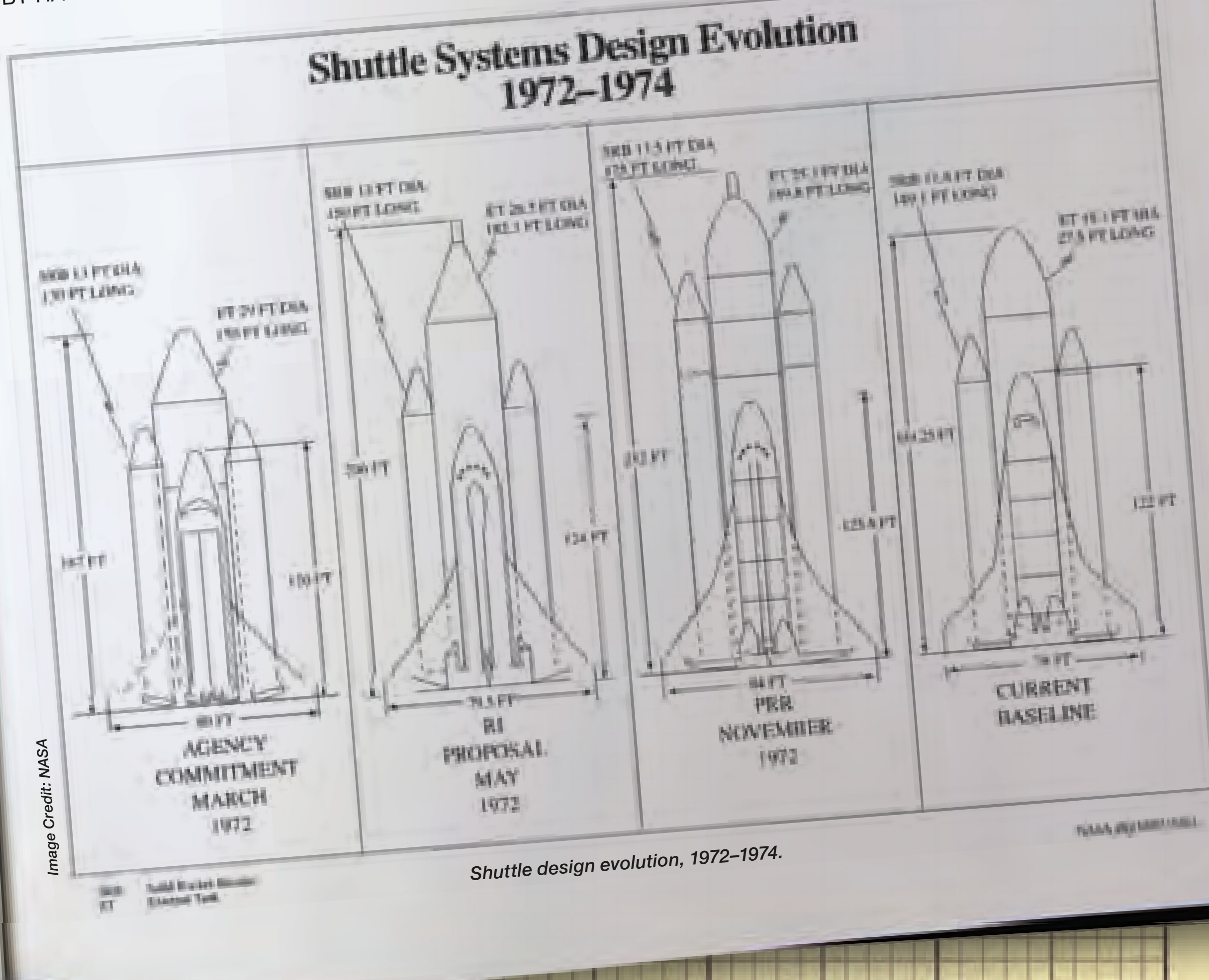
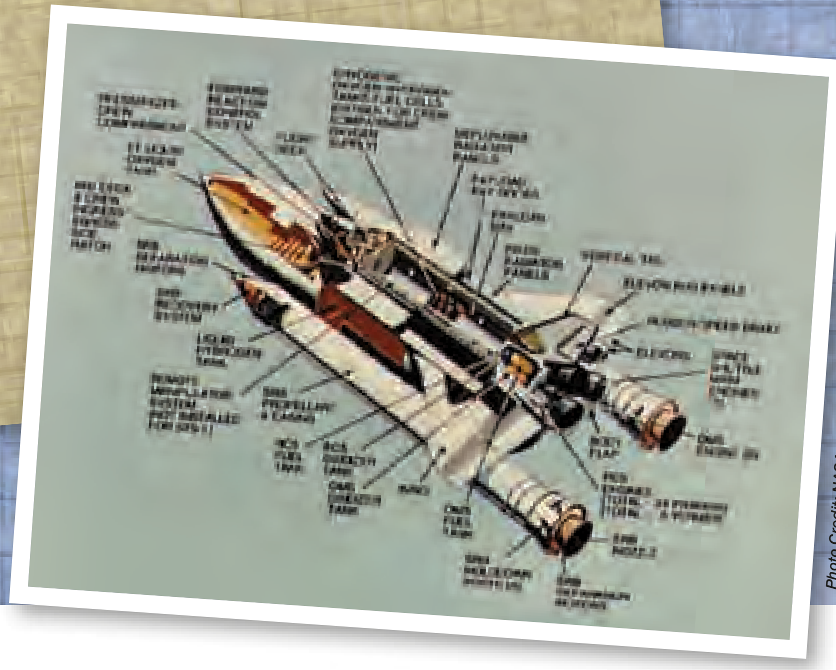


Image Credit: NASA

Shuttle design evolution, 1972–1974.

STS-1 launches April 12, 1981.

Photo Credit: NASA



This "cutaway" artist's concept reveals systems of the major components of a Space Shuttle vehicle.

Photo Credit: NASA

For Tom Moser, getting the first shuttle off the ground took more than technical know-how.

In the summer of 1980, the Space Shuttle program was in trouble. Technical challenges, especially those with the thermal protection system, were causing the program schedule to slip. Deputy Administrator Alan Lovelace held a meeting to address the problem. Moser, the engineering manager responsible for the tiles at Johnson Space Center at the time, was one of thirty-three engineers at the meeting. "Tell me what the schedule is, and I'll want a firm commitment that you will make that schedule," Lovelace said. He was very serious, Moser remembers, but Lovelace lightened the mood by telling a story:

A pig and a chicken were having a talk in the barnyard one day. The pig asked the chicken, "Are you involved in the big dinner our master is planning for next week?"

"Of course I'm involved," replied the chicken. "I'm furnishing the eggs."

"Aw, that's nothing," the pig snorted. "You're just involved. I'm supplying the ham. I'm committed."

"I want all of you to be like that pig," Lovelace said, "I want you to be committed."

The story added levity to a serious situation and served as inspiration for a group that later became known as the "Space Shuttle Ham and Eggs Society." "We made that commitment and did what we said we were going to do," Moser said. The group agreed to launch in April 1981.

A Beginning

Even before Apollo 11 made history with the first manned moon landing, the space community was looking for the next big thing. Shuttle studies and design efforts started to emerge during the mid-sixties and picked up momentum in January 1969. Input from the commercial and government sectors resulted in requirements ranging from delivering payloads to orbit to conducting Earth observations. "It was going to be a truck to carry goods to low-Earth orbit," said Moser. "Everybody had a need."

NASA initiated several studies to come up with a design that would facilitate a cost-effective, quick-turnaround, fully reusable space transportation system. The studies produced several concepts, including lifting-body designs. Max Faget, then director of engineering at Johnson Space Center, acknowledged the merits of lifting bodies. According to Faget, "You avoid wing–body interference," which brings problems of aerodynamics. "You have a simple structure. And you avoid the weight of wings." He saw difficulties, however, that effectively ruled them out for a practical shuttle design. They had low lift and high drag, which meant a dangerously high landing speed. As he put it, "I don't think it's charming to come in at 250 knots."[1]

EVERY DECISION—FOR INSTANCE, BETWEEN A TITANIUM OR ALUMINUM STRUCTURE, HOT STRUCTURES OR TILES FOR THERMAL PROTECTION, AND STRAIGHT WINGS OR DELTA WINGS—HAD COMPLEX IMPLICATIONS FOR THE OVERALL SYSTEM DESIGN.

Faget had something else in mind. Influenced by the X-15 rocket plane, he envisioned a winged vehicle that would glide back to Earth, its nose tipped upwards. He formed a "skunk

Photo Credit: NASA Dryden Flight Research Center

The Space Shuttle prototype Enterprise rides smoothly atop NASA's first shuttle carrier aircraft, NASA 905, during the first of the shuttle program's approach and landing tests at Dryden Flight Research Center in 1977.

works" team at Johnson to develop that concept. A network of support teams in communications, aerodynamics, and heat transfer contributed to analysis done by the core team. During that time, Moser was part of the structural design engineering group, which he would later lead. "We had all of the requirements, and we looked at almost a configuration a day," Moser recalled. Each concept was analyzed in terms of weight, manufacturability, cost, schedule, risk, and technology readiness. "This is where really good engineering, leadership, and management was necessary," said Moser.

Every decision—for instance, between a titanium or aluminum structure, hot structures or tiles for thermal protection, and straight wings or delta wings—had complex implications for the overall system design. The material for the thermal-protection system, for instance, depended on whether the structure was titanium or aluminum. "Any time there was a decision to be made there was a set of requirements associated with that decision," said Moser.

By the end of 1969, engineers had agreed upon a basic configuration for the shuttle, though it wasn't exactly what they initially imagined. To balance development and operational costs, the shuttle could only be partially reusable. The expense of developing a fully reusable design encroached upon operational spending later on, Moser explained. NASA got the green light to proceed with shuttle development three years later.

Decision and Change

The detailed development of the shuttle began in 1972. This phase of the program was characterized by challenging discussions and their outcomes. "One thing that didn't change from Apollo to shuttle is the way we made decisions," said Moser. "Somebody was in charge, but everybody got to say what they thought needed to be said at that meeting." Representatives from all engineering disciplines had a seat at the table. "All of the facts were laid on the table, and everybody got to argue and debate and present their views of what they thought the right answer would be," said Moser. "Quite often it was a heated discussion."

Once a decision was made, changes were rare. He recalls that there were always people who wanted to make changes during the shuttle development. Unless testing showed otherwise, "we did our work well enough to where we didn't have to make changes," said Moser. They lived by the philosophy of "better is the enemy of good." Quite simply, Moser said, "We closed the door on changes."

In It from Start to Finish

Over nine years of development, the individuals who started work on the shuttle saw it through to the finish. "I think that's something that a lot of people don't realize," said Moser. "The team stayed together the whole time." Moser believes this was a huge part of the success of getting the shuttle off the ground. Shuttle arrived in the wake of the Mercury, Gemini, Skylab, and Apollo–Soyuz programs, giving it a deep bench of seasoned engineers who had already worked on multiple programs. "We had that experience that is very, very difficult to obtain," said Moser. This experience, combined with the team's determination to see the shuttle succeed, proved a winning combination. "You've got to commit on the requirements and the mission, but you've got to commit to the team, too," said Moser.

The team had both good managers and good leaders, according to Moser. Managers control the implementation of a program, explained Moser, but leaders set the path and establish a rapport. During shuttle development, he looked up to people such as John Yardley, Chris Kraft, Bob Thompson, and Aaron Cohen. Their personalities differed, but all those leaders had the ability to make tough decisions.

The team wasn't always perfect. Screw-ups happened, said Moser, but the permission to learn from them made the team stronger because they stayed together. "People make mistakes," he said, "but when you have a team and you believe in them and support them, then that's what'll work."

SHUTTLE ARRIVED IN THE WAKE OF THE MERCURY, GEMINI, SKYLAB, AND APOLLO–SOYUZ PROGRAMS, GIVING IT A DEEP BENCH OF SEASONED ENGINEERS WHO HAD ALREADY WORKED ON MULTIPLE PROGRAMS.

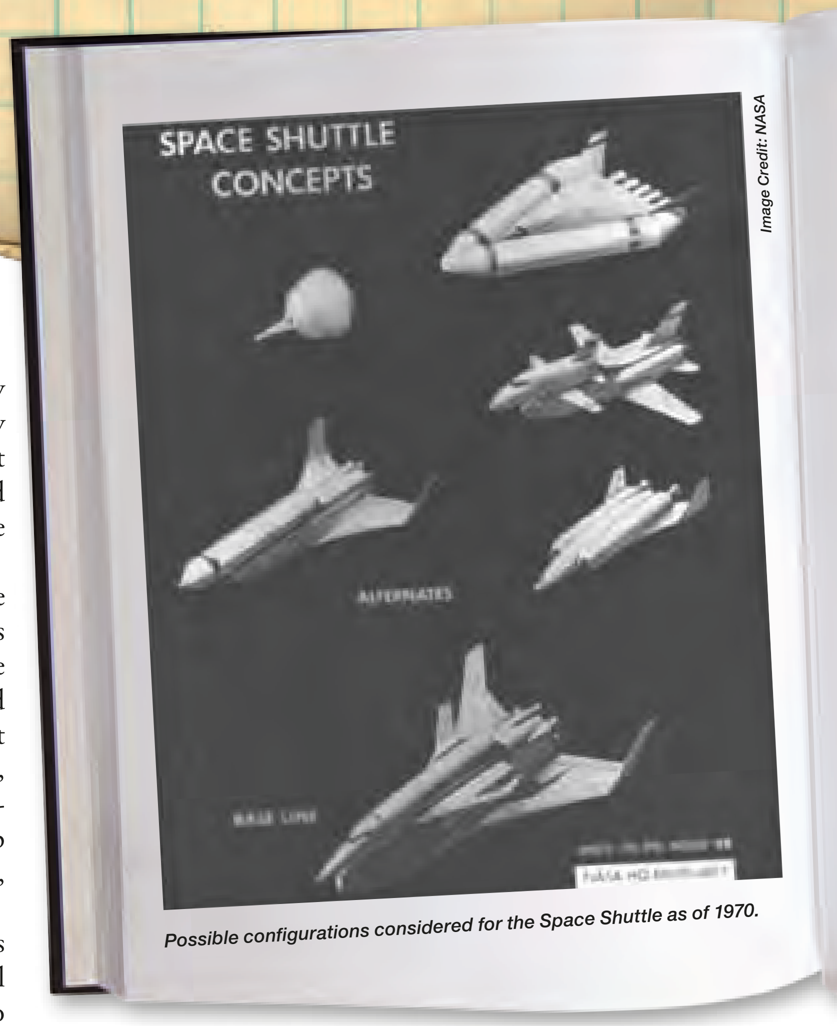


Image Credit: NASA

Possible configurations considered for the Space Shuttle as of 1970.

Sell It. Then Keep It Sold.

Wernher von Braun once wrote that Apollo "had the beauty of simplicity. Everybody knows what the moon is, everybody knows what this decade is, and everybody can tell a live astronaut who returned from the moon from one who didn't." Shuttle had challenges of complexity. While the technical challenges were substantial, the political challenges were monumental.

While NASA initially managed to make the case for the shuttle to the White House, Congress, and the public, it was difficult to fend off a developing sense of buyer's remorse. The program never received the budget it requested, which caused continuous changes to planning and scheduling. The constant change and delay resulted in the program nearly being cut, though renewed enthusiasm emerged with the first approach-and-landing tests of the Space Shuttle *Enterprise* mated to the top of a Boeing 747 in 1977. The stakeholders saw their investment, and it was quite a sight.

"Keeping it sold is difficult," said Moser, who encourages engineers to understand how to operate within the political system. "It doesn't sound like engineering, but if you don't do it, [the work] doesn't get done." You have to define the political environment and structure an approach consistent with it, he said. Keeping the program sold means communicating with stakeholders, writing letters, opening lines of communication with people in government, and creating effective public relations strategies to communicate to the public the importance of their investment.

Liftoff

The commitment came to fruition on April 12, 1981. Moser, who had been up since the early morning hours to support the launch, remembers standing in Launch Control at the Cape with minutes left in the countdown as STS-1 sat waiting on Launch Pad 39A. Moser realized he couldn't see the vehicle from his location. "I couldn't stand it, so I had to go outside," he recalled. "I walked outside and looked across the open water to where the vehicle was and all I could see was just the nose of the external tank sticking above the launch complex."

Space Shuttle *Columbia*'s engines started, the smoke came up, the fire was bright, "and then the vehicle just rose," Moser remembers. "It was like something coming to life."

After the launch, the members of the newly dubbed "Space Shuttle Ham and Eggs Society" were recognized for their significant contributions to getting the shuttle off the ground. Each member of the group received a personalized, laminated membership card with a picture of two fried eggs and a slice of ham with the words "Are you involved—or committed?" ●

1. T.A. Heppenheimer, *The Space Shuttle Decision: NASA's Search for a Reusable Space Vehicle* (Washington, D.C.: NASA History Office), 1999, p. 207.

INTERVIEW WITH

Wayne Hale

BY MATTHEW KOHUT

Former Space Shuttle Program Manager Wayne Hale's career roughly paralleled the life cycle of the Space Shuttle program. Hale began his career with NASA in 1978 as a propulsion officer at the Johnson Space Center and later became a flight director in Mission Control for forty-one Space Shuttle missions. He went on to hold numerous positions in the shuttle program, including launch integration manager, deputy program manager, and program manager. For the last two years and four months of his NASA career, he served as the deputy associate administrator for strategic partnerships, responsible for coordinating interagency and intergovernmental partnerships for the Space Mission Operations Directorate at NASA Headquarters. Matthew Kohut spoke with him two weeks before his retirement at the end of July 2010.

KOHUT: Throughout your career you worked in the shuttle program at just about every conceivable level. Which jobs presented the steepest learning curves, and what did you do to get up to speed?

HALE: The first job that I had coming in as a "fresh-out" from college—trying to learn how to be a flight controller, trying to learn about the Space Shuttle and its systems, particularly its propulsion system—was a big challenge to me because it was unlike anything I'd ever done academically or in any other part of my career. NASA is a special culture, with a special mind-set. You have your engineering background, but you have to put it to use in ways that are completely different in operation than what they teach you in the university.

Fortunately, I was mentored quite a bit by some of the Apollo veterans who were still there in the early days before shuttle. They helped teach us not just the facts, figures, and technical items, but how to

"THEY [APOLLO VETERANS] helped teach us NOT JUST THE FACTS, FIGURES, AND TECHNICAL ITEMS, BUT how to think, how to make decisions, AND how to communicate THOSE DECISIONS."

think, how to make decisions, and how to communicate those decisions.

Going from being a person in Mission Control sitting at one of the consoles being responsible for one discipline to being a flight director, where you have to understand all twenty-three different disciplines that are present in the Shuttle Flight Control Room, was also a big step. It was like going back to school again. There was so much technical [knowledge], so much rationale behind why things are done the way they're done. It's a huge amount of knowledge you have to amass to be able just to ask the right questions to lead the team toward having a safe and successful shuttle flight.

Then when I made the transition to the Space Shuttle Program Office, first as launch integration manager, then deputy program manager, and finally program manager, I found out that there were gaping holes in my knowledge and background, in particular regarding contracts, law, business, accounting, budgeting. All of these were things that I had never had to deal with during twenty or so years of working for NASA. I had to learn about all of those things in very short order.

So each one of those jobs presented a different challenge, and the only way I know to get through any of those is the same thing that I've done every step of the way, which is to buckle down. You talk to people who know how to do what you're attempting to do. You get a list of subject matter that you need to study, and you just roll up your sleeves and get after it. And of course you watch the people who are doing it, who are experts, and you ask a lot of questions. At some point you get to spread your wings and see how you can do. Sometimes you soar with the eagles and sometimes you crash. That's part of the learning experience, too.

KOHUT: You mentioned that you had mentors early on. Who were your mentors? Did you have different mentors at different stages of your career?

HALE: I absolutely had different mentors at different stages. At the end game when

I was in the program office, having never been in a program office before, Bill Parsons was a great mentor to me. He was the program manager. He taught me a tremendous amount about running a big program, about the things I didn't know, the things that I needed to learn. I also learned a lot from Lucy Kranz, who was our procurement/business office manager. She helped fill in all those parts of my education that were blanks. A large part of what I know about federal acquisition regulations, contracts, procurement, and how to do budgets comes from Lucy Kranz, who continues to do great work on different programs for the agency.

When I worked in the Flight Directors Office, the boss was Tommy Holloway, who was a master flight director. I also learned from some of those who had preceded me, like Chuck Shaw and Ron Dittemore. They were all great mentors to me. Going back to right when I walked in the door, there were several Apollo veterans who were ready, willing, and able to teach young graduates what it meant to work in Mission Control, and what sort of things you needed to prepare yourself for. And of course Gene Kranz was in charge of the organization in those days, and you learned a lot at what we used to call the Gene Kranz School for Boys. He taught us in no uncertain terms what was expected.

KOHUT: Nearly a year after the *Columbia* accident, when you were serving as shuttle deputy program manager, you wrote your team an e-mail (which you reprinted in your blog) that said, "… we dropped the torch through our complacency, our arrogance, self-assurance, sheer stupidity, and through continuing attempts to please everyone." Do you have any thoughts on how large organizations can keep their edge and continue to improve even when they succeed?

HALE: The best advice I ever got—Tommy Holloway told us over and over—is, "You're never as smart as you think you are." If you ever get to the point where you think you've got it under control, you really don't, and you need to be always hungry and looking out for the indications that things aren't going well. It's a difficult thing in a big organization to keep that edge, and it's particularly difficult when things are going well. The shuttle had had a long run of success. I think we flew eighty-seven flights in a row that were all successful.

In particular, the political leadership in charge expected us to do more with less. They kept telling us that spaceflight was routine and mature, and that we had solved all the major problems and just needed to not slip up on little things, and that it ought to be easier and faster and less expensive.

The truth of the matter is that, with the current state of the art, spaceflight is extremely difficult. It is fraught with danger because of the high speeds and extreme environments involved. It requires extraordinarily close calculations on the amount of material and the physical structure of the space ship, because mass is at a premium in everything we do.

After a while of getting, "This is not as hard as you think it is. This is mature technology and a mature vehicle with large margins. We know what we're doing," drummed into your head, you begin to fall into that trap, even though deep down in your heart you know that's not true. I've seen that happen in other industries and other organizations that have had a long run of success. The fact of the matter is that, particularly in spaceflight, you cannot let yourself get arrogant. You cannot think that you've got everything under control. You've got to be vigilant. I think that's true for any kind of high-risk, high-technology endeavor, though it may be true in other fields as well.

A lot of us wish spaceflight were easier. I do. I wish it were easier and less costly. I wish it were like getting in your car and driving to the grocery store. But it's not there. Many people in the media profess that it is easy, that it should be simple and cheap, and that somehow those folks who are currently in the field have not done a good job, and therefore it's costly and looks hard. I just don't believe that to be true. I believe it's a very difficult thing to do that requires a great deal of dedication and precision. And unfortunately it's not inexpensive at this point in history.

KOHUT: What are you most proud of from your tenure as shuttle program manager?

HALE: The thing that I am most proud of is building a team that has been as successful as it has been in the five years after we returned the shuttle to flight. Things have been going very well. Being basically a worrier, I worry about things when they're going well, but the team is doing very well because I think they are paying attention to the fundamentals and looking very hard at the symptoms

THE FACT OF THE MATTER IS THAT, particularly in spaceflight, you cannot LET YOURSELF GET ARROGANT. YOU CANNOT THINK THAT you've got everything under control.

of things that are not going as well as one might wish. So I'm very proud of the team and the culture change that we brought about. You would think that returning the shuttle to flight would be at the top of the list, and it is in some ways, but the thing I'm most proud of is building the team that has been able to carry on and be so successful.

KOHUT: You mentioned the culture change. I'd like to get your perspective on what it was and what it became.

HALE: Again, the culture change had to do with the arrogant mind-set that basically said, "We have been doing this for so long so well that we know what we're doing. We have got this difficult subject, this difficult environment under control, and we know we can get by with cutting corners because we know there's a lot of margin in the system." The culture change was to take a step back and say, "No, we really don't know." To go back to what Mr. Holloway taught me, we're not as smart as we think we are. This is a very difficult thing to do. The margins everywhere are very small. It's not ordinary, routine, or mature. And, therefore, we have to take great care with what we do.

And, oh, by the way, our political overseers had kept cutting our budget to where we had emaciated our safety and engineering systems. We had to go back and tell them that that just would not do if we intended to fly this vehicle safely. It was going to take the resources to provide the proper oversight and insight. We were able to convince them of that. And so it goes. I think that was a huge culture change, both for those of us that worked in the program and for those who were outside the program and in positions to make decisions about national resources.

KOHUT: In your blog, you've shared a lot of "stories from the trenches" of the shuttle program that had not previously seen the light of day. In your first post, you said you wanted to start a conversation. Did the purpose of the blog change over time for you?

HALE: The purpose of the blog was outreach, to tell people a little bit about what it takes to fly human beings in space and run a big program, and [share] a little bit of what goes on "behind the curtain" inside NASA, because I think people are interested. So much of what we at NASA put out is what somebody once termed "tight-lipped and technical." Not very interesting, very arcane. This is a human endeavor, and there are people involved in it. The things that happen show us to be frail and mistaken at times, but strong, resolute, and innovative at other times, which is the way it is with people. I've enjoyed sharing some of these stories. Trust me, there are more out there, some of which I may never share [laughs] and some of which I have in mind to share, because it's not just about spaceflight. It's about people, and how people can rise to the occasion, react under pressure, and do something that is very difficult, with great élan and great pride in what they do.

It's been a lot of fun. We get feedback. People get to make comments and post them. I get to review those comments before they go out, which is an interesting process. I originally thought I'd just approve them all. Then you find out that there are certain features of the Internet—people perhaps are trying to do some things that are not appropriate. You really do have to read them and evaluate whether or not they're appropriate to post. Those that are appropriate have been thoughtful in many cases, and frequently they have brought to mind another topic that I need to discuss. So it has been a conversation.

Shaping the Shuttle

BY JIM HODGES

Photo Credit: NASA Langley Research Center

A Space Shuttle model undergoes a wind-tunnel test in 1975. This test simulated the ionized gasses that surround a shuttle as it reenters the atmosphere.

On April 12, 1981, they sat in the Reid Conference Center at Langley Research Center and watched the first Space Shuttle launch on television, just like everybody else.

No, not just like everybody else.

"You were thinking of all of the things you could still be doing to it if you had the time and money," said Dick Powell, who worked on the shuttle's flight-control system as an engineer fresh out of Virginia Tech and remembered that, with shuttle, "the first thing you learned was that everything you learned in school was about thirty years out of date."

Powell and others in flight control had taken aerodynamic data provided by George Ware, Delma Freeman, and a team who tested a host of designs and derivatives in a dozen different Langley wind tunnels. With the shuttle on the launchpad at Kennedy Space Center that day, Ware was wondering about the tests and about a meeting with the data verification committee.

"There was a parameter that they were unsure of because it had some variation," Ware said. "We got a Rockwell guy and me in the hall to hash it out, and we came back with an answer.

"Now, that's not a big deal, but it shows you why you might wonder: Did we make a mistake? We took a straight edge and drew a line and figured out the slope and that was the number we gave Dick for the controls. Did I do it right? Is that number right?"

Paul Holloway, later to become Langley's center director, wondered about a project he had worked on since its inception as a member of NASA's Space Shuttle Task Force. And he considered the time Langley invested in the project. "At its peak, Langley had 350 people, 350 man-years of effort at the completion of Phase B, in '76," he said.

That effort began with the formation of the Space Directorate at Langley in 1970. A Vehicle Analysis Branch was spun up, with volunteers brought over from Langley's full-scale wind tunnel. They were given concepts to test by Johnson Space Center, which was still running the Apollo program at the time, only a year after Neil Armstrong first walked on the moon.

"Essentially, we had four configurations using a straight-winged orbiter and a straight-winged booster," Ware said.

The orbiter looked like a fighter airplane, and power was going to be used to land. Ware and the group tested to determine what they already suspected: a straight-winged configuration wouldn't work.

"With a straight wing, flow doesn't become attached to both wings at the same time," Ware said. "One of the wings attaches first, and it flips over and will crash."

More configurations were tried, with wings swept back. Then a contractor suggested that the orbiter be boosted into space with a solid-fuel rocket and become a glider during descent. Rockwell gave it a try with a model that approached today's 81-degree sweep, tapering to 50 degrees.

"They had estimated aerodynamic data, and it was our job to validate that data," Ware said. "In a month, we ran a full set of data across a wide speed range and got the information to Headquarters. We said, yes, with a few caveats, it will work."

Along the way, several adjustments had to be made in the thought process. "Changing directions with a program this big was like trying to steer an elephant," Ware said.

One adjustment required the engineers to consider just what they were building: a flying truck.

"The shuttle's job was to carry a payload into orbit," Ware said. "It wasn't designed to fly anything like an airplane. It was to survive the return to Earth and land."

It was to become the first craft to do so under digital control from hypersonic speeds in space.

"There were a number of things we could have done to improve the flyability, but this was what they wanted," Ware said. "The clock was running and the dollars were flying out."

Once the shape of the shuttle orbiter was determined, the tests accelerated. Every flight-control configuration demanded testing.

"Shuttle had to rewrite a lot of textbooks," Powell said. "It was the first digitally controlled aircraft … and it was directionally unstable."

Where airplanes had ailerons on their wings and elevators on their tails, shuttle had "elevons"—combinations of the two on the single big wing.

"You were using elevons for yaw control, and that was absolutely unheard of," Powell said. "The vertical tail was unstable. We were using yaw off the elevons to trim hypersonically while the vertical tail was shielded [from airflow by the wing].

"It had never been done before, so we had to design a control system to do that."

Then, too, there was a body flap to deflect gasses from the engines used to help the orbiter in its ascent. In reality, the shuttle has fewer control mechanisms than any airplane. But what was asked of the controls made the process more complex.

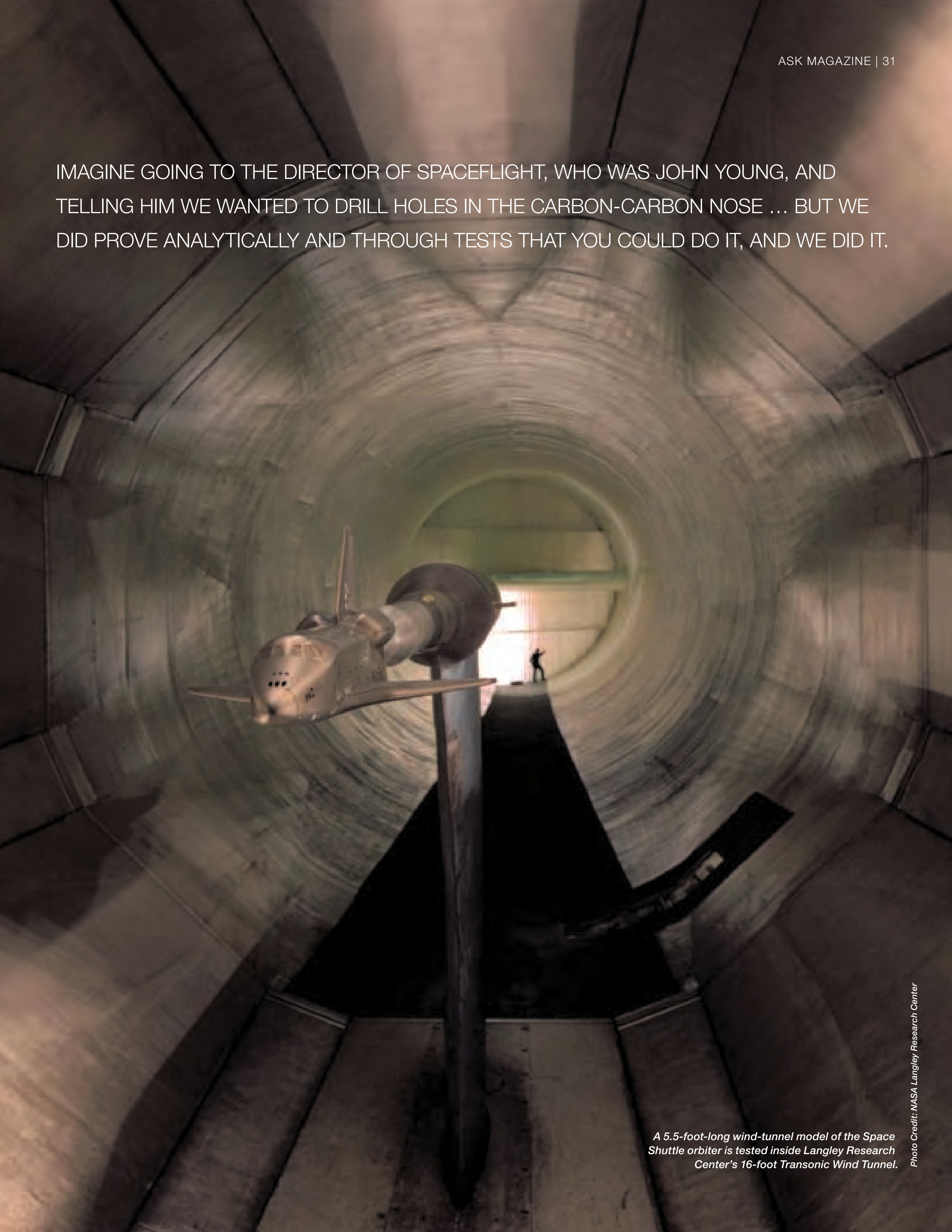
"The issue there is that the center of pressure, where the forces are acting, moves from hypersonic to subsonic," Powell said. "So the trick is to design a vehicle to be controlled through all of these readings. Hence the flight mechanics issues."

Each of those control ideas was tested by Ware and the wind-tunnel engineers. They also inherited another problem when it was found that tiles attached to the shuttle for heat protection were falling off.

"They were testing in the 8-foot pressure tunnel, using the bonding system they had for shuttle," Holloway said. "They were testing to see how strong the bond was. If a tile got loose and several tiles came off behind it, it was called the zipper effect, and it terrified everybody associated with the program."

There also were problems to work out with expansion of the aluminum skin of the shuttle orbiter during the heat of reentry. There was fear that that expansion would cause tiles to pop off the vehicle. That, and problems with the engines, deflected scrutiny from other issues.

IMAGINE GOING TO THE DIRECTOR OF SPACEFLIGHT, WHO WAS JOHN YOUNG, AND TELLING HIM WE WANTED TO DRILL HOLES IN THE CARBON-CARBON NOSE … BUT WE DID PROVE ANALYTICALLY AND THROUGH TESTS THAT YOU COULD DO IT, AND WE DID IT.



A 5.5-foot-long wind-tunnel model of the Space Shuttle orbiter is tested inside Langley Research Center's 16-foot Transonic Wind Tunnel.

Photo Credit: NASA Langley Research Center

The high temperatures that were to be encountered by the Space Shuttle were simulated in the tunnels at Langley in this 1975 test of the thermal insulation materials that were used on the orbiter.

Photo Credit: NASA Langley Research Center

"Flight mechanics was having troubles, too," said Powell. "But the other two took the brunt of the arrows."

Though Johnson Space Center oversaw the shuttle project and developed flight-mechanics algorithms, Powell and Larry Rowell built a simulator at Langley at the behest of aerothermodynamics chief Gene Love.

"We found an old airplane cockpit and refitted it with an old Apollo hand stick and some CRT displays," Powell said. "It was like an old golf cart, and we could roll it up to a computer console to run tests.

"It helped that we were single," he added. "Computer time was scarce then, but computer time at night wasn't scarce. We would work nights, weekends, whatever."

And with their cobbled-together machinery, they uncovered a problem with the shuttle's rudder aerodynamics that called for the flight-control system to be redone.

As aerodynamic questions were answered, more were posed. When Langley's Jim Donovan wanted to put a camera in the tail of *Columbia* to shoot infrared video over the wing, it took more tests to determine that it wouldn't affect the shuttle's handling.

"The camera showed that part of the shuttle was over-engineered," Holloway said. "That was weight, and weight was payload."

When Langley's Paul Siemers wanted to install pressure caps in the nose of the shuttle to determine the flow field, there was more consternation.

"Imagine going to the director of spaceflight, who was John Young, and telling him we wanted to drill holes in the carbon-carbon nose," Holloway said, laughing. "You can imagine what the welcome was. But we did prove analytically and through tests that you could do it, and we did it."

Data still comes from those sensors.

Each change generated more tests. From 1970 to 1982, 52,900 hours of wind-tunnel time were used on shuttle at Langley. On that April day in 1981, Ware, Powell, and others sat in the Reid Center and wondered if it was enough. The shuttle went aloft and came back safely in the first of what would be four test flights. But it was hardly routine. Nothing about shuttle has ever been routine.

"This was nothing like anything we'd ever done before," said Freeman. "It wasn't like an airplane. An airplane, you'd send it out to a boundary, get it back, then send it out again at a different boundary. We had to get this right the first time."

They got most of it right—enough to get the shuttle back safely. But before it could go out again, lessons learned from the first flight had to be applied.

"I think George Ware had wind-tunnel models ready to go," said Powell of the moments after the shuttle landed safely, much to everyone's relief. Data was quickly disseminated, and everyone learned how serious some of the problems were.

"You could see that every discipline had something to work on," Powell said.

Flight control had misjudged the effect firing the thrusters on the aero Reaction Control System had on the orbiter's aerodynamic flow field. The effect of the body flap on reentry demanded another look. The shuttle didn't fly the predicted ascent profile.

"If you look at the shuttle, with all of the work on it, we had at least four things that could have led to the loss of the vehicle in that first flight," Powell said.

Seven months later, the shuttle flew safely again. It was the beginning, but not of the operational life that had been proposed for shuttle.

"What you should understand was that, in 1969, this vehicle [was projected to] have a lifetime of ten years," Holloway said. "It was designed for fifty flights a year … and the cost was going to be $10 million a flight."

The Space Shuttle flew nine times in 1985, the year of its greatest use. Each flight now costs about $500 million.

"While we were using it, we would be developing the technology base to move on and make it significantly cheaper to come up with a replacement system," Holloway said. "And none of that happened."

It's why he isn't sad that the shuttle program is ending. "It was never supposed to last this long," Holloway said.

His sadness comes from knowing that there is nothing ready to take its place. ●

Former *Los Angeles Times* reporter **JIM HODGES** is managing editor/senior writer of the *Researcher News* at NASA's Langley Research Center.

Case Study: Making Compliance Comprehensible

BY JOSEPH A. HORVATH

Because of their potential to affect human health, biopharmaceutical companies are highly regulated. Among the regulations with which they must comply are those that set standards for conducting laboratory studies, clinical trials, manufacturing, and associated processes. These regulations are often referred to as good practices.

A hallmark of compliance, in any field, is control. By demonstrating control of its good-practice operations, a company shows that it is able to comply with applicable regulations in a systematic way. This requires that they document their processes and standards, train qualified people to carry them out, monitor performance continuously, and take corrective action when needed. It also requires that a company document that all these things took place. These dual imperatives are captured in two, oft-quoted maxims:

- Say what you do, then do what you say.
- If it wasn't documented, it didn't happen.

In response to these imperatives, biopharmaceutical companies have created information bureaucracies to ensure that the creation, revision, and dissemination of good-practice information is tightly controlled. New procedures are reviewed, approved, published, incorporated into training, periodically re-reviewed, expired, and archived. When those procedures are revised—as they frequently are—the process repeats. New employees are trained in the procedures in which they will participate, assessed on their knowledge of those procedures, and retrained at set intervals or for cause. When their responsibilities change—as they frequently do—the process repeats. Everything is documented and "inspection ready." Paper records are signed, dated, versioned, and stored in access-controlled archives. Electronic records are stored in validated software systems that capture electronic signatures and maintain "audit trails" of every addition, deletion, or change. With respect to control of compliance information, the biopharmaceutical industry has truly built a better mousetrap.

In principle, the mechanisms that confer control and demonstrate compliance should also help workers perform their jobs correctly and efficiently. Well-documented processes carried out by well-trained workers should ensure high performance. In practice, however, the manner in which compliance information is controlled can interfere with its effective access and use, a paradoxical and potentially dangerous situation. Managing procedures in highly controlled document repositories can discourage workers from consulting them frequently. Writing procedures in a way that addresses all possible regulatory objections can make them complex and difficult to read. Holding workers accountable to train (and retrain) in a large and frequently changing list of procedures can engender a "box-checking" mentality in which learning is subordinated to simply staying caught up.

At Millennium: The Takeda Oncology Company, we believe that well-controlled information will not ensure product quality if it is not readily understood and used by employees. We are not satisfied with building a better mousetrap—we insist on actually catching mice (figuratively speaking, of course). To this end, we have undertaken a series of projects to simplify access to compliance information, to make that information clearer and more useful to workers, and to improve the quality of compliance training so our workers' training time is well spent.

Making Documents Accessible

As any quality-assurance professional will attest, it can be challenging to get employees (particularly experienced ones) to consult documented procedures regularly. As humans, we are prone to cognitive biases and may overestimate our own level of comprehension or fail to notice shortcuts and errors as they creep into our well-worn routines. These biases are at play in the workplace and can lead workers to neglect written procedures in favor of their own memories or memory aids. A classic example is the manufacturing operator who writes machine settings on his or her glove instead of walking across the suite to consult the standard operating procedures.

The challenge of getting workers to consult procedures is compounded by the loss of accessibility that can accompany strict document control. This loss of accessibility is subtle but cumulative in its effects. Controlled documents are more likely to be managed by a central group in a central repository, so paper documents are not as close at hand. Electronic documents are likely to be embedded in a more complex directory structure and within software systems that require separate user authentication. The printing and distribution of documents may be discouraged in order to minimize the availability of non-current versions. These impediments to access, when combined with employees'

THE CHALLENGE OF GETTING WORKERS TO CONSULT PROCEDURES IS COMPOUNDED BY THE LOSS OF ACCESSIBILITY THAT CAN ACCOMPANY STRICT DOCUMENT CONTROL.

natural disinclination to consult procedures, can form a recipe for error.

At Millennium, we have moved aggressively to ease access to controlled documents while maintaining a high standard of control and compliance. We pressed our document management software vendor to make significant improvements to the user interface and have served as early adopters of the resulting product. This product features familiar and intuitive screen conventions, a Google-like search function, and a list of "Recent" and "Favorites" documents to allow users to quickly and directly access their documents of interest. With respect to paper documents managed in file rooms, we have enhanced our document-scanning capability so more documents can be accessed online. We are in the process of streamlining file-room records management. And we are actively looking at how the organization of information in our central, controlled document repository can be optimized to better suit the needs of multiple departments.

These changes to our document-control program have been well received but are really just the beginning. The potential of currently available technologies to deliver information at precisely the moment of need is largely untapped within the compliance space.

Making Documents Useful

Being able to access documents more easily will hold little value if those documents are not themselves helpful—both for learning and for ongoing reference. Unfortunately, many compliance documents fail to meet this standard, owing in part to the goals that led them to be created in the first place:

- To instruct employees on how to perform their work
- To demonstrate to regulatory agencies that a process is well thought out, under control, and compliant

In practice, the latter of these purposes often tends to dominate; controlled documents are written more for inspectors than for those who will be required to use them. Documents are often written in a formal style that values explicitness and exhaustive description over clarity and readability. They may be structured and formatted in ways that are not conducive to first-pass comprehension or rapid visual search. And they are often written by subject-matter experts who lack technical writing skills and are prone to overestimating the appropriate level of detail. In this light, it is somewhat vexing to hear the common lament that "people don't consult the standard operating procedures" as it seems to beg an obvious question: were they even written for them?

In 2009, we conducted an evaluation of our own documentation practices, focusing on their usefulness for purposes of learning and performance support. We reviewed research and best practices in the area of document design and readability. We conducted a close-reading and critical review of a sample of our controlled documents. And we interviewed employees regarding their experience with controlled documents and solicited suggestions for improvement. Our evaluation identified a number of opportunities for improvement that we are currently addressing:

- Improvements to our document templates to de-clutter, enhance readability, and provide embedded guidance for authors
- Establishment of a style guide along with writing-center support for document authors
- Allowance of employees to rate the value and readability of controlled documents via the company's learning management system

These improvements are still in progress, but feedback on prototypes has been very positive and has reinforced our commitment to reconciling the dual purpose of our documentation: to record how we do things and to actually do them that way.

Making Training Meaningful

Access to useful documents is not enough, of course. Employees need to understand them and, often, to acquire new concepts and skills. This is the realm of training, and its objective, from a compliance standpoint, is clear. Training must be sufficient to ensure all employees are qualified for the work they do.

Because employees in our industry work in a highly complex and interdisciplinary environment, there is a lot of training. Employees must be trained on companywide policies and on the use of enterprise systems. They must be kept abreast of regulatory expectations and current good practices in their areas of specialization. And they must be trained on the particular systems, procedures, specifications, and other concerns to which their jobs expose them.

To these are added several other drivers of training volume. Procedures are created and revised frequently, and each new or revised procedure must be incorporated in training. Health-authority regulations require sufficient training to ensure ongoing qualification. This has conventionally been interpreted as a requirement for periodic retraining on all procedures (typically, every two years). Finally, it can be difficult to effectively target training below the department or group level, so training is sometimes assigned very broadly.

Given the sheer volume of training to be produced, companies struggle to deliver high-quality, meaningful training at the required rate. In the worst-case scenario, high training volume results in low training quality, and something has to give. Unfortunately, that something is learning. Employees may plow through a mountain of assigned training that delivers little value, and training becomes an exercise in "signing them off" on the relevant documents. The literature on good-practice training includes numerous examples—usually uncovered during inspection or audit—of employees who were trained on thirty or more standard operating procedures in a single day. Such cases demonstrate that learning has failed and that training has degenerated into a documentation exercise—a troubling and unacceptable state of affairs.

At Millennium, we place a high priority on training effectiveness and are working along multiple lines to both improve the value and lessen the burden of required training for our employees. We have developed a process of ongoing curriculum review to ensure that employees are assigned the training their role requires—neither more nor less. We have implemented a risk-based model to ensure the design of training materials and assessments is appropriate to the difficulty and risk inherent in a given procedure or subject matter. We are moving away from training employees on individual standard operating procedures and toward qualification-based training in which the procedures relevant to a given competency are taught via a single, tailored course. And we are increasing our use of job aids and other adjuncts to training. In interviews, our employees have expressed a strong preference for accessing information at the moment of need—rather than training on every detail then being expected to recall it months later.

These and other initiatives have begun to enable us to simultaneously reduce the volume of training and improve its effectiveness.

Beyond the Better Mousetrap

With the safety of their patients at stake, biopharmaceutical companies cannot be satisfied with building a better mousetrap. Validated repositories, process controls, and inspection readiness are not ends in themselves. Rather, they are means of ensuring that employees perform well: that they follow procedures, report problems, make good decisions. To do this, they must

- Truly understand the company's procedures and their quality-related obligations
- Have ready access to the information they need at the moment they need it
- Find that information to be useful to their purpose

The particular requirements of the compliance arena can make this a challenging standard to meet, but they certainly do not make it impossible. Unless we do so, as an industry, we will fail to satisfy the true intent of the regulations and, more important, we will fail to satisfy our obligations to the patient. ●

JOSEPH A. HORVATH is the senior director of training and documentation at Millennium: The Takeda Oncology Company.

A Carrier Team One Risk Management Success Story

BY DAN FONTAINE

An aircraft carrier is a floating city with power plants, satellite telecommunications, convenience stores, and medical, dental, and hotel facilities. Maintaining and modernizing these ships can involve up to fifty different organizations simultaneously conducting all sorts of work, from painting to structural repair to electronic, electrical, and mechanical system upgrades. As an added project management challenge, the ship's crew typically lives onboard during a major overhaul, which means that work cannot be conducted day and night, and services such as telecommunications, heating, ventilation, air conditioning, electricity, sanitation, and fresh water supply must remain intact as much as possible. With up to 500,000 man-days of work scheduled during an eleven-month dry-docking period, you can imagine the tremendous amount of activity that must be carried out in a confined space and on a tight schedule.

USS Theodore Roosevelt *(CVN 71) is drydocked during a Refueling and Complex Overhaul.*

Photo Credit: U.S. Navy

The Naval Sea Systems Command (NAVSEA) established Carrier Team One (CT1) in 1997 to define, champion, and improve cross-organizational processes for planning and executing these complex aircraft carrier overhauls, known as "availabilities." CT1 provides the structure for managing and systematically improving cost, schedule, and quality performance by focusing on key planning and execution processes. They also integrate the efforts of numerous contributing organizations into an effective total-maintenance process.

CT1 took notice when two aircraft carrier availabilities were completed a number of weeks late in 2006. The team identified many factors that contributed to the delays, including large work packages with a number of high-risk items, critical-path work with minimal margin, significant new and expanded work, and project team inexperience and turnover. All these issues affected both projects, yet project managers lacked an effective means of identifying, assessing, mitigating, and communicating the risks they posed to their project's timely completion. As a result, the carrier maintenance community was unaware that help was needed until it was too late to take steps to avoid or limit delays.

In response to the problems encountered on those projects, CT1's Executive Steering Committee formed a Risk Management Working Group (RMWG) and tasked them to (1) develop a standard process for comprehensive availability risk management that could be applied consistently across all aircraft carrier shipyards and (2) support and monitor a risk management pilot project to be implemented on nine carrier availabilities at five different locations. CT1 used the existing Northrop Grumman Shipbuilding Newport News Operations (NGSB-NN) Risk Management Program (already in compliance with Department of Defense guidance) to develop a formal process for all aircraft carrier availabilities.

EARLY IN THE PROJECT, TEAM LEADERS WANTED TO SEE VALUE BEFORE ENGAGING, BUT THE BEST WAY TO SEE RISK MANAGEMENT'S VALUE FOR THEIR PROJECT TEAM WAS TO ENGAGE IN IT.

NGSB-NN based their 1998 risk program on a NASA-proven practice. NASA's Goddard Space Flight Center conducted a number of risk management training sessions at NGSB-NN and provided copies of their risk management procedures. Building on

A Hornet launches at sunset aboard USS John C. Stennis *(CVN 74).*

Photo Credit: U.S. Navy

this knowledge transfer from NASA, NGSB-NN developed a risk management process designed specifically for ship construction and repair. This process included developing a risk management strategy; developing and conducting risk management training; identifying program risks; analyzing potential technical, quality, cost, schedule, and human-capital impacts; determining likelihood of problem occurrence; developing plans to mitigate risks; developing and maintaining a risk tool for capturing and updating project and shipyard risks; capturing risk management lessons learned; and continually improving the process to reflect customer feedback. To indicate the probability and impact of risks, the process uses the red/yellow/green risk cube described in the Defense Acquisition University Risk Management Guide for Department of Defense Acquisition. It adds environmental and safety risks to cost, schedule, and technical/quality risks. Proving its value over time, NGSB-NN's risk management program is now used companywide.

The CT1 risk management pilot project focused on the cultural journey required to convince naval shipyard aircraft carrier project teams of the value of a formal risk management process and to actively engage in it. That journey included the following essential elements.

Catalyst: As in any cultural journey, a catalyst for change is essential. In this case, the catalyst was the late completion of the two 2006 aircraft carrier overhauls in an environment that lacked a formal risk management process.

Infrastructure: The Executive Steering Committee formed the RMWG to establish a formal risk management program and associated training tools.

Initial Buy-In: Once the infrastructure was in place, the RMWG leader met with key stakeholders to share risk management background and procedures and develop their implementation plan and customer expectations.

Launch: As Executive Steering Committee chairman, Captain Daniel Seigenthaler, USN (assistant chief of staff for carrier maintenance at Commander, Naval Air Forces Pacific Fleet), signed a letter directing the implementation of a risk management pilot program for nine aircraft carrier availabilities over a one-year period. This was followed by the RMWG leader meeting with project leaders at the headquarters of all three aircraft carrier shipyards to discuss ideas for implementation. During the pilot project, the RMWG leader provided peer assistance and training for each project's assigned risk manager to support skills development and team acceptance.

Integration into the Organization's Culture: From the outset, each project team's leadership needed to perceive the value of risk management to encourage their engagement. The initial direction and expectations set by CT1 provided the "push;" the challenge was to create a "pull" from the project teams. This was done by integrating risk management into command briefings, progress briefings, meeting agendas, team training, awards and recognition, newsletter articles, project

Shipyard workers depart the USS Harry S. Truman *(CVN 75).*

Photo Credit: U.S. Navy

strategies, retrospects, and the "hot wash" meeting at project completion. ("Hot wash" is a military term for a meeting used to capture learning and develop related recommendations at the end of a major activity or engagement.) CT1 thinks of a hot wash as a carrier-overhaul project team's "gift" to future project teams.

Establishing a cross-project risk manager community of practice for knowledge sharing and comparison was the key to the pilot's accelerated adoption. This community provides a peer-assist environment for the risk managers to communicate and collaborate. It is also a forum for risk managers to discuss their challenges and share experiences and learning.

Retrospect and Process Maturity: The one-year pilot involved eight different overhaul projects that were either planned and less than a year from starting or in the process of executing four- to six-month-long repair projects. The pilot work proved to be process easy, implementation hard. Early in the project, team leaders wanted to see value before engaging, but the best way to see risk management's value for their project team was to engage in it.

At the conclusion of the risk management pilot, project-leadership interviews captured what went well and what could be improved. A risk management process retrospect was held to capture lessons learned and recommendations from the one carrier project whose risk implementation extended from the start of planning to availability completion.

Resistance occurred on all projects, but the quickest adoption came from the one that was furthest from their start date (ten months of planning remaining). As one would expect, the team that was a month into their six-month overhaul and focused on executing the work that was already under way saw the least value in the risk program. Data gathered during the pilot showed that project teams who embraced the formal risk management process quickly achieved risk-exposure reductions similar to those NGSB-NN teams that had been using it for years. These metrics helped convince other project teams of the value of the process and encouraged their engagement.

Captured risks were shared via CT1's portal. The commonality of risks gave valuable insights to shipyard and program leadership personnel. Some examples of frequent risk categories were material availability, work package size and changes, constraints from shipyards or naval bases, planning performance, key event management, unidentified work and weather impacts, scheduling conflicts, worker availability, funding, ship's crew readiness, and project team turnover.

Following the pilot project, feedback from leadership showed that they were all fully engaged and appreciative of this tool's ability to help communicate and mitigate their biggest concerns. Matt Durkin, Norfolk Naval Shipyard's project superintendent for USS *Harry S. Truman*'s (CVN 75) 2009 overhaul, commented, "Risk management provided me with more visibility of our project's key issues. I'm not sure we

AT THE CONCLUSION OF THE RISK MANAGEMENT PILOT, PROJECT-LEADERSHIP INTERVIEWS CAPTURED WHAT WENT WELL AND WHAT COULD BE IMPROVED. A RISK MANAGEMENT PROCESS RETROSPECT WAS HELD TO CAPTURE LESSONS LEARNED AND RECOMMENDATIONS FROM THE ONE CARRIER PROJECT WHOSE RISK IMPLEMENTATION EXTENDED FROM THE START OF PLANNING TO AVAILABILITY COMPLETION.

would have completed our last availability on time without the RM process."

And Tim Ferguson, Puget Sound Naval Shipyard and Intermediate Maintenance Facility's project superintendent for USS *Abraham Lincoln*'s (CVN 72) 2009 overhaul, said, "Our project team leveraged the risk management program to support open and honest discussion of issues that could have impacted delivering the ship on time."

Pilot participant suggestions for taking the risk management program to the next level included

- Adapting the process to address potential problems that were beyond the program manager's scope of influence
- Using the risk management process to identify and communicate potential shipyard and ship's crew work-distribution conflicts
- Integrating risk management into a work package's development process during planning

Captain Kevin Terry, USN, CT1's chairman, summed up the work so far: "The Risk Management Working Group has been a true success story. The pilot project was a home run. Aircraft carrier public and private shipyards are using the same language and risk cube to mitigate and communicate their issues."

The U.S. Navy's Ship Maintenance Enterprise is currently building on the success of CT1's risk management pilot project. A NAVSEA instruction is being issued to formalize the process for all the U.S. Navy's ship and submarine overhauls. Over the next few years, NAVSEA will expand from individual project teams to the entire shipyard enterprise. As Cleve Butts, NAVSEA's director for Carrier Support, notes, "It is absolutely essential that we complete our maintenance periods on time and within cost, not only for aircraft carriers but for all our ships. Risk management is a great communication and management tool for ensuring that the right actions are being applied effectively and early. The RM [risk management] process has now been successfully implemented at all aircraft carrier shipyards." ●

To learn more about Carrier Team One's risk management experience, contact their working group's leader, Dan Fontaine, at Daniel.Fontaine@ngc.com.

DAN FONTAINE of Northrop Grumman Shipbuilding is team leader of Carrier Team One's Risk Management Working Group.

Peer Assist: Learning Before Doing

BY KENT A. GREENES

Knowledge workers in NASA work on the edge, carrying out complex projects that have never before been attempted. It shouldn't be a surprise to discover that teams working on these projects cannot possibly know everything they need to know to perform to the highest standards. In many cases, they haven't had the opportunity to learn from previous experience, or they haven't had ready access to those who have "done it before."

It's not always easy to admit we don't know everything, but once we do and ask for help, the process of gaining new knowledge has already begun. It takes time and effort, though, to get the right knowledge to flow and transfer when and where it's needed. Fortunately, there is a proven knowledge management technique that can help. Called a peer assist, it accelerates the transfer of knowledge from those who have it to those who need it in many organizations.

The Peer Assist

A peer assist is a facilitated work-session, held face to face or virtually, where peers from different teams and organizations share their experiences and knowledge with a team that has requested help in meeting an upcoming challenge. Knowledge in the form of good practices, lessons learned, and insights is typically shared through relevant stories told by the people who experienced them. A peer assist does three things:

- Targets a specific technical, mission, or business challenge
- Acquires assistance and insight from people outside the team and identifies possible approaches and new lines of inquiry
- Promotes sharing of learning and develops strong, and often new, connections among staff, partners, suppliers, and customers

I recently facilitated a peer assist for a health care provider in Alaska whose aim was to develop a capital business plan that would gain approval from budget holders outside Alaska to renew aging facilities and grow capability for long-term health care. A preliminary version of the plan had met resistance from these decision makers; the Alaska team was told to go back to the drawing board and develop a plan that required significantly less investment. The team had been working for months at reducing the cost and had gotten to a point where they exhausted what they knew and the knowledge they were able to get their hands on. They called me in to plan and facilitate a peer assist.

After calls with potential peers from the provider's operations in Washington and Oregon, we held the peer assist in Anchorage with the home team and eight visiting peers. The peers openly shared the lessons they learned from developing capital plans for long-term-care facilities in their regions. It was clear by early afternoon on the first day of the peer assist that their advice to the Alaska team was to reduce their capital plan by remodeling and repairing existing facilities.

The Alaska team insisted that their environment and customer needs were different from those in the northwestern United States and remodeling wouldn't provide the long-term care needed to attract, serve, and retain potential Alaskan customers. Later that afternoon (and planned as part of the session) the peers visited several long-term-care facilities. The experience made all the difference in the world. The visitors now understood the Alaskan context for long-term care and changed their advice. They felt new facilities were warranted in Alaska and spent the second day of the session developing new options and approaches for capital-plan submission with the home peers.

One of their recommendations was to perform a new survey of the aging population in the region. The peer from the Oregon provider operations had recently done something similar and offered a set of questions and a survey approach that were geared to providing design input for the development of long-term-care facilities. On the spot, the peers modified the design of the survey to address the Alaskan environment, native Alaskan culture, and other unique aspects of the aging customer base in that region.

The session led to a breakthrough in the Alaska team's thinking and capital plan. Not only was their plan approved, but the visiting peers benefited from the experience as well. An e-mail received by the Alaska team leader reinforced this: "Thank you again for the wonderful opportunity to work together last week. I really applaud your willingness to hear new ideas and your dedicated commitment to the people you serve. Kent, you taught us a new appreciation for the power of coming together to harness our collective knowledge to fulfill our mission. It was an enlightening two days for me, and I am very grateful for the experience."

Many of the peers who came together for those two days continue to communicate and collaborate on a routine basis.

Why It Works

A peer assist works because peers more readily share their knowledge with each other—and accept knowledge from each other—than through hierarchies or official channels, where politics and other issues often hamper free exchange. And they are more likely to tell the truth about problems they have encountered.

When the peer assist occurs is critical. People are more open and inclined to use knowledge they gain from others if they get it before they commit to a specific plan of action. Once we start down a certain path, it's hard to get ourselves to think differently. So the key to a successful peer assist is to convene the session after a team has exhausted what it already knows and created its plan, but before the start of actual work.

Peer assists are most successful when the participants have time to socialize and get to know and understand each other. This helps people open up and share their hard-earned expertise, especially the wisdom gained from painful experience.

When I was with British Petroleum (BP), our retail business wanted to enter the Japanese market. The international team responsible for creating the business in Japan hosted a peer assist to learn from other BP retailers before they implemented their plan to enter this new market. Peers came from all over the world to share their experience. The hosting team didn't want to spend much time on the process, but we convinced the leader that the session should take two days. On the first day, the home team showed the peers their proposed station sites, visited competitor sites, and shared their building plans and challenges. When they asked for the peers' input, the quality and amount of contributions were very low.

In side conversations and in private, however, they all said Japan had too mature a retail market for our typical new-entry approach. Plus, there was a "gas war" going on in that region. But nobody

dared say openly that they thought the Japan team's approach was seriously flawed. After dinner that night, we went to karaoke bars then to a Japanese bath, where we all had to get naked, as is the tradition in Japan. The next morning, the feedback, storytelling, and sharing differed phenomenally from the day before. The peers honestly and openly shared their skepticism and their own tough experiences. As a result, the Japan team modified their plan in a matter of days and went on to an accelerated, successful entry into the market. I have no doubt that taking time to build relationships and trust during the peer assist enabled the participants to open up and share their knowledge truthfully.

Who Can Help You Learn?

It's surprisingly easy to find people with relevant knowledge. One of the easiest and most effective methods is to tap your personal network to find who might have experience in the particular challenges you are facing. Even if the people you contact don't have relevant experience themselves, they will likely know "someone who knows" and may offer to connect you to them.

The other obvious approach is to search your company intranet for people with relevant skills and relevant experience. Better yet, if your organization has internal social networking sites, blogs, and wikis, these can be quickly and conveniently searched for potential peers. Similarly, you can contact people in relevant communities of practice, professional forums, and networks to ask for help or contacts. Sometimes it is helpful to involve people with diverse experience who can push boundaries and lead to innovative thinking in the session. In some organizations, teams announce their intent to do a peer assist by posting the subject and associated challenge on their company's intranet or electronic news facility. This enables people with relevant expertise to offer their help.

Engineering for Success

Based on my experience facilitating hundreds of peer assists, here are some critical things to do to ensure a successful outcome:

- Define the problem or opportunity that you are facing, and decide whether a peer assist is the most appropriate process.
- Write and disseminate a brief description of your need to peers, giving them the chance to self-select for participation.
- Look for diversity, that is, people who will help your team confront the problem from different perspectives.
- As soon as possible, identify people who can participate on your selected dates—fitting into their schedules is critical.
- Identify an experienced facilitator who understands the learning process.
- Design the event to ensure plenty of time to reflect.
- Allow the peer-assist team members time as a group during the session to analyze their findings.
- Ensure the key lessons and good practices shared during

ALSO, TRANSFERRING KNOWLEDGE IS ONE THING, AND GETTING PEOPLE TO USE IT IS ANOTHER. KNOWLEDGE DOESN'T MATTER UNTIL THE RECEIVERS APPLY IT TO MAKE A DIFFERENCE. THIS IS SOMETHING I LEARNED EARLY ON IN MY YEARS APPLYING THIS TECHNIQUE IN BP.

the session are captured. This may require some follow-up work to gather sufficient detail for those who did not participate.
- Agree to a set of actions.
- Make your findings accessible to others outside the group.

Peer Assists in a Virtual World

One of the things that limits the application and impact of the peer assist is a team's ability to hold the session in a timely manner. Virtual meeting technologies can really make a difference. I have facilitated many virtual peer assists online using standard web-conferencing tools. Yes, it's tougher to socialize and build the respect and trust needed for open sharing and transfer. But what you lose by lack of face-to-face interaction you gain by making it feasible for peers to participate. More often than not, you are likely to get the right peers to participate because they don't have to travel.

Virtual peer assists are most effective when the challenge is specific and bounded. A good example is one I facilitated for an international oil company that was drilling their first high-pressure, high-temperature well in thirty years off the coast of Norway. The Norwegian government had set very high standards and extensive requirements for drilling in this deepwater environment, which included how the well was cased in cement to prevent gas blowouts and other operational risks.

The team was two months away from setting casing when they realized their plan for cementing the well was way beyond budget. To make up for their lack of local experience and knowledge about procuring and setting casing in such an extreme environment, they had over-engineered a solution that required a greater amount of cement to minimize risk. I was brought in to facilitate a peer assist targeted at optimizing the cement-casing job. After eight hours of phone calls and personal networking, the Norway engineers were able to identify seven engineers across their global operations who had relevant experience and could spend a few hours on short notice in a virtual peer-assist session.

They reviewed well schematics online and in downloaded form, and asked lots of questions. Although most of them never met or knew each other, in a two-hour session the peers shared enough cementing knowledge to significantly change the Norway plan, reducing costs by $2 million.

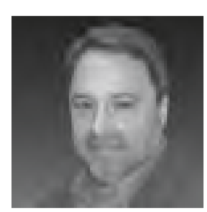
Not a Silver Bullet

The effectiveness of a peer-assist technique in transferring knowledge in real time from those who have it to those who need it has been demonstrated over and over again. But that doesn't mean it will always lead to improvements in performance. There are times when a peer assist is not really needed or the cost outweighs the benefits.

Also, transferring knowledge is one thing, and getting people to use it is another. Knowledge doesn't matter until the receivers apply it to make a difference. This is something I learned early on in my years applying this technique in BP. Recently, a lot of people have asked me, "If BP had such great knowledge-exchange techniques, how come they've screwed up so badly?" My simple answer is peer assists work, but they can't force people to use the knowledge they make available.

One thing I do to address this issue is try to get the home peers to agree in advance to allow me to do some follow-up facilitation to complete the knowledge-transfer process. Basically, this involves tracking their work after the peer assist is over and prompting and provoking them to apply the knowledge they gained from the visiting peers. ●

This article is based on the work and experiences of the author and the knowledge management team at BP from 1995 to 1999.



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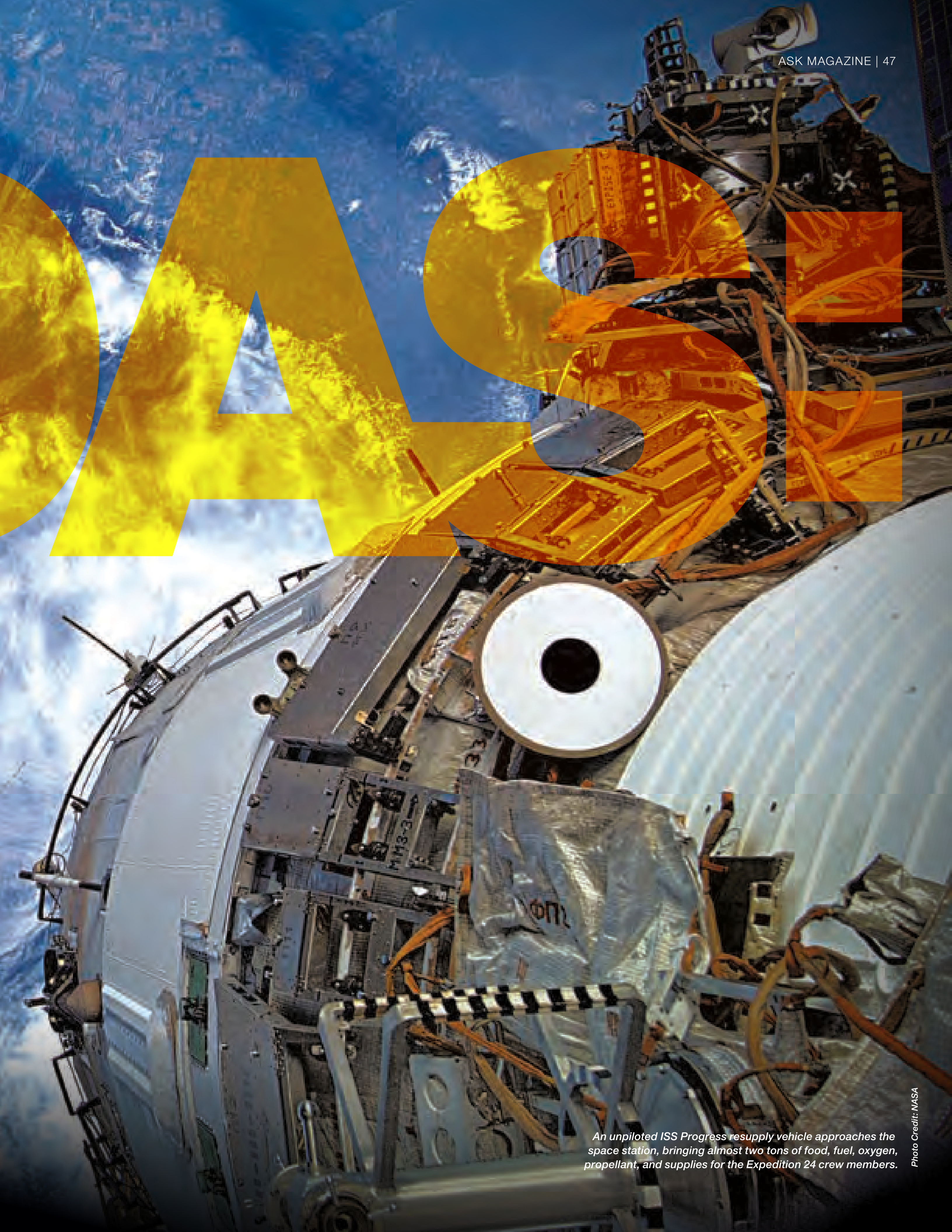
Keys to Software Success

BY JEFF CLINE

A 1995 Standish Group survey of 365 respondents spanning 8,380 software applications showed that only 16 percent of software development projects finished on time and on budget; 31 percent were canceled; and the remaining 53 percent overran costs by an average of 189 percent. Similar surveys predict that information technology projects are more likely to fail than succeed.



An unpiloted ISS Progress resupply vehicle approaches the space station, bringing almost two tons of food, fuel, oxygen, propellant, and supplies for the Expedition 24 crew members.

Photo Credit: NASA

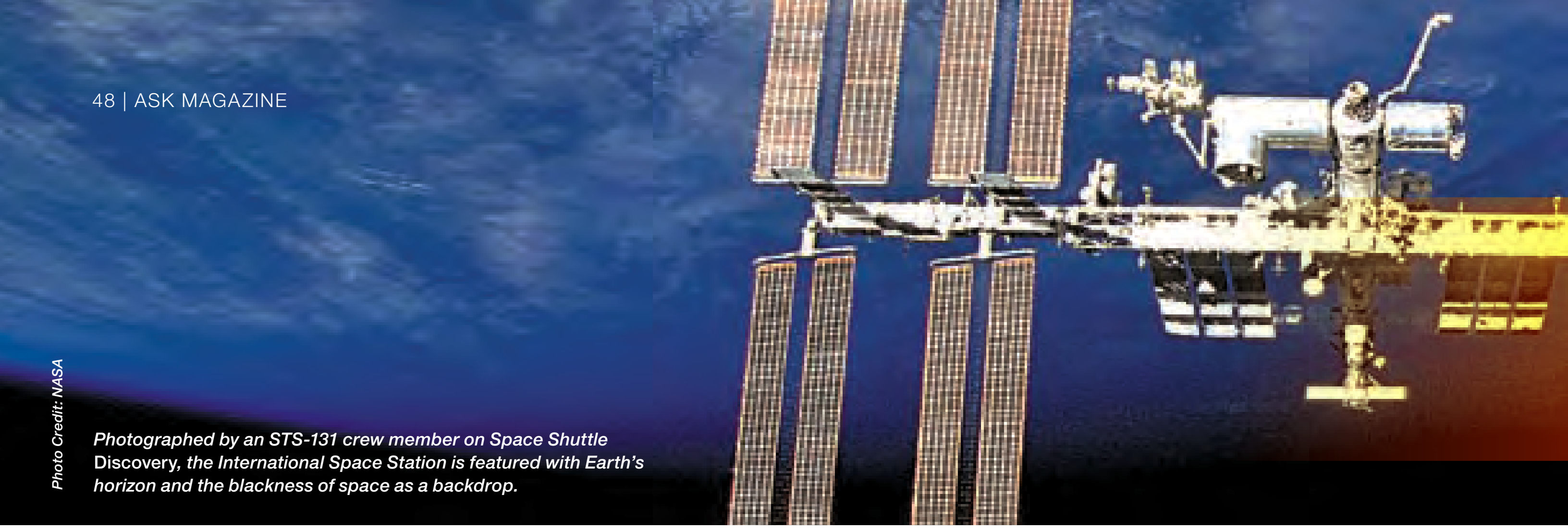


Photo Credit: NASA

Photographed by an STS-131 crew member on Space Shuttle Discovery, *the International Space Station is featured with Earth's horizon and the blackness of space as a backdrop.*

For the past decade, a team led and managed by Barrios Technology, Ltd., at the Johnson Space Center has avoided the pitfalls associated with software development. In addition to launching the Mission Integration Database Applications System (MIDAS), a successful, large software application that supports the International Space Station (ISS) program, the team has a productive customer relationship, properly utilizes personnel, and empowers its employees, resulting in a highly functional software team.

What Is MIDAS?

MIDAS supports approximately twenty organizations that use the system to develop and manage a wide array of ISS products, including flight manifests, imagery plans, hazards and toxicity analyses, cargo packing plans, cargo certification, and consumables planning. The application consists of approximately 24 subsystems, 160 user-interface modules, and more than 330 database tables. It integrates the subsystems to allow each customer organization to use active, current data from other customers to help develop its products and make data about its own products available to others. This high level of data integration allows organizations to develop timely, high-quality products, increases cooperation among ISS organizations and partners, and provides a cost avoidance of approximately $3 million annually for the ISS program.

The NASA application owner and driving force for MIDAS, Tim Brown, has said, "Not only do we have a system in place that benefits almost every corner of the ISS program, but that software has also acted as a 'glue' for the various areas within ISS. It is my firm belief that MIDAS has been a major contribution to the increased coordination and cooperation ISS now has among the various individual areas."

Task Origin and Initial Release

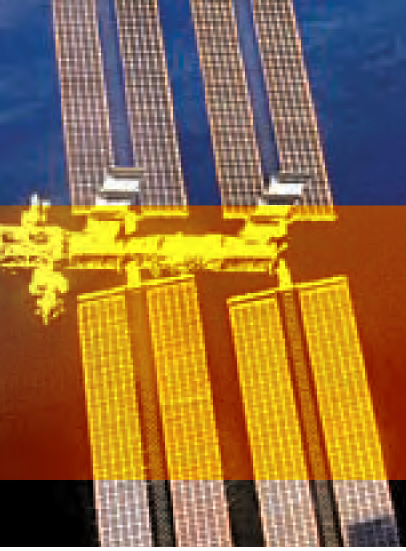
In August 1999, Tim approached our company with several pages of high-level requirements for a flight-manifesting tool and asked us to consider bidding for the development of the application with a target release in fall of 2000. After reviewing the requirements with NASA and internally, we decided that the task came with a high probability of failure, given immature requirements coupled with the task complexity and aggressive schedule. Recognizing the risk, but also the potential reward, we agreed to take on the work only if we could create a process that would give us the best opportunity for success.

We explained to NASA that we would prefer to estimate the cost of developing detailed requirements before submitting a build bid. We proposed that a select team of senior developers from another Barrios project meet a few hours a day for several months with NASA to develop a more detailed requirements document. We could then deliver a requirements document and a realistic build bid based on more mature data. To support this requirements-definition effort, we asked NASA to provide a dedicated MIDAS application owner who would have authority to make decisions and provide guidance.

NASA accepted our plan in November and identified Tim as our dedicated MIDAS application owner. In December we provided a schedule for the requirements-definition phase, which identified project tasks, external dependencies such as customer reviews and feedback, and milestones that would be necessary to produce a requirements document that would later inform our build bid.

In January 2000 our team began meeting with NASA to identify software requirements, evaluate target technologies, and demonstrate prototype designs. In mid-April we provided a draft requirements document for review. When the review comments came in later than the schedule allowed, we explained the importance of commitments being made and kept by both parties. The review comments were incorporated and the requirements document and build bid were delivered on time, but only after a few tense days as both sides defended their positions. This first speed bump was an unpleasant necessity that ultimately provided a good foundation for mutual trust and a very strong working relationship.

That painful event showed NASA that our schedules were real and that both parties were responsible for the success and on-time delivery of the project. This doesn't mean the schedule rules all else, but commitments and dependencies are often related and need to be coordinated. After this event



WHEN SCHEDULES ARE DEVELOPED FROM THE BOTTOM UP (BY THE EXECUTERS OF THE TASKS) INSTEAD OF FROM THE TOP DOWN (BY MANAGEMENT), THE DEVELOPMENT TEAM TAKES OWNERSHIP OF THE SCHEDULE.

both parties have always provided extremely timely support to the project.

NASA reviewed our build bid and authorized us to proceed. We developed a detailed schedule for design, development, testing, and deployment. The content was determined by collecting estimates from each software developer for the desired capabilities; integrating those inputs; adding time for integration testing, holidays, and vacation plans; and letting work management software predict the end date. When that date did not align with the customer's desired delivery date, we negotiated with NASA to remove content from the release and then updated the task list until the work management software predicted an October 27, 2000, release date.

This approach to schedule development has proven to be extremely valuable in several ways and provides key lessons:

- Software developers are best equipped to understand the effort required to develop and test software.
- When schedules are developed from the bottom up (by the executers of the tasks) instead of from the top down (by management), the development team takes ownership of the schedule. Because the team is committed to the schedule, members are invested in the project's success and willing to work extra hours if necessary. Conversely, when an unrealistic schedule is dictated from above, schedule risks can be viewed as "not my problem" by development staff, fostering resentment and adversely affecting team unity and performance.
- Resource loading the tasks in work management software and including vacations and holidays allows the program to provide an objective, realistic schedule prediction for the software delivery date.
- Investing the effort to develop a schedule this way creates a structured plan by which to communicate project progress and potential risk to both internal and external customers.
- Successfully executing a software release in accordance with an approved schedule creates additional trust between NASA and the contractor, demonstrating that our approved schedule is effectively a commitment, not a plan. Repeated successful execution of these schedules over time increases customer confidence in the contractor.
- Following this approach, MIDAS enjoys a 100-percent on-time delivery rate for approximately 33 major software releases and 112 maintenance releases while running under budget.

In May of 2000 we began design and development of the manifesting tool, conducting numerous reviews to demonstrate progress and identify course corrections in our approach. We included key users in integration testing. This not only confirmed the tool was performing up to their expectations but also trained them in the new system. After substantial internal and external test support, MIDAS was delivered on November 3, 2000—one week later than the work management–software plan. Although MIDAS was ready for delivery on the original date of October 27, an unexpected flight freeze restricted software changes. The first release of MIDAS is considered an on-time delivery because the delivery date was altered by an external, unexpected event.

Extending MIDAS

We began to look up- and downstream of the manifest process itself to automate preceding and succeeding steps. For example, all manifest changes must be approved through a request process. By automating this step and previous steps, as well as those steps that follow flight manifesting (cargo packing, hazards analysis, cargo/transfer priorities, etc.), we have developed a fully integrated system of twenty-four subsystems that provides comprehensive traceability for hardware.

Organizations are often apprehensive of change, particularly when they comfortably work with internally developed tools such as a spreadsheet or database, but local tools isolate the data from other customers. By explaining the benefits of integrated data and committing to develop any MIDAS software upgrades without cost to candidate organizations, we were able to attract many organizations to our requirements table. We promised to provide them software funded by a specific NASA budget in exchange for their data and support of MIDAS. Integrating

A WRITTEN REQUIREMENT CAN BE INTERPRETED IN MANY WAYS, SO THE KEY IS WHETHER OR NOT THE SOFTWARE DOES WHAT THE USERS THOUGHT THEY WERE ASKING FOR, NOT WHAT WE, THE DEVELOPMENT STAFF, UNDERSTOOD THE REQUIREMENTS TO BE.

After an aborted docking on July 2, Progress 38 successfully docked to the aft end of the Zvezda Service Module on July 4, 2010. The docking was executed flawlessly by Progress's Kurs automated rendezvous system.

Photo Credit: NASA

data from these organizations promotes stronger working relationships and contributes to job satisfaction for those involved in the product development.

While this level of growth and success has been wonderful for our users, team, and company, it has also created challenges. The development team in place in May 2000, still intact today, has fewer than five full-time people, who are now responsible for twenty-four subsystems and more than 900,000 source lines of code. Each person must have knowledge of five subsystems, on average, in order to ensure the system can be effectively sustained, and yet requirements for new features are identified every month and added to the queue for MIDAS releases. A typical software developer can maintain only about 50,000 source lines of code,[1] which suggests we should have eighteen software developers on staff.

Our small team is able to support so much complex software due to the successful development and implementation of many key lessons.

General Lessons

We've implemented several key elements into our structured processes that have proven to be very helpful in ensuring high-quality products, maintaining developer interest, and protecting our customer from single-point failures.

Employee Respect and Growth

The personnel we hire are highly trained adults, and we treat them as such. Our management approach is built upon trust and empowerment, not oversight or checkpoints. Once work is assigned to a developer, that developer is responsible for creating and meeting schedule estimates, performing testing, and managing requirements and user interaction.

If a customer's prioritized requirements cannot be accommodated by our team in the time requested, we negotiate a reduction in content or move the release date so our team can accommodate both content and schedule. This shows our employees that we value their professional *and* personal time. We want them to see this job as an enjoyable, satisfying career, not a twenty-four-hour-a-day obligation. As a result, our team members have never failed to step up when schedule challenges occasionally arise.

When software anomalies are identified, we focus on understanding the root cause of the problem and develop process changes to reduce or eliminate the potential for repeating the error rather than assessing blame. When necessary, we work with employees to improve a skill or revisit a process.

We demonstrate to our NASA customer that our people are the reason for our success and balancing their needs is just as important as the needs of the customer. People tend to experience stress over family, finances, and their job. If I can eliminate the job stress from their life, we've given our team members more energy to focus on their more critical life concerns.

We also use rotational task assignments to provide new opportunities for staff development. Rotating personnel gives them new skills and a deeper and broader knowledge of our system design. A side benefit is our expanded ability to handle surges in requirements. Rotations also give staff expanded opportunities to learn from their coworkers.

Trusted Partnership with NASA

A strong working relationship with NASA allows our team to excel. We established early on that our word was our bond. By empowering our developers to own schedule estimates, consolidating those estimates into a scheduling tool to produce realistic schedules, working hard to honor those commitments, and admitting when we've made mistakes, we have created a working environment of mutual trust between NASA and Barrios. NASA trusts our schedule estimates are realistic. If we determine a new requirement is too complex for our technology, or not a fair effort–benefit trade, NASA trusts our assessment instead of assuming we are avoiding work.

As a result, NASA empowers us to identify and recommend ways to make the software better, trusts our opinion on which changes make the most sense, and often comes to the development team to discuss ideas before taking them to our user community.

Quality

We work hard to ensure that the software we deliver is of the highest quality. While we've been successful during the ten-year (and counting) delivery history of MIDAS, our philosophy is "our users will remember software was delivered on time and wrong long after they've forgotten it was delivered late but right."

Delivering what users need takes precedence over delivering on time. As users test our software, they often realize they really need something other than what they requested. We work with them to identify the difference between where we are and where we need to be, and develop a plan to respond. This may mean an update to the software prior to delivery, or we may deliver as is and on time if the software is usable but not optimal. In this latter case, we schedule a follow-up release to add features identified during testing.

Delivering "what they asked for" on time just because they agreed to that requirement three or four months ago doesn't mean that requirement is still accurate or appropriate. We don't want to deliver software if it isn't ready. We deliver only after our users have tested the software and agreed that it meets their expectations and appears to be bug free, or meets their expectations except for minor acceptable discrepancies. We ensure high quality through a four-phase integration-testing approach that includes testing by the developer; testing by two other developers on the MIDAS team, one of whom is not familiar with the software; and testing by our customer-support group. Finally, key users test the software to ensure it meets their *expectations*. A written requirement can be interpreted in many ways, so the key is whether or not the software does what the users thought they were asking for, not what we, the development staff, understood the requirements to be.

A Good Team Is Like a Good Marriage

After ten years, I've found that our MIDAS team operates much like a good marriage. The keys to a successful relationship among our MIDAS team members include identifying each other's strengths and utilizing them, identifying each other's weaknesses and strengthening them, and identifying each other's hot buttons and avoiding them. Treating each person with respect and empowerment while providing a stable, interesting, and nurturing working environment promotes team unity and stability.

By working with such a high-caliber team of software developers and NASA for a decade, we've learned a tremendous amount about successful team development, customer relationships, and the importance of teamwork. The team's dedication allows our developers to sustain almost four times as much code as a typical developer. To replace this team of "almost five" would require more than twice as many new people of a similar skill level in order to barely get by. That is a testament to the power of positive team dynamics. ●

JEFF CLINE is an information technology manager and certified Project Management Professional for Barrios Technology. Supporting the ISS program for more than twenty-two years, he has served in various software-related capacities, including software architect, developer, and trainer, and he has led teams for the past fifteen years.

1. Tom Love, "10 Must Knows for CIOs About Software Development," November 16, 2006, www.itmpi.org/assets/base/images/itmpi/privaterooms/tomlove/MustKnows.pdf.

The Impact of Energy on Projects

BY CHRISTIE DOWLING, ALEXANDRA GERBASI, AND VIC GULAS

It's no surprise that success in project-based organizations is driven by how well project teams perform. The quality of performance depends not only on the demands of the project but on the team makeup and dynamics. In fact, those human factors can have a much greater impact on results than the challenges of complexity and scope. Collaboration, communication, leadership, and effective knowledge sharing are vital to success, and the "spirit" of teams matters at least as much as their technical skill.

We've all seen teams that succeed beyond anyone's wildest dreams. They seem to be driven by more than great processes, good communication, and individual heroics. They exude an infectious *energy*, outwardly and among their members. Talk of energy in teams is often relegated to the list of "intangibles" that may find their way into promotional documents or performance reviews but do not trump the "numbers." But we all have people in our work lives that we gravitate toward to get a "boost" and others we avoid because they "suck the life out of you." The effects of energy are real and important. Furthermore, energy in organizations can be studied and the results used to improve performance.

Over a six-year period, we measured the impact of energy on large and small teams of a large engineering/construction company. The results of the studies verified our intuition about the importance of energy. We have found that it has direct impact on leadership, performance, engagement, and project delivery. We measured the energy within a global information-technology (IT) team of 160 people. Using organizational network analysis, we created network diagrams that map the connections among individuals in an organization. Specifically, we focused on energy networks. Energy was measured by asking a simple, powerful question: When you interact with this person, how does it affect your energy level? The responses ranged from "strongly de-energizing" to "strongly energizing." The patterns that emerged from the energy maps were then used to develop and grow teams within a changing organization.

Work by Rob Cross and others identifies behaviors that create energy. They include creating a compelling vision, having the opportunity to contribute meaningfully, being fully engaged in an interaction, seeing progress through interactions, and believing in a worthy and attainable objective. These conditions create an infectious can-do mentality among individuals and teams.

An Example: Energy and Leadership

Colleen began her career as a trainer providing information to civil engineers on new software applications. Her ability to deliver this information effectively engaged even the stodgiest engineers. Thanks to her skill, she was given an opportunity to begin managing small IT projects. She was adept at this task, too, and began to excel under the tutelage of her supervisor; pursuing a project management career path was exciting to her.

When her company merged with another engineering company, the regional IT functions were merged. Her project management abilities were quickly recognized by the new company. Informal comments circulated about her abilities and the "energy" she brought to projects. She was positive, yet doggedly persistent in meeting objectives on time. When the IT function in the company transitioned from regional to global, Colleen became part of a newly formed global Project Management Office (PMO) under the guidance of her long-time supervisor. With her strong training background, she was primarily responsible for communicating and teaching the global IT community about the new PMO practices; the rapid adoption of those practices showed how effective she was. She was sought after to manage the most difficult and challenging IT projects. Recently, an opportunity to direct the services for

the Americas portion of the IT unit came along and she was selected to fill this role, moving her from leadership in project management to leadership of a regional service function—one step below the chief information officer (CIO).

Her success was driven, in large part, by how she engaged with her teams and coworkers. The energy measurements over these six years indicate that Colleen was rated as energizing by 95 percent of her network ties, compared with the group average of 75 percent.

Colleen is one example of the relationship between energy and effectiveness (and success). Of those receiving the highest evaluations over time, one rose to be CIO, another became a division director reporting to the CIO, and another rose three levels to global functional director. Like Colleen, these individuals were rated as energizing by more than 90 percent of their contacts. Highly placed individuals who, on the other hand, received more "de-energizing" scores either left the company over time or were asked to leave.

Energy and Performance

The importance of energy is not limited to leaders. Cross and his colleagues note that energizers are "more likely to have their ideas considered and put to action, … get more from those around them, … attract the commitment of other high performers, … [and] impact what individuals and networks as a whole learn over time."

Collecting both performance and energy data, we found high performers in the IT team were consistently rated as energizing by 77 percent of their connections. Average performers were rated as energizing by only 59 percent of their connections. The energy difference between average and low performers was only 7 percent. Energy appears to make the difference between high and average performance in this IT team. The individuals who have high energy scores were more likely to be in leadership roles in the organization or move into them over time.

Energy makes a difference in team performance as well. In 2007, an important project to migrate the existing company to a new e-mail system began. The project languished for almost twelve months, not getting past the planning phase. Then team leadership and a few other core team players were changed to jump-start progress. The project was completed in six months. The energy data revealed that the original core team members were viewed as "energizing" by only 43 percent of their connections; the second core leadership team energized 87 percent of their connections. An even starker contrast between these teams was the energy scores of the sponsor and project manager. The sponsor and project manager of the original team energized only 26 percent and 30 percent of their connections; the replacement sponsor and project manager energized 90 percent and 64 percent, respectively. Based on these observations, we strongly believe that energy and performance at the individual and team level are closely linked.

Energy and Retention

Jack was a member of the IT team dating back to globalization in 2003. Between 2003 and 2007, other team members indicated that he had high relative energy. Between 2003 and 2008, though, the percentage of people working with Jack who found him energizing dropped from a high of 94 percent to 56 percent. Shortly thereafter, Jack left the organization.

In Jack's case, the number of energizing ties was an indicator that his job satisfaction and level of engagement had changed. We found the same trend with other individuals who voluntarily left the organization—the year before their departure, energy scores dropped by an average of 10 percent. So energy can be an indicator of employee engagement, and analysis can help management identify employees at risk of leaving.

Individuals with higher "energizing" scores exhibited a lower turnover rate in the six years than those that were identified as "de-energizing." On average, those who left the firm were rated as de-energizing by 45 percent of their contacts, compared with those who stayed with the firm, who were rated as de-energizing by only 16 percent of their contacts. Such results can help identify key team members as targets for retention efforts.

Creating Energy

While a focused network survey will provide the clearest analysis, you can get insight into the energy level in your group by asking and answering these questions:

Is there a compelling vision and mission for the team? A well-articulated, clear, and meaningful vision differentiates energizers from de-energizers. Energized teams look to future possibilities rather than past problems.

Are deadlines met? People tend to follow through on commitments when they are energized by the activities.

Are ideas freely offered and discussed? People are energized when they feel they contribute to the team. When an idea is rejected, does the individual who proposed it still feel they have been heard and given a fair chance?

It is also possible to identify energizers within groups. They are the people who

- Subscribe to principles and goals that go beyond their personal benefit
- Engage others in meaningful and realistic conversations that capture their hearts and imaginations
- Create an environment where teammates meaningfully engage in important conversations and make them feel that their ideas are valued
- Balance the need for progress and welcome new ideas
- Effectively disagree with others in a way that makes their contribution valued even if it is not followed
- Consistently follow through on commitments to the individuals and the team

Individuals with these characteristics are likely to be the main energy sources on their teams. As you plan for the future, make the most of those energizers by placing them in visible leadership roles. Modeling energizing behaviors yourself also helps to propagate energy. When leaders energize others, energy has a tendency to pass down through the organization. Developing energizing behaviors may require shifts in behavior, leadership philosophy, or maybe even core values, but the great positive impact of energy on performance makes the effort worthwhile. ●

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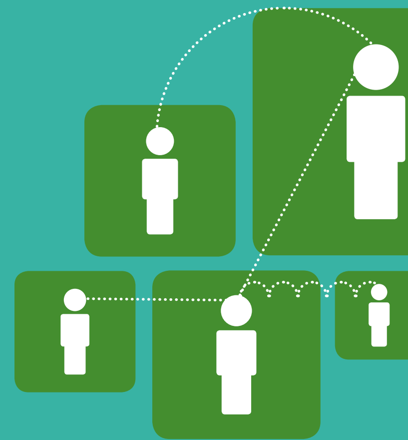
NASA Knowledge Forum 2: Knowledge in Projects



BY HALEY STEPHENSON

The NASA Academy of Program/Project and Engineering Leadership, along with co-host MITRE, brought together knowledge experts from NASA centers and members of industry and academia for the Academy's second NASA Knowledge Forum in April. MITRE hosted the event in San Diego, California.

"The rubber meets the road in projects," said Jean Tatalias, director of Knowledge Services at MITRE, at the beginning of the daylong discussion. "We have been working toward improving our knowledge sharing and knowledge management." Tatalias pointed out that MITRE had been managing knowledge for fifty years. "You might think, 'Well, fifty years, you must have it all done,'" she continued, "but we all know if you work in KM [knowledge management], it's never really done."

Over the course of the day, attendees shared stories and ideas about knowledge in projects. As projects increase in complexity, they demand greater organizational attention to identify and transfer valuable knowledge effectively. In addition to NASA and MITRE, representatives from organizations including Petrobras, the International Centre for Complex Project Management, MWH Global, the University of Southern California Marshall School of Business, Greenes Consulting, Fluor, and Common Knowledge Associates gathered to explore staffing, knowledge preservation, and communication, as well as to exchange stories, research, ideas, and experiences.

Defining "Community"

Paul Adler, professor at the Marshall School of Business at the University of Southern California, opened the forum by challenging the attendees to define what it means to be a community, asking, "What makes a group of people a community?" It is an important question in a discussion of project knowledge because so much organizational knowledge is developed and shared in communities.

Communities share a vision, purpose, identity, or values, the group agreed. A community has a common language and shares time and information. Communities built around science, religion, art, military, politics, and hobbies are often characterized by different hallmarks. For instance, the arts place great value on individual contributions, whereas the military focuses more upon the whole. Religious communities tend to respect and preserve tradition, while scientific communities gravitate toward innovation. "What I'm struck by is that some of these communities … need exactly the right context to stimulate innovation, and some of them are devoted to maintaining tradition," said Adler.

"Traditional forms of communities are antithetical to innovation," he said. "There's a very distinct type of community that encourages innovation." Adler explained that innovative and traditional communities have different values, norms (that is, the behavior members expect of one another), rewards, and authority distribution (for instance, top-down or distributed).

Both types of communities have advantages and drawbacks, and Adler maintains that organizations need to understand the impact that each can have on performance. "If you want an organization in which innovation is a crucial performance outcome, you need to be looking carefully at the possibility that the traditionalistic community is hampering your progress."

Staffing a Project with Knowledge and Talent

The first panel, comprising Vic Gulas, senior advisor and former chief people and knowledge officer for MWH Global; Ed Rogers, chief knowledge officer at Goddard Space Flight Center; and David Coomber, director of Operations at MITRE, addressed how organizations staff projects with the knowledge and talent they need. Knowing how to set up, design, and initiate

“EXPERTISE DOESN’T NECESSARILY COME FROM PEOPLE YOU KNOW,” COOMBER REMARKED. LOOKING OUTSIDE KNOWN NETWORKS INVITES RISK INTO A PROJECT, BUT TAKING THIS CHANCE OFFERS THE POSSIBILITY OF A SERENDIPITOUS OUTCOME.

projects is half the battle, remarked Larry Prusak, editor-in-chief of NASA’s *ASK Magazine*, who facilitated the panel. The other half is knowing what knowledge you need, and how that knowledge will fuel the project. “The project is becoming the unit of analysis within an organization,” said Prusak. Projects shape how organizations structure themselves and how they measure progress.

Knowledge acquisition happens in one of two ways: through traditional methods of choosing people known to those leading the project, or through the more risky method of looking outside a known network and taking a chance on someone less familiar who has specific knowledge. Most organizations rely on the traditional method: going with someone they know or have worked with. “The majority is done by relationships,” said Gulas. “There may actually be a better person out there, but … there’s this trust that [someone has] delivered and they’ll deliver again that is a huge bias.”

This is common practice for staffing projects at Goddard, said Rogers. It’s not the knowledge that usually earns someone a spot on a project team. “It’s ‘I want Joe on my team’ or ‘I want Sally on my team,’” explained Rogers, but “it shouldn’t matter what engineer is matrixed to your group …. It’s not ‘You get Sally,’ [it should be] ‘You get the electrical engineering branch’s knowledge applied to your project.’”

MITRE has gone through a transition, said Coomber, and is now looking at more formal ways of organizing its people and knowledge. MITRE is structured to support knowledge staffing using web-based knowledge networks everyone can access, and integration directors who are responsible for talking to one another across disciplines identifying talent, best practices, and valuable knowledge. “If I know I need talent in a certain area, I’ll go to them,” said Coomber.

“Expertise doesn’t necessarily come from people you know,” Coomber remarked. Looking outside known networks invites risk into a project, but taking this chance offers the possibility of a serendipitous outcome. For MWH, said Gulas, this means evaluating how their organization looks different from their competition. To stand out from the rest, they go in search of knowledge outside their typical network. “We have to go in search of that new knowledge,” said Gulas. After interviewing a candidate for a position, Gulas asks himself if he walked away feeling energized or de-energized by that person.

NASA, a project-based organization, doesn’t offer a cookbook for individual success. Rather, opportunities are visible to those motivated to look for them, explained Ed Hoffman, director of the Academy. “This way you get a variety of answers … the people that you want, the minds that you want.”

Organizations expecting to thrive cannot insulate themselves from outside knowledge. “The world is too complex,” said Prusak. “No one can possibly know everything. The world will beat you in the end.”

Preserving and Communicating Knowledge in Projects

Knowledge transfer is often treated as a simple task when it is actually quite complex, requiring time, money, and personnel. Most project knowledge is tacit, difficult to document in a standard way, and heavily reliant upon context. Often project teams aren’t even really sure what knowledge others will find valuable. What they consider a “no brainer” or too specialized for reuse may in fact be important to other project teams, explained Don Cohen, managing editor of *ASK Magazine* and moderator of the second panel, which included Kent Greenes, chief executive officer of Greenes Consulting; Hal Bell, director of NASA’s Advanced Planning and Analysis Division; and Nancy Dixon, founder and principal researcher of Common Knowledge Associates.

Understanding the needs of the knowledge customer is of utmost importance, the panelists agreed. This process begins with a conversation. Watching when people in a group are sitting up, listening, and engaged in a topic indicates what knowledge customers are interested in, said Tatalias. Dixon refers to these

group meetings as "sense-making" discussions, whereby people come together to understand their contribution to the larger puzzle of the project. "I might be able to tell you what I did and what actions came from it, but someone else in the room might be able to provide their outside perspective of their own actions in response," said Dixon.

Whenever Greenes goes into a knowledge-capture session, he requires that the customer for the knowledge is present, because the customer should have the greatest say in what the knowledge looks like in the end. Greenes consulted for British Petroleum (BP) when it was having problems with knowledge transfer between workers during shift hand-over, which was costing money and risking employee safety. Greenes observed the workplace in action, which allowed him to advise BP on how to tailor the knowledge and its transfer to their workers—the knowledge customer.

In addition to understanding the knowledge customer, understanding how to move or transfer knowledge appropriately is also essential. Many organizations use "wikis" to capture and post knowledge. These systems are usually search-based, however: a user goes in search of the knowledge they know they need, not the knowledge they don't know they need. A wiki is a "pull" mechanism, explained Dixon—user initiative pulls knowledge from a source. "You can only learn from a pull mechanism if you know what you don't know," she cautioned. Designing a system to push needed knowledge is the other half of the battle.

A push mechanism, similar to the one Amazon.com uses to suggest other books a reader might be interested in based on previous browsing and purchasing history, requires that the knowledge supplier understand the customer well enough to push the right information, said Dixon. Georg Siebes of NASA's Jet Propulsion Laboratory pointed out that too much push can be counterproductive. "If the pond is full of bait and the fish are saturated," Siebes said, "the knowledge transfer fails."

Effective knowledge transfer depends on the support of organizational leadership and resources for communications experts and knowledge-sharing events like storytelling over lunch. Withholding resources threatens the success of effective knowledge sharing, said Bell. He cited the example of the Phoenix lander mission to Mars in 2007. The successful project captured the attention of people working outside the project. Of particular interest was knowledge gained about the heat shield for the lander, which protected the spacecraft from damage as it entered the Martian atmosphere. The project team didn't have the resources to share their story, however, and the data from the heat shield was on the verge of being eliminated. Bell's group stepped in and provided the resources needed to prevent the data from being lost. "It's not always money, it's people," said Bell. "It takes management and commitment to make these discussions happen. It's all too easy to get caught up in the here, now, and today, and not five years down the road."

Looking Ahead

Attendees suggested that future forums could feature more real-life stories from expert practitioners and focus more on the next generation of knowledge workers. One particular interest is gaining a better understanding of the way the younger generation communicates, networks, and learns. Today's young professionals will be the future custodians of organizational knowledge, and current leaders must help prepare them to take ownership.

The discussion reinforced the value of bringing people together and exchanging ideas. The forum is an example of a community founded upon an affinity for knowledge, looking to evolve and progress in order to support organizations, programs, and projects. "We're coming together and sharing our stories and lessons," said Hoffman, "learning from each other." ●

The Knowledge Notebook

What's Right About Being Wrong

BY LAURENCE PRUSAK

A number of years ago I was asked by some clients to come up with a rapid-fire indicator to determine whether a specific organization was really a "learning organization." Now, I have always believed that all organizations learn things in some ways, even if what they learn does not correspond well to reality or provide them with any useful new knowledge. After thinking about the request for a bit, though, I decided the best indicator would be to ask employees, "Can you make a mistake around here?"

When people in various organizations tried this out in practice, asking groups of employees that key question, they were almost always given the same response: "Yes, you can make a mistake, but you will pay for it." Some of these organizations were the very same ones that touted themselves as "learning organizations" in their annual reports and public-relations statements, but if they penalize their employees for making mistakes, not much learning will happen.

Why? Well, if you pay a substantial price for being wrong, you are rarely going to risk doing anything new and different because novel ideas and practices have a good chance of failing, at least at first. So you will stick with the tried and true, avoid mistakes, and learn very little. I think this condition is still endemic in most organizations, whatever they say about learning and encouraging innovative thinking. It is one of the strongest constraints I know of to innovation, as well as to learning anything at all from inevitable mistakes—one of the most powerful teachers there is. Some recent political memoirs by Tony Blair and George Bush also inadvertently communicate this same message by denying that any of their decisions were mistaken. If you think you have never made a mistake, there is no need to bother learning anything new.

The early history of NASA is partly a history of making mistakes—some of them very costly—that helped develop the knowledge needed to land men on the moon and put rovers on Mars, among other triumphs. Some believe that NASA has become too mistake-averse over time and that an emphasis on avoiding mistakes limits the agency's ability to innovate. (Take a look at the interview with Robert Braun in the summer 2010 issue of *ASK*, for instance.)

A recent book has a novel and appealing approach to this whole subject. Written by Kathryn Schultz, it is called *Being Wrong*. Ms. Schultz wants to establish an entirely new discipline called "wrongology" to study the causes, implications, and, most of all, the acceptance of being wrong. She presents a more populist version of the great book by Charles Perrow, *Normal Accidents*, but her take on the subject is more individually based and funnier.

What would happen if we all accepted that being wrong is as much a part of being human as being right, and especially that errors are essential to learning and knowledge creation? What would our values and institutions look like under this new dispensation? I can easily summon up the grave image of Alan Greenspan testifying before Congress last year on the causes of the financial crisis. What was so very startling was seeing him admit that he was wrong! It was such an unusual event that it made headlines around the world. But why should it be so rare and so startling? Greenspan had a hugely complex job, one where many critical variables are either poorly understood or not known at all. Nevertheless, neither he, nor any other federal director I have heard about, has ever said anything vaguely like what he did that day before our elected officials and the public.

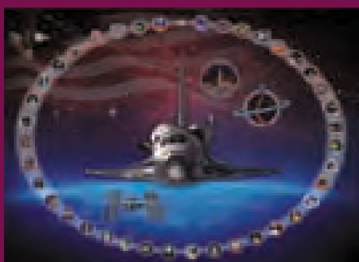
Perhaps Ms. Schultz's book will at the very least cause us to reflect a bit more on this oft-buried subject. It was a favorite theme of philosophers, when philosophers still wrote for the masses, and in literature. Being too proud to admit you are wrong—or to admit it only when it is too late—is central to several of Shakespeare's plays. *King Lear* comes to mind. It is the subject of more novels than I can begin to list here. If you are interested, try tackling *War and Peace* (and I highly recommend it; it's a great read), and you will see how Tolstoy deals with the subject of Napoleon's colossal mistakes and (Tolstoy being the great writer he is) the stubborn mistakes of some Russian generals, too.

While Alan Greenspan is not often thought of as a heroic figure, he has the laudable distinction of being one of the very few people to say directly and clearly that he made a mistake. In doing so, he at least opened the door to the possibility of learning to do things differently—and better—in the future. ●

… IF YOU PAY A SUBSTANTIAL PRICE FOR BEING WRONG, YOU ARE RARELY GOING TO RISK DOING ANYTHING NEW AND DIFFERENT BECAUSE NOVEL IDEAS AND PRACTICES HAVE A GOOD CHANCE OF FAILING, AT LEAST AT FIRST.

ASK interactive

NASA in the News



NASA's Space Shuttle fleet began setting records with its first launch on April 12, 1981. The shuttle has carried people into orbit repeatedly; launched, recovered, and repaired satellites; conducted cutting-edge research; and played a major role in building the largest structure in space, the International Space Station. As humanity's first reusable spacecraft, the Space Shuttle required not only advanced technologies but the tremendous effort of a vast workforce. As the program approaches its final planned launch, NASA is paying tribute with a collection of feature stories and videos documenting Space Shuttle operations. Learn more about what it takes to maintain and fly this technological marvel at www.nasa.gov/mission_pages/shuttle/flyout/index.html. NASA will continue to add stories and videos to this collection, so check regularly for new content.

Reminder: PM Challenge 2011

The NASA PM Challenge is the agency's annual forum for NASA stakeholders to learn about and discuss current trends in program management, project management, and related disciplines by sharing their knowledge, lessons learned, and new ideas that enhance mission success. PM Challenge 2011 will be held February 9–10, 2011, in Long Beach, California. Registration is open October 25, 2010, to January 18, 2011. For more information, and to register, visit pmchallenge.gsfc.nasa.gov.

Web of Knowledge

One of the first places scientists turn when volcanoes, wildfires, pollution plumes, dust storms, and other phenomena—both natural and manmade—make an appearance is NASA's Aerosol Robotic Network (AERONET). A team of scientists at Goddard Space Flight Center along with numerous institutions around the world started setting up the network of portable instruments decades ago to validate and calibrate satellite measurements. That remains the network's core function, but thousands of scientists have found ways to use AERONET data to gain insight into a variety of research areas ranging from air quality to cloud microphysics to precipitation dynamics. And one of the best things about the network is the data are free for all to use. To learn more about AERONET, visit aeronet.gsfc.nasa.gov.

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