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Academy Sharing Knowledge

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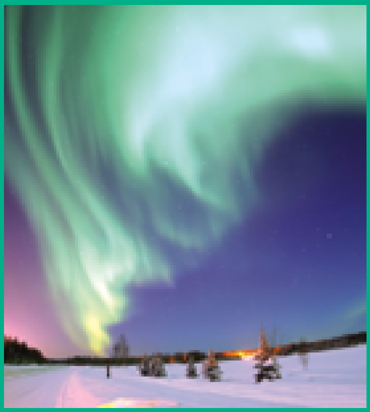

Photo Credit: U.S. Air Force, Senior Airman Joshua Strang

ON THE COVER

Above Bear Lake, Alaska, the Northern Lights, or aurora borealis, are created by solar radiation entering the atmosphere at the magnetic poles. The appearance of these lights is just one way solar radiation affects us; it can also interfere with NASA missions in low-Earth orbit. To achieve long-duration human spaceflight missions in deeper space, several NASA centers are working to find better safety measures and solutions to protect humans from space radiation.

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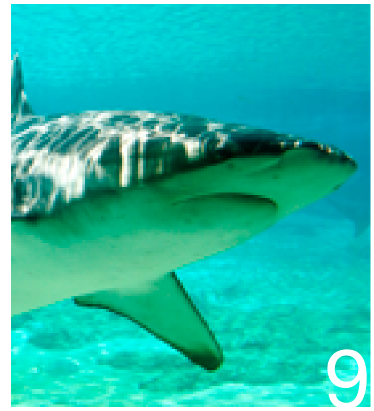

DEPARTMENTS

INSIGHTS

STORIES

ask

Issue No. 51

Staff

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*.

You can help *ASK* provide the stories you need and want by letting our editors know what you think about what you read here and by sharing your own stories. To submit stories or ask questions about editorial policy, contact Don Cohen, Managing Editor, doncohen@rcn.com, 781-860-5270.

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In This Issue

In "Our Knowledge Legacy," NASA Chief Knowledge Officer (CKO) Ed Hoffman describes his visit with elementary-school children in Brooklyn, some of whom may become NASA engineers, scientists, or managers decades from now. Talking to those smart, enthusiastic students, he realized how important it is to preserve and transmit the agency's rich store of knowledge so that future employees can build on it to advance aeronautics and space science and exploration. No NASA mission starts absolutely from scratch. They all depend on knowledge gained from the experience of earlier work. As several articles in this issue of *ASK* make clear, effectively fostering and sharing that knowledge demands thoughtfulness, skill, and creativity.

Edward Rogers, who has been Goddard's CKO for more than a decade, shares lessons from "The Knowledge Management Journey," including the importance of fitting knowledge activities to people's specific needs and ways of working, rather than trying to impose pre-existing knowledge management techniques on them. Rogers has helped make "pause and learn" reflection and case-study discussion an integral part of work at Goddard.

In "Creating NASA's Knowledge Map," Matthew Kohut and Haley Stephenson discuss a new tool that shows the richness and diversity of knowledge work at NASA's centers. As it continues to be enriched and refined, the map is likely to be a valuable way to locate essential knowledge anywhere in the agency. That matters because the knowledge required to solve a problem or avoid disaster almost always exists somewhere in the organization. But it is not always available to the people who need it to make sound decisions. Sometimes that knowledge is discounted or ignored, a point Pedro Ribeiro makes in "Predictable Surprises: Bridging Risk-Perception Gaps." He outlines a technique for addressing that danger.

Of course NASA is also in the business of developing new expertise. In "Back to the Future: KSC Swamp Works," Kerry Ellis describes labs at Kennedy Space Center designed to create knowledge by bringing together people with diverse backgrounds and by hands-on experimentation, building prototypes that teach the experimenters things they could never have learned from abstract planning or design. Aware of the importance of making what they discover available to others, the Swamp Works teams are also careful to document their work as they go along.

Laurie Stauber's "University Capstone Projects: Small Investments, Big Rewards" describes another way to acquire new knowledge. Glenn Research Center partners with several universities on student projects that explore space-medicine issues, providing valuable experience for the students and valuable learning to NASA.

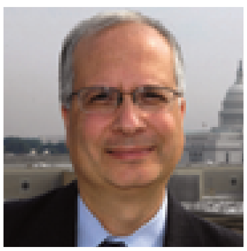
The right knowledge is essential to project success but not sufficient to make it happen. A couple of articles in this issue demonstrate the importance of leadership and good communication. In "The Road to New Flight Software," Christopher Krupiarz shows how the Applied Physics Laboratory at Johns Hopkins worked with several NASA centers to build complex new software. And Keith Woodman and Debi Tomek's "Lessons on Leadership: The Evolution of the Radiation Protection Project" describes the skilled leadership that kept a project alive and well in spite of numerous changes that could have killed it.

Don Cohen
Managing Editor

From the NASA CKO

Our Knowledge Legacy

BY ED HOFFMAN



When we're young, we are excited by our dreams. Our future possibilities seem endless and alluring.

This spring, I had the opportunity to step back into that childhood world of possibilities when I returned to my elementary school in Brooklyn. Going back to P.S. 199 (Frederick Wachtel school) after forty years was a profoundly moving experience. I'd been invited to talk with students from kindergarten to grade six about my experience working for NASA. My purpose was to use the powerful connection between art and science to communicate to the students that "you can do anything in your life, as long as you dream big and work hard." I wondered and worried: Would I be relevant?

Then the day unfolded, and every minute was something I treasured. The students were alert, energized, passionate, and smart. They wanted to know more about life onboard the International Space Station, the challenges of landing the Mars Curiosity rover, and the aircraft of the future. The teachers were welcoming and inspiring. The art activity that followed my talk was highly interactive and engaging for the students—the combination of science and art can unlock new realities and big dreams. Many asked about working as engineers, project managers, artists, and scientists, and more than a few indicated they would see me in a few years. (They promised to be good bosses.) I walked away believing they could make that dream a reality.

As I reflected on that day, it occurred to me that most of the programs that inspired the students in my talk will be history by the time they would be able to join NASA in a decade or more. There will be new programs by then, of course, but the people who carry them out—today's students—will need the knowledge and expertise that has enabled us to complete the construction of the space station while manning it continuously for over a decade and to land a car-sized rover in a crater on Mars. That knowledge will only live on and be available to them in the people who worked on these programs and the systems we design to preserve and share it.

NASA has come a long way since Apollo in its effort to capture knowledge from its flagship programs. The Shuttle Knowledge Console at Johnson Space Center is the go-to source for thirty years' worth of knowledge about the Space Shuttle. Knowledge about the Ares I-X launch vehicle was captured very deliberately. The Mars program has made an intensive effort to document lessons from the innovative approach used to land Curiosity on the Martian surface. In the case of the International Space Station, the partner space agencies have developed a joint document of lessons learned based on their experience working collaboratively.

This knowledge is our real legacy to the students of P.S. 199 and other schools if they are to continue the work of space exploration and aeronautics research. There's no question that the passion remains alive. They are counting on us to share what we know. ●

BACK TO THE FUTURE:

KSC SWAMP WORKS

BY KERRY ELLIS

After the retirement of the Space Shuttle and completion of the International Space Station, NASA has been looking toward what's next in human space exploration. Several centers have begun working on projects that could pave the way for the new ambitious goals of exploring asteroids and launching missions beyond low-Earth orbit. But such a shift in goals also requires a shift in culture. Taking a cue from NASA's Apollo days, Kennedy Space Center (KSC) has taken steps toward changing the culture to one of hands-on, lean engineering and innovation development with the KSC Swamp Works.

A panoramic view of the new KSC Swamp Works space.

Photo Credit: NASA

"KSC Swamp Works is what I call 'Back to the Future,'" said Rob Mueller, senior technologist for the Systems Surface Office. "It's an attempt to return to the early years of NASA when it was very hands-on, projects happened quickly, there were a lot of experiments, and sometimes failures happened, but we learned from the failures."

KSC Swamp Works includes the Granular Mechanics and Regolith Operations Lab and the Electrostatics and Surface Physics Lab. Both have been around for a few years as part of the Surface Systems Office but were previously located in an off-site building. When the opportunity—and budget—became available to move the labs back to Kennedy, the teams discussed their vision for an ideal environment in which to do new hands-on work.

"AND WHAT I'VE NOTICED IS INNOVATORS FROM DIFFERENT GROUPS WILL HAVE GREAT CONVERSATIONS ABOUT WHAT THEY'RE WORKING ON AND ASKING, 'HAVE YOU THOUGHT OF THIS? HAVE YOU THOUGHT OF THAT?' IT'S WORKED OUT VERY WELL."

"I asked the team, 'What do you want?'" said Jack Fox, chief of the Systems Surface Office. "I made sure the requirements matched the building we wanted. It's a huge building because we wanted to reinvent everything into being a Swamp Works environment—cost-effective, hands-on, rapid ideas—and have both labs in the same space." The teams didn't want different codes and buildings that would inhibit joint brainstorming. Another building requirement to support this goal was to include an "innovation space."

With café seating and white boards, and walls and tables painted with whiteboard paint as well, the innovation space is located in a small, open loft. "It's completely flexible, reconfigurable. The whole dynamic of the room can change," said Mueller. "It's not designed to be a room to have meetings. It's designed to be a room where people can interact spontaneously and informally to come up with new ideas and innovative ways of working."

To further encourage openness and collaboration, the team also included a flexible work space as part of the building requirements. Meant to operate as a technology incubator, it allows anybody with a good idea to come in and have real estate available to try out a new technology. "They can't stay there forever," Mueller explained, "since it's an incubator, but at least there's a place for new ideas to get started."

The labs have a mix of primarily engineers, physicists, and chemists—both senior and fresh-outs—to help encourage innovative thinking and problem solving. But that diversity is part of the challenge of running a Swamp Works operation. "How do you get people together from different disciplines?" asked Mueller. "Usually we do this by creating a multidisciplinary team for a project, but we don't always have all the disciplines we need." To fill the gaps, the Surface Systems Office takes advantage of Kennedy's matrix organization and asks the Engineering and Technology Directorate for the help they need.

Sometimes they find that expertise through more informal means. Every other week the teams have innovator get-togethers during lunch. "We talked about having after-work activities, but people kind of want to go home," said Fox. "We learned that lunchtimes every other Friday work well. And what I've noticed is innovators from different groups will have great conversations about what they're working on and asking, 'Have you thought of this? Have you thought of that?' It's worked out very well."

With an abundance of knowledge and ideas flying about, KSC Swamp Works has taken steps to formally capture lessons learned in the midst of their fast-paced efforts.

Capturing Lessons Learned

Using a "make it, test it, and improve it" model of work, projects in the KSC Swamp Works labs often undergo several generations of builds, each an inexpensive attempt to improve on the one before. With so much excitement generated by doing hands-on work, it can be a challenge to get the teams to slow down and capture what they've learned from their efforts.

Mueller reminds his teams of the incentives for taking the time to document that knowledge. "We try to tie things together with positive outcomes—like a conference or a new technology report or a patent application," he explained. "In order to get credit for the work we've done, we write conference papers, which require us to document things well. We also write new technology reports, which could get published in NASA *Tech Briefs* and eventually lead to getting a patent on the work. We would like to protect intellectual property and license the new technology transfer to the public, and in order for the legal process of patenting to happen, you have to have documentation."

"WHY DON'T YOU UNDERSTAND WHAT'S BEEN DONE FIRST BEFORE YOU START TRYING TO CREATE NEW WAYS TO DO IT?"

Since much of KSC Swamp Works' focus is on openness and collaboration, the teams try to make their lessons learned as broadly available as possible. Currently, they use SharePoint to make formal knowledge-capture documents readily accessible. But they also use it to capture lessons in real time.

Projects traditionally complete the work, stop to document it, and then move on to the next phase. This process doesn't work as well for the faster-paced work involved in lean-engineering research and development. "We do have formal processes like design reviews, and we create documentation for those reviews, but we try to document as much as we can real time so the records are always available and you don't have to stop to generate a report," said Mueller.

The labs maintain continuity of knowledge between generations of designs by having the same team work on every successive generation together.

The collaboration among scientists and engineers, seniors and fresh-outs, is open, allowing everyone to learn from each other and ask questions along the way. One recent graduate, Rachel Cox, said the knowledge she has gained by working with senior engineers on the Regolith Advanced Surface Systems Operations Robot (RASSOR) has been invaluable.

RASSOR

The KSC Swamp Works labs currently focus on the engineering and science of dealing with regolith—or space dirt. The superfine substance has a habit of getting into places it shouldn't. Sneaking into space suits, jamming mechanical gears, and sticking to everything with strong electrostatic charge, regolith is a known nuisance. But mined effectively, it could be a valuable resource for future long-duration missions beyond low-Earth orbit.

RASSOR is a robot designed to excavate regolith on an extraterrestrial surface with very low gravity, like the moon or an asteroid. The teams are currently working on the third generation of the robot, having learned a lot from their first two efforts.

One generation ended up being too heavy. That isn't a big concern for a prototype, but weight matters to a flight-ready robot. The heavier the robot is, the larger the rocket needed to launch it, and the more expensive it becomes. A key contributor to the robot's weight was its metal tracks. In the initial planning, the team debated using tracks versus wheels for RASSOR.

"The treads you use for a track give you more traction, letting you operate in more extreme environments, on steeper hills, and very dusty soil that is fluidized," explained Mueller. "But wheels are much simpler and lighter. We did end up using tracks, but they caused a lot of problems, so now we're looking at going back to wheels. Tracks versus wheels is one good example of a problem that was designed to be addressed by rapid prototyping."

The first RASSOR used rubber-belt tracks because they're cheap, easy to obtain, and don't have to be heavily modified. But those tracks didn't hold up well during testing. The team

With a pair of drums positioned on arms, RASSOR can take on a number of different shapes to accomplish its work.

then moved on to using metal tracks. Cox, a recent mechanical engineering graduate, has been working on improving the tracks for the third-generation robot, a process she says has increased her knowledge exponentially.

"I just graduated from college, so I thought I was pretty smart and could come up with new ideas," Cox said, "but I don't have the knowledge to back it up." For a few weeks she struggled with the metal tracks, coming up with new designs that kept running into problems. "I'd fix one, and it would create

Photo Credit: NASA/Jim Grossmann

NASA Chief Knowledge Officer Ed Hoffman (left), Jack Fox (center), and Rob Mueller discuss KSC Swamp Works and techniques to enable innovation during a weeklong series called "Masters with Masters" at Kennedy Space Center.

another," she said. Then she went to one of the lead engineers for advice. He pointed out that tank tracks had been designed and created for years, and there was no need to reinvent the technology. "He said, 'Why don't you understand what's been done first before you start trying to create new ways to do it?'"

Cox found a large military textbook about tank tracks and spent a couple of weeks reading it and figuring out what applied to RASSOR. "It set me straight," she said. "I had a baseline to go off. Instead of trying to pull things out of my head, I had real-world examples and could see that this might not scale, but this is probably doable.

"So going to that engineer and asking for help, it's been really helpful. I wish I had done that sooner."

Everyone involved on RASSOR has gained invaluable knowledge by building the robot, seeing how it operates, and improving on the design. The process has allowed the team to learn not only what doesn't work, but also what might work much better than they had originally thought—or in unexpected, but advantageous, ways.

For example, after building the first generation of the robot, they learned through testing that it was capable of doing acrobatics. "We designed it so it could flip itself over again to avoid getting stuck," Mueller explained, "but then we learned just by experimenting that there were several different ways of driving it. You could drive it on its bucket drums, which it wasn't designed to do. We could also stand it up and dump regolith into a bin. So we discovered many different modes of operation just by experimenting with it. You can't get that from just white-boarding it. You need a physical prototype to try new things with."

Currently, the team foresees building RASSOR through a fourth and possibly fifth generation, each time using what they've learned from the previous build to improve the design. KSC Swamp Works aims to have each new project go through this process, benefiting NASA as well as the scientists and engineers with new knowledge and innovations.

Future Plans and Collaborations

The knowledge gained doesn't stay inside KSC Swamp Works. The labs collaborate with several NASA centers and projects, as well as commercial partners. They have worked with Project Morpheus, building the hazard field at the landing facility and building launch and landing pads for the vehicle. And they have been interacting with the Multi-Mission Space Exploration Vehicle team at Johnson Space Center and working with Desert Rats, as well as collaborating with Kennedy's Spaceport Innovators. The labs hope to do much more in the future.

"We're reinventing Kennedy to be a place where we do the high-risk, high-payoff work needed for future space exploration," said Mueller. "It's different from what we've done in the past, so there's a big culture change. KSC Swamp Works is a pile of projects designed to show how Kennedy could be a different place in the future—still very successful, but probably a different way of doing business."

SWAMP WORKS
NASA KENNEDY SPACE CENTER

KSC Swamp Works logo.

Image Credit: NASA

"Our mission is to provide government and commercial space ventures with technologies they need for working and living on the surfaces of the moon, planets, and other bodies in our solar system," added Fox. "We're the provider of technologies. We're laying the groundwork for future NASA programs and commercial ventures. We feel that's the role of a government lab." ●

Predictable Surprises: Bridging Risk-Perception Gaps

BY PEDRO C RIBEIRO

"Unfortunately, my King … here I am, unwilling and unwanted … because I know that no one ever welcomes a bearer of bad news." —Antigone by Sophocles, circa 442 BC

"It is pardonable to be defeated, but never to be surprised." —Frederick, the Great

Photo Credit: Steve Garner

Photo Credit: Fiona Ayerst

Many failed projects provide early warnings that they will run into trouble, but these signs are often ignored. They fly under the organization's risk radar, evading even sophisticated risk management processes. Organizations end up not recognizing early signs of failure until nothing can be done other than trying to manage a crisis.

The Good and Bad News About Project Failure

Projects may fail for many reasons. Common causes range from unrealistic expectations and unclear requirements to inadequate resources and lack of management support. Whatever the reason for a specific project failure, we should ask ourselves if it was a complete surprise for all involved, an outcome no one could possibly have imagined. Were 100 percent of the people involved in the project blind to the signs of an impending crisis?

The good news is that failure is rarely a complete surprise. Almost invariably, some people perceive the danger and try to warn the organization. Sometimes warnings from outside the organization signal trouble ahead. In other instances, the grapevine—the organization's informal communication network—talks about it in the cafeteria or by the water cooler. According to research (see the *Silence Fails* report of 2006), up to 90 percent of employees involved in a project may recognize far in advance when projects are headed for failure.

The bad news is that 71 percent try to speak up about their concerns to key decision makers but do not feel they are heard, and 19 percent don't event attempt to speak because they already know they will not be heard. The result: important risks are unnoticed or ignored until it is too late. Then the project suddenly collapses, leaving management wondering what went wrong. When the project is a large one, they may first learn about the failure from the news media.

Postmortem analyses, inquiries, and audits of failed projects often uncover streams of unheeded warnings in the form of letters, memos, e-mails, and even complete reports about risks that were ignored, past lessons not learned, and actions not taken—a failure of leadership that creates the conditions for a "perfect storm" of problems that could and should have been prevented, but nevertheless catch leaders by surprise.

Harvard Business School professors Max Bazerman and Michael Watkins apply the term "predictable surprise" to an event that takes leaders by surprise despite prior availability of the information necessary to anticipate the event and its possible consequences. I define "predictable project surprise" as an event characterized by sudden project status change or a discontinuity in a project's expected or actual result that takes management by surprise when project team members or sources outside the organization tried to warn the organization about the danger.

Predictable project surprises can result from unmanaged differences in project risk perceptions.

Risk-Perception Gaps and Predictable Project Surprises

Risk perception is the subjective judgment we make about the characteristic, severity, and likelihood of a risk. It varies from individual to individual and from group to group. Education, experience, level of expertise on a specific subject, psychological traits, cultural context, and even the way risks are described all influence how we perceive the riskiness of a given situation. There has been a considerable amount of empirical research undertaken about why we perceive risks differently. Differences in risk perceptions are a fact of life and a strength in well-managed multidisciplinary teams, since they mean that some people will be aware of risks that others cannot see.

Look at the photo above. Depending on previous knowledge of the context, information, perspective, training, and expertise about scuba diving with sharks, we may have different perceptions about the inherent risk of this situation and our ability to cope with it.

Even perception of so-called "black swans"—high-impact, low-probability events—depend on the observer. According to

THE BAD NEWS IS THAT 71 PERCENT TRY TO SPEAK UP ABOUT THEIR CONCERNS TO KEY DECISION MAKERS BUT DO NOT FEEL THEY ARE HEARD, AND 19 PERCENT DON'T EVENT ATTEMPT TO SPEAK BECAUSE THEY ALREADY KNOW THEY WILL NOT BE HEARD.

Nassim Taleb, author of *The Black Swan*, what may be a black-swan surprise for one observer is not for another. A black swan is something not expected by a particular observer, and whether or not an event is considered a black swan depends on individual knowledge and experience.

Such differences in perception mean that at least some members of a diverse group are likely to identify risks that threaten project success. But their insights will not save the project if they are not effectively communicated.

Horizontal communication disconnects between department and division silos, as well as vertical communication disconnects between senior management, sponsors, and project managers on one hand and project managers and team members on the other, also contribute to the formation of isolated and ineffective clusters of risk perception.

Communication disconnects can be aggravated by attitudes toward risk. (In a previous *ASK* article, "Sinking the Unsinkable: Lessons for Leadership" [Issue 47, Fall 2012], I discussed some examples of the impacts of communication disconnects.)

Certain attitudes function as communication blockers, increasing the chances risks will be ignored. These include denial ("This cannot happen"), minimization ("You are stirring up a tempest in a teacup"), overconfidence and grandiosity ("We are the best organization in this field, we have the best systems in place"), idealization ("We are installing a new system or hiring a new manager that will solve all our problems"), and transference ("If this happens, department X or another entity is to blame").

Defense mechanisms, when ingrained in an organization's culture and endorsed by leaders, are detrimental to teamwork and collaboration among departments. They encourage faulty rationales for decisions and complacency, and can lead to intimidation of those who question management.

In the absence of appropriate channels, good multidisciplinary team management, and a positive conflict culture for articulating concerns, team anxiety will flow through the grapevine, and important differences in risk perceptions will end up being discussed out of management awareness and control—in the cafeteria, by the water cooler, or outside the office.

According to research, grapevine activity accelerates any time there is an ambiguous or uncertain situation and absence of sanctioned, open, and trusted channels for venting concerns, including office politics, hidden agendas, and pressure for results perceived as harmful to project objectives. Employees in any organization receive most of their information from informal networks and from a small number of people whose opinions are highly respected. The strength of the informal network will vary according to factors such as organization and country culture. With the Internet, interactions among people sharing and exchanging information in informal virtual communities and networks are accelerating, jumping over organizational, national, and geographical boundaries.

Mapping Risk-Perception Gaps

Recognizing, discussing, and addressing risk-perception gaps are critical to project success, reducing the chances of project-risk blind spots.

To address this need and complement and leverage other risk management information-gathering techniques and processes, I developed a tool for mapping and easily visualizing risk-perception gaps. The Risk-Perception Map (RPM) charts "perceived risk level" and "perceived risk-response capability" in a 2-by-2 matrix.

Perceived risk level represents an individual's subjective assessment of risk level absent any action to alter the likelihood or impact of the risk. The perceived risk-response capability is an individual's subjective assessment of her organization's ability (using technology, processes, and people) to effectively formulate, plan, and execute responses to identified risks.

The two dimensions group risk perceptions into four categories: Mission Impossible or a Crisis Waiting to Happen; The Big Challenge; A Walk in the Park; and Just Another Day's Work.

Mission Impossible or A Crisis Waiting to Happen: The observer perceives the project as high risk and does not feel the

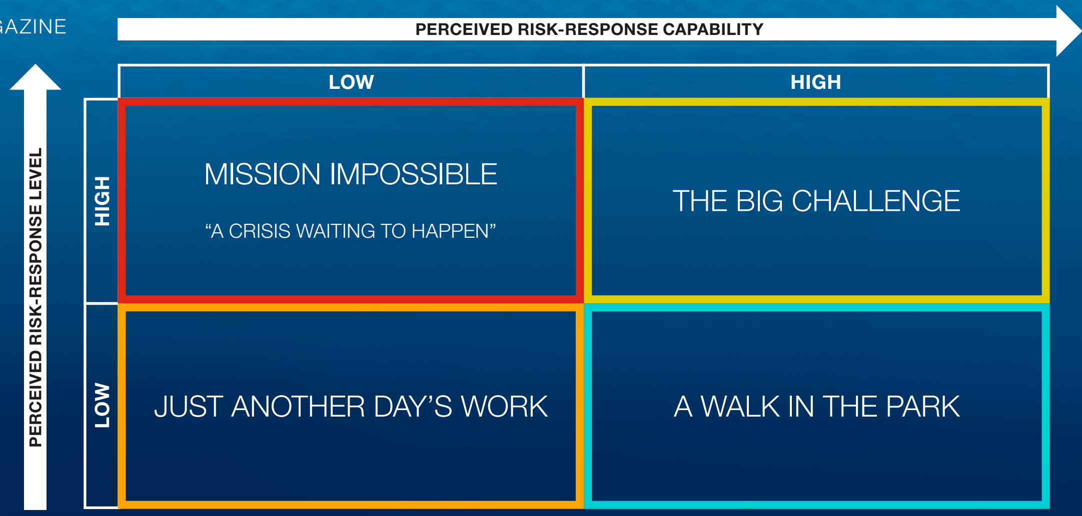


Figure 1. Risk-Perception Map.

Image Credit: Pedro C. Ribeiro

organization has adequate capabilities and controls in place do deal with it effectively.

Say, for example, that the undersea photograph represents a project that involves scuba diving with sharks. If one judges that swimming with sharks is dangerous and believes that the organization does not have adequate scuba-diving training capabilities, depth of knowledge about shark habits, scuba-diving equipment maintenance policies, practices of regularly feeding sharks, and explicit contingency plans in case something goes wrong, he may be inclined to think this to be a Mission Impossible or a Crisis Waiting to Happen project.

The Big Challenge: The project is perceived by the observer as very risky, but the organization is perceived as having the right capabilities in place to effectively face and manage the risks.

A Walk in the Park: The project is perceived as low risk (the observer perceives sharks or this situation as relatively harmless), and the organization is thought to excel in capabilities, policies, and preparedness to effectively deal with this type of project.

Just Another Day's Work: The observer perceives the project as low risk and does not believe the organization has adequate capabilities and level of preparedness to deal with it. The likelihood of the risks are small and the consequences, if they do happen, will be minor.

Different stakeholders of your project—project team members, auditors, management, quality, finance, compliance, and other units within and outside the organization—are likely to have different risk perceptions, positioned in different quadrants. Multidisciplinary teams consisting of representatives from different departments and professional backgrounds bring different areas of expertise and provide multiple points of view, and potentially reduce risk blind spots. Some key members of your team may judge the project as Mission Impossible or a Crisis Waiting to Happen, while management may consider it a Walk in the Park or Just Another Day's Work. If these differences in risk are ignored or not understood and addressed, the project may not only lack necessary support from key stakeholders but also be headed for a predictable project surprise.

Bridging Risk-Perception Gaps

The RPM helps to overcome communication gaps and defense mechanisms by providing a template and a visual tool for structured discussions about risk-perception differences. By making these differences visible, it makes it much harder to ignore or discount them. Evaluating risk-perception differences becomes an explicit part of project work.

By focusing on capturing, showing, and understanding diverging risk views, the RPM complements other risk management information-gathering techniques and processes. It is especially useful when an organization's existing risk management processes do not provide adequate, sanctioned, open, and trusted channels and processes to capture and address differences in risk perceptions or when teams become biased or so concerned with reaching consensus and converging to a single "risk score" that they fail to evaluate important risk-perception gaps. It can also help reduce the chances of predictable project surprises and increase the chances of project success. ●

PEDRO C. RIBEIRO is the founder of Stratech/TheProjectOffice. A director of the Risk Management SIG and a former member of the board of PMI Educational Foundation, he is the author of the book *Licoes do Titanic sobre Riscos e Crises* (*Lessons from the Titanic on Risk and Crises*), the article "Sinking the Unsinkable: Lessons for Leadership" (*ASK Magazine*, Issue 47, Fall 2012), and has contributed to the PMI Practice Standard for Project Risk Management. E-mail: pedrocribeiro@stratech.com.br

UNIVERSITY CAPSTONE PROJECTS:

BY LAURIE STAUBER

Small Investments BIG REWARDS

Looking for solutions to vexing technical problems can sometimes yield serendipitous results. Here at Glenn Research Center, the search for new medical expertise that will be needed for long-duration spaceflight has led to an unexpected, mutually beneficial relationship with several universities.

Photo courtesy of Laurie Stauber

Capstone team from the University of Michigan.

Crews on long-duration exploration missions beyond low-Earth orbit will need medical capabilities to diagnose and treat disease as well as to maintain health. The Exploration Medical Capability element at Glenn develops medical technologies, medical informatics, and clinical capabilities for different levels of care during those space missions. About two years ago, the Human Research Program (HRP) and Exploration Medical Capability (ExMC) project management team asked me to develop a Technology Watch solution for ExMC gap needs. ExMC gaps are areas where the agency has limited expertise. Industry, other agencies, or academia may already have some of that expertise or be in a position to develop it, but—since little had been published about these particular knowledge needs—it was difficult to gauge where that expertise and those capabilities were likely to exist.

My initial task involved gathering information specific to each gap need, preparing documentation, and then publishing in a variety of venues, including the Federal Laboratory Consortium (FLC) technology locator, and then online in both their national and Midwest newsletters. We held discussions at FLC meetings, both national and Midwest; at Cleveland Engineering Society, Bioenterprise, Nortech, and Baldwin Wallace University's Center for Innovation and Growth. An additional document was published in the February 2012 issue of NASA *Tech Briefs* magazine to attract other potential knowledge sources. And we created an ExMC brochure for wide dissemination at conferences, to organizations with potential interest, and on technology web sites throughout the Midwest region, including the Autoharvest site, an automotive industry foundation based in Detroit. As a result, we received many valuable contacts.

We made additional contacts in person or via teleconferences with many more organizations, including the Cleveland Clinic Foundation, University Hospitals, Case Western Reserve University, University of Akron, Ohio State University, Procter & Gamble, United States Air Force School of Aerospace Medicine, Battelle Memorial Institute, University of Cincinnati, Northwestern University, Carnegie Mellon University, Cleveland Bioenterprise, Baldwin-Wallace University's Center for Innovation and Growth, the Mayo Clinic, National Institutes of Health, U.S. Food and Drug Administration, the Research Institute of Chicago, the Wright Brothers Institute, and others.

That extensive list seemed promising, but we made little progress with our industry associates since the commercial appeal of this work is limited. We found, however, that universities are clamoring for meaningful senior engineering projects that require minimal funding. In addition, the turnaround time of student projects is relatively short; they begin in the fall semester, and results are presented to Glenn in May at the close of the school year. Most universities categorize these senior projects as "capstones"—student assignments often performed as a team effort and culminating in final reports that are a curriculum requirement for graduation.

We contacted regional universities based on geographic location and areas of specialization, with Glenn covering the Midwest. Our focus centered on universities that have a biomedical or biomechanical engineering department. I worked with either a department head or capstone advisory group at each university to develop the project, visiting Ohio State University, University of Michigan, University of Akron, and Wright State University to explain HRP and ExMC goals. The ExMC gap list was circulated among the appropriate faculty to determine a proper fit. Two or three potential topics were agreed upon, and then department advisors asked student teams to indicate their areas of interest. Given the demand for capstone work at multiple universities and the limited availability of funding and mentors, the program typically supports one project per university per school year.

WE FOUND … THAT UNIVERSITIES ARE CLAMORING FOR MEANINGFUL SENIOR ENGINEERING PROJECTS THAT REQUIRE MINIMAL FUNDING. IN ADDITION, THE TURNAROUND TIME OF STUDENT PROJECTS IS RELATIVELY SHORT; THEY BEGIN IN THE FALL SEMESTER, AND RESULTS ARE PRESENTED TO GLENN IN MAY AT THE CLOSE OF THE SCHOOL YEAR.

At the close of their senior year, student teams present their findings. The university team provides Glenn with a final report that gives ExMC a valuable start on gap closure. This successful outreach activity also provides a meaningful experience for Glenn employees to act as a mentor or gap manager.

Aaron Weaver, of Glenn's Bioscience and Technology Branch, commented, "During the mentoring experience, I felt it important for the students to guide their own development. They were not just responsible for developing the product; they

Photo Credit: NASA

Crews on long-duration missions beyond low-Earth orbit will need medical capabilities to diagnose and treat disease as well as to maintain health.

THE UNIVERSITY STUDENT-CAPSTONE PROJECTS HAVE THE POTENTIAL TO BE EXPANDED TO ASSIST OTHER CORE COMPETENCY AREAS AT GLENN RESEARCH CENTER. THE OBVIOUS BENEFITS TO THE AGENCY ARE LOW COST, RELATIVELY QUICK RESULTS IN THE FORM OF A FINAL REPORT, AND A FRESH PERSPECTIVE ON A SERIOUS TECHNICAL CHALLENGE.

were responsible for the development of the requirements, how the requirements would be verified, product development, and testing. This gave the students a feel for the entire design process and led to a great learning experience and final product."

The capstones provide an inexpensive mechanism to obtain first-rate research results. According to ExMC Project Manager DeVon Griffin, "The Exploration Medical Capabilities element originally conceived of capstones more as an education/outreach activity. Given the high-quality work produced by teams mentored by GRC [Glenn], the element is now working to provide targeted research options and archiving all results. This activity has become a key part of the element's technical work." Dr. Griffin mentored both of the University of Akron teams in 2012.

NASA Glenn's Human Research Program/ExMC project sponsored three student-capstone projects that were completed in 2012, including bone stabilization in microgravity and three-phase medical suction, filtration, and containment designed for a microgravity environment, both carried out at the University of Akron; and a wrist-fracture stabilization device for microgravity at the University of Michigan, mentored by Dr. Weaver.

The goal of the University of Akron team was to develop solutions addressing the agency need for a medical suction device for use in a microgravity environment. They built a proof-of-concept device that met the requirements of their lab-testing protocol. While the students were not able to conduct microgravity testing, they did conduct extensive computational-fluid-dynamics simulations to verify performance. Additionally, they conducted 1 g testing for validation in a gravitational field.

The goal of the University of Michigan team was to create a device that would immobilize the wrist, protect a fracture from external perturbations, maintain hand function for daily work, and have low mass and volume. At the close of the semester, the students determined the device was on track to be validated and that it functioned as designed. Rachael Schmedlen, student advisor for biomedical engineering at the University of Michigan, noted, "This is the first opportunity students have had to work with a real client and design, build, and test a prototype that aims to solve a need. They receive an appreciation for the practical challenges with the development of a new device."

Six additional student-capstone projects have been carried out in 2013, including diagnosing and treating radiation sickness, University of Akron, mentored by Debra Goodenow-Messman of the Diagnostics and Data Systems Branch; treatment of soft-tissue injuries during Exploration-class missions, University of Michigan, mentored by Dr. Griffin of the ISS and Human Health Office; medical-suction fluid containment for microgravity and partial-gravity environments, Northwestern University, mentored by John McQuillen of the Fluid Physics and Transport Branch; medical device sterilization, Ohio State University, mentored by Lauren Best of the Bioscience and Technology Branch; eyewash in microgravity, Wright State University, mentored by McQuillen; and medical suction in microgravity, University of Illinois–Chicago. (This last capstone uses a NASA topic but has no NASA oversight or financial support.) The cost associated with the ExMC capstone projects ranges from $0 to $2,000 per project, with funding provided by HRP.

Mark Ruegsegger is assistant professor of practice in the biomedical engineering department at Ohio State University. He remarked, "This has been a very rewarding experience for the students. They have been able to work on an open-ended, real-world problem that has application beyond medicine in space. The team has also gained valuable skills in working with NASA professionals as project consultants."

The university student-capstone projects have the potential to be expanded to assist other core competency areas at Glenn Research Center. The obvious benefits to the agency are low cost, relatively quick results in the form of a final report, and a fresh perspective on a serious technical challenge. ●

LAURIE STAUBER is currently the Bioscience Collaboration and Partnership lead at Glenn Research Center and is responsible for business development focused on biomedical work with external partners. She is also the Exploration Medical Capabilities Tech Watch agent for the Human Research Program, formulating university capstone projects to solve long-term astronaut health issues.

ONE PERSON'S MENTORING EXPERIENCE

BY NATALIE HENRICH

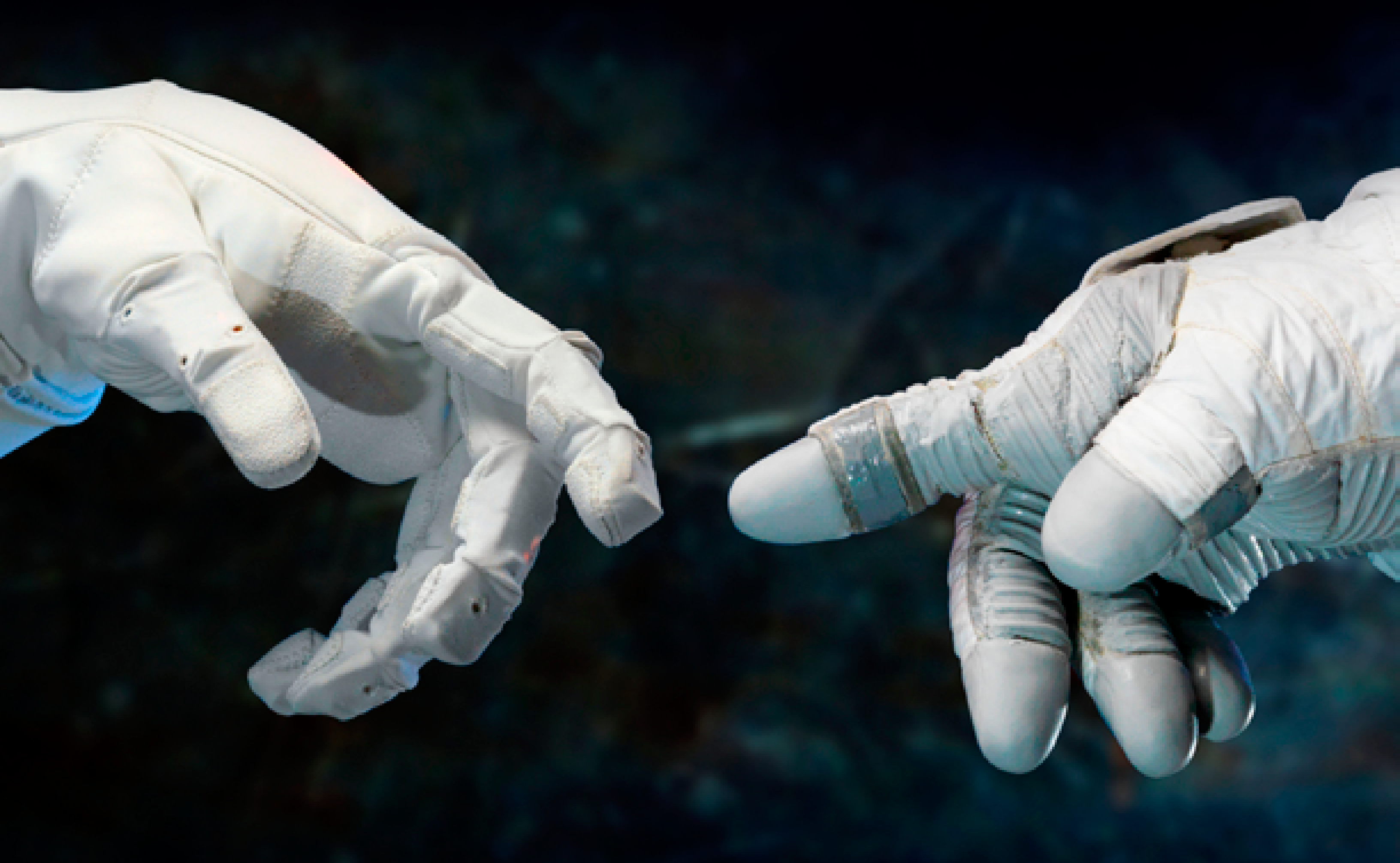
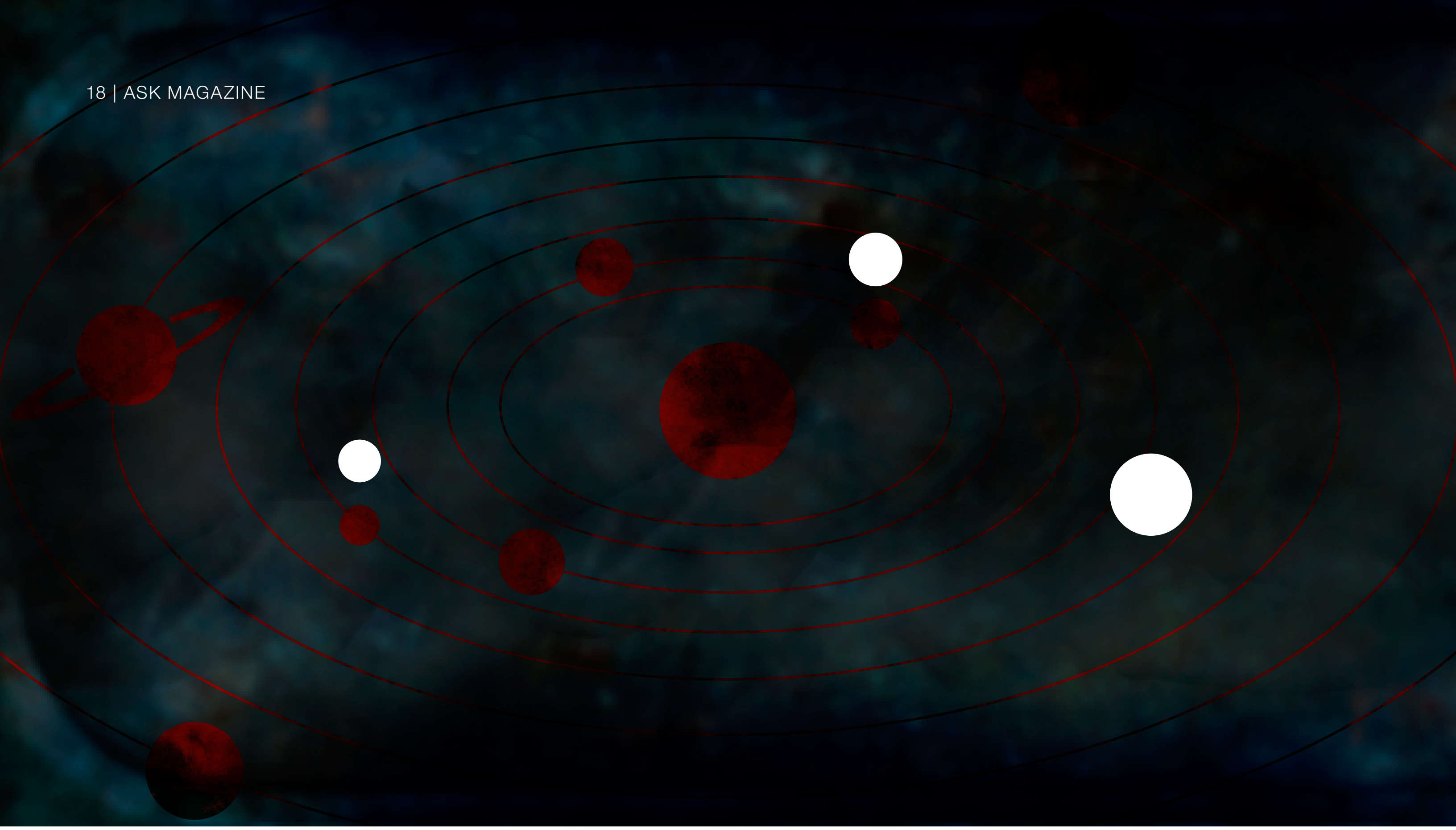


Photo Credit: NASA

Robonaut and a spacesuit-gloved hand are extended toward each other to show collaboration.



Calling all mentees and mentors for ACES class of 2012–2013.

That was the headline that grabbed my attention and ultimately led to my participation in a formal mentoring program. ACES is an acronym for Advancing Careers and Employee Success. The agency-supported program is designed to help employees achieve their potential, to help NASA meet the challenges of a changing workforce, and to contribute to making NASA a strong learning organization. The headline attracted my attention because I had been looking for a way to gain a greater understanding of NASA as a whole and reach beyond the circle of my day-to-day working network. When I think about where I want to be in five or ten years, I am not sure I still want to be in my current role. I thought a mentoring experience would be a good first step in exploring other areas of interest.

Step One. Apply. This was a simple process of completing an application and getting supervisory approval to participate in the yearlong program.

Step Two. Mentor Match. That was not as straightforward as step one. There were two options: (1) specifically request a mentor or (2) opt for being matched with someone within a pool of available mentors. Not sure which option would be best, I focused on my goals. I wanted my mentor to have experience-based NASA knowledge in a field that aligned more specifically with my academic background in communication and knowledge management. I wanted someone who had an interesting job, who would readily tell stories about the work, and who would be willing to expose me to his professional world and network.

That was when I remembered the "From the Academy Director" articles from *ASK Magazine* by Edward Hoffman, NASA chief knowledge officer (CKO) and former director of the Academy of Program/Project and Engineering Leadership (APPEL). I remember being drawn in by the headings: "I Would Prefer Not," "Saturdays with Sinatra," "Don't Trust Anyone Under Thirty," "And the Band Played On." In these brief essays, Ed communicates a pointed lesson while underscoring the important work of NASA … all within a few paragraphs. I remember repeatedly shaking my head in agreement as I read them.

I thought, "Ed meets all my 'would likes' in a mentor. He has significant experience-based NASA knowledge. He is a gifted storyteller. He has an interesting job that is outside my functional area and professional network." I realized having Ed agree to be my mentor would be a big reach. He was the CKO of NASA. At the time, he was also the director of APPEL. He worked at NASA Headquarters in Washington, D.C. I worked at Glenn Research Center in Cleveland, Ohio, as the Scientific and Technical Information manager in the Logistics and Technical Information Division. Maybe even more of an obstacle, Ed had never heard of me and was not listed in the pool of available mentors. What made me think he would even consider mentoring me?

Photo Credit: NASA/William Hrybyk

Ed Hoffman talks about his transition into the role of NASA chief knowledge officer.

THE MENTORING AGREEMENT CLARIFIED THE GOALS FOR LEARNING, DETERMINED THE STRUCTURE FOR MEETINGS, AND ESTABLISHED NORMS FOR THE PARTNERSHIP.

The first thing I did was comb through the application materials to see if the fine print required a mentee and mentor to be located at the same center. I could not find any such requirement. I did find a line that read, "If you need more information, please contact the program manager." When I asked her if a mentee could be matched with a mentor located at a different center, she responded, "Who do you have in mind?"

I replied with hesitation and a wince, "Dr. Edward Hoffman at Headquarters."

To my surprise she did not scoff or chuckle, but replied, "I have known Ed for over twenty years. I will give him a call and let you know." The rest, so to speak, is history. I sent Ed an e-mail describing myself and why I requested him as a mentor. He graciously agreed to the match without so much as a prescreening phone interview.

I later asked him why he was willing to become my mentor. His answer: "You seemed genuine in your interest, smart about the work, and passionate about your motivations. That is an unbeatable combination, so I felt it was important to support you in your growth and journey."

Step Three. Partnership Defined. The program kicked off with an orientation session. New mentees were joined by experienced mentors to meet and network—think "speed dating," but in this case, it was "speed mentoring" to define the roles and responsibilities of both mentors and mentees and outline the organization of the program. My mentoring partnership officially began during a half-day mentoring workshop. Ed traveled to Glenn from Headquarters to participate and to meet me for the first time in person. In one of the first e-mails I received from Ed, he wrote, "There are many things going on across the agency in terms of knowledge, so I will look to give you the opportunity to take part. I'll start making a list of areas of potential interest for you and importance to NASA."

Our formal action plan identified agreed-upon developmental experiences that would be of the greatest benefit to me. The mentoring agreement clarified the goals for learning, determined the structure for meetings, and established norms for the partnership. The program also specified individual assessments and evaluations at various checkpoints to allow for proactive adjustments, if needed. These tools not only provided a road map for keeping the mentee–mentor partnership on track, they also defined expectations for both of us.

Step Four. The Experience. Ed introduced me to individuals in his professional network, included me in agency knowledge working groups and activities, invited me to the annual NASA Knowledge Community Forum at Kennedy Space Center, and introduced me to knowledge management scholars. He provided me not only with a peek through the window of his professional world, but also access to people and projects that I would have not otherwise been exposed to or known about. For example, in an e-mail sent to some of his colleagues, he wrote, "I want to introduce you to Natalie Henrich, who I am mentoring. Natalie is from Glenn and works Scientific and Technical Information activities, among other assignments. She will be involved in our knowledge work and I want you to know her."

When I was asked to write this article for *ASK Magazine*, the editors urged me to be honest and paint an accurate picture of my mentoring experience, including Ed's accessibility (or lack thereof). At that moment, I remember thinking that people enter mentoring relationships for different reasons. Some may want to gain experience outside their immediate working groups; senior professionals close to retirement may pair with junior employees to pass on knowledge; some may want to learn particular new skills from experts with unique expertise. There are many reasons to seek out a mentoring partnership. In my case, I wanted to hear the stories of an experienced NASA employee and be exposed to a new field. My goal was to watch

Knowledge Forum participants draw out their knowledge networks.

and learn. In truth, my expectations were in check from the moment I requested Ed as a mentor.

I knew we were geographically separated, so weekly meetings or casual run-ins would not be part of the experience. I figured he was extremely busy and likely traveled a great deal, so there would probably be times when he would not be immediately available. All that was okay with me. In reality, I found Ed to be accessible via phone and e-mail. He shared great stories with me about his experiences at NASA over the years. He not only allowed me to "watch and learn," but encouraged me to "ask and participate." On more than one occasion, he prompted me to ask questions and let him know if I wanted to participate in an activity he was involved with or working on. My expectations were not only met, but exceeded.

Step Five. Lesson Learned. From this mentoring experience, I learned to "reach for it." NASA is a place where "reaching for it" happens on a daily basis, whether it is reaching to launch a vehicle into space, land a rover on Mars, or become one of the best places to work in the federal government. My "reach" was to connect with Ed Hoffman and do all I could to listen and learn. Ed supported my reach and strengthened it by inviting me into his professional network, encouraging me to participate, and making time to be accessible to answer questions and offer suggestions for navigating the organization.

Step Six. Thanks. I would like to thank Ed for mentoring me this past year; my supervisors, Richard Flaisig and Seth Harbaugh, for supporting my participation in the program; and NASA for supporting employees with professional growth and learning opportunities. Mentoring programs like this one make me optimistic that NASA will continue to develop knowledge, which leads to innovations that help the agency realize its vision: To reach for new heights and reveal the unknown, so that what we do and learn will benefit all humankind. ●

FROM THIS MENTORING EXPERIENCE, I LEARNED TO "REACH FOR IT." NASA IS A PLACE WHERE "REACHING FOR IT" HAPPENS ON A DAILY BASIS, WHETHER IT IS REACHING TO LAUNCH A VEHICLE INTO SPACE, LAND A ROVER ON MARS, OR BECOME ONE OF THE BEST PLACES TO WORK IN THE FEDERAL GOVERNMENT.

NATALIE HENRICH serves as the Scientific and Technical Information manager of the Logistics and Technical Information Division at Glenn Research Center. She earned her BA in communication from Denison University in Granville, Ohio; MA in communication and education from Columbia University; and MS in knowledge management from Kent State University in Kent, Ohio.

The Knowledge Management Journey

BY EDWARD W. ROGERS

On May 13, 2003, I reported to work at Goddard Space Flight Center as the center's "knowledge management architect." Looking back after ten years there, I will try to summarize why knowledge management was successfully adopted at Goddard. Of course, the process was not as neat and orderly as this retrospective analysis may suggest; it was more of a journey of discovery with a few basic guiding principles to help keep me on course.

NASA employees are busy working on complicated missions, so finding knowledge management strategies that fit within hectic schedules is key.

Photo Credit: NASA/Chris Gunn

Take Time to Understand What Fits the Organization

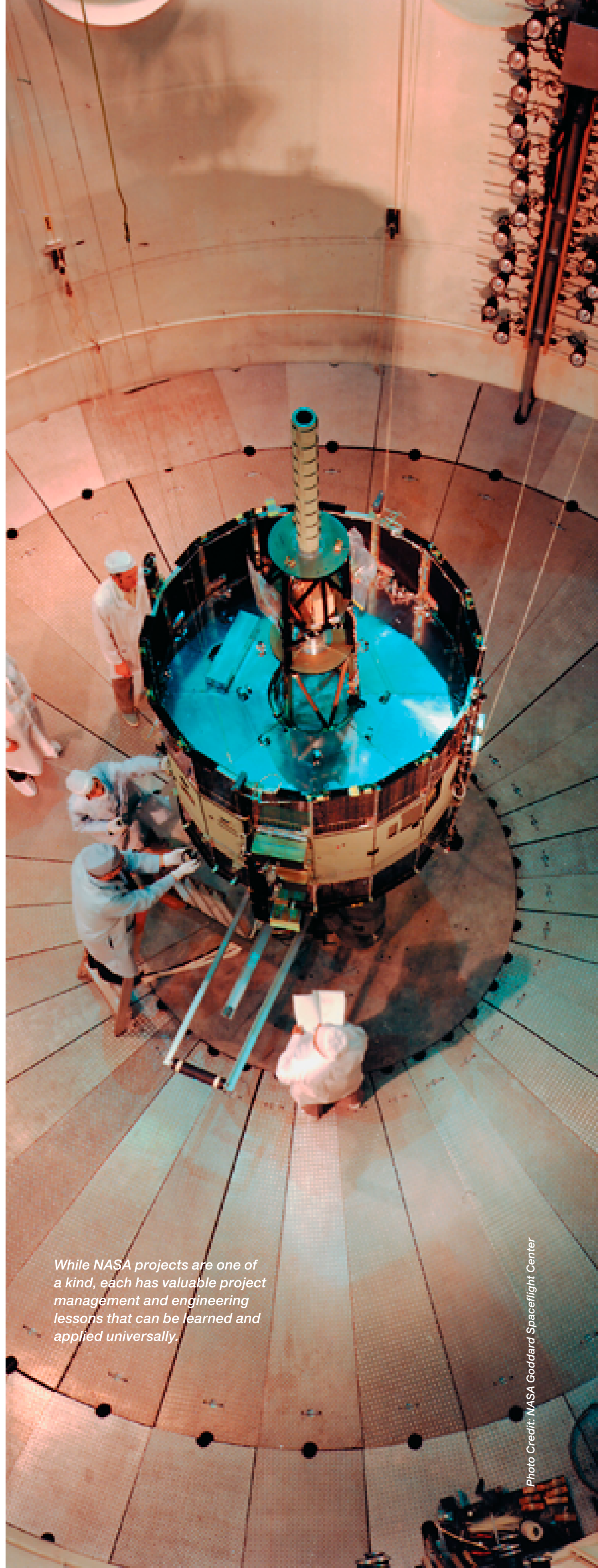
The first thing I realized was that knowledge management would come across as a fad or a waste of time to the competent and busy people at Goddard—more than three thousand government employees and six thousand contractors on site—unless what I did clearly met the organization's real needs and suited its way of working.

I began by thinking about what Goddard actually does repeatedly as a business. What we "produce" over and over again is not any particular mission but the assembly and execution of a project. Because each project team has a different assignment and a different mission, people tended to think, "We never do the same thing twice. Lessons don't apply since the mission is always unique." But what we do over and over is put together a team to accomplish a mission. So that suggested what the knowledge management focus should be. Many of the lessons we should be learning had to do with how we manage those teams as much or more than the technology or design of a specific mission. To be useful, knowledge management would have to address issues of how we manage our projects, not just pass along test and failure data at the technical level.

One fact of working life was immediately clear: Smart people make rational decisions about how they spend their time. They rarely see value in management meetings and events designed to extract knowledge from them. On the other hand, they see high value in the exchange of knowledge among peers. The critical difference is whether individuals leave the meeting knowing more than when they came. I knew I would have to design knowledge sharing and learning sessions as "exchanges" and not knowledge-extraction activities.

I modified the After Action Review (AAR) concept used by the U.S. Army into a NASA process we called Pause and Learn (PaL). Most NASA projects last years; some go on for a decade or more. An AAR at the end of a long project would be almost meaningless with respect to design decisions made years earlier by people who may have left months or years before. So I introduced the idea of pausing during development at appropriate points to reflect on what has been learned so far. I called it Pause and Learn to make it unique to NASA and to distinguish it from an AAR. It focuses on group reflection and learning that will be valuable for the participants first and foremost. Participants are encouraged to share their perceptions of what happened and process the insights together. Because the PaL is local and real, it is seen as valuable. After PaL sessions, participants often comment that this was a lessons-learned activity from which they actually learned something.

Building on the PaL success, I focused on two other learning activities at Goddard. I set out to write case studies to help people think about the project and management aspects of



While NASA projects are one of a kind, each has valuable project management and engineering lessons that can be learned and applied universally.

Photo Credit: NASA Goddard Spaceflight Center

Taking time to share knowledge in the moment, such as with Pause and Learn sessions, provides an opportunity to learn and apply lessons before a project ends.

our missions in addition to the technical lessons. I also started holding interactive discussion sessions often using these case studies to engage people in learning from prior missions.

Use Terms That Have Meaning for People

Rather than talk up the value of knowledge management to a skeptical audience, I used words the technical workforce understood and cared about, things like "cost," "schedule," "reliability," and "decision making."

I argued, for instance, that knowledge had to be better organized and shared at the working level so Goddard could assemble teams more reliably. The hook I used to explain this was asking whether it was important which engineer was assigned to a project. Many project managers were quick to admit they spent much time trying to get the "A team" of engineers onto their project. I had my opening. If the engineering branch as a group shared and organized their knowledge effectively, then it would matter less which engineer was assigned, because any engineer would bring the network of knowledge from the entire branch to the project.

Similarly, good decision making is a practice that all managers treasure. Using case studies, we focused on improving decision making, something managers could recognize as an immediate benefit to them and their team. Project managers who thought of their projects as unique could see that decision-making processes are similar across projects and they could learn from others. So we connected knowledge management to something considered a core cultural attribute at Goddard: the ability to make good decisions.

Brand Your Knowledge Activities

As the previous section suggests, what you call your knowledge activities and aims matters. While "knowledge management" didn't resonate with project teams, "reliability" did. The names of things should tell what they are about and what their value is to your specific organization. So, for instance, I coined the term Pause and Learn to describe exactly what those sessions were for and to indicate that they were designed specifically for Goddard—not just imported from other organizations.

Start with Small Steps and Use What's Already There

The PaL sessions and case-study-based workshops I've described were relatively small-scale and opportunistic knowledge activities. Based in particular projects and designed to create immediate benefits to participants, they justify themselves with clear practical results and encourage others to take part in similar activities. These relatively modest initiatives are much more likely to demonstrate their value and win converts than big systems that take months or years to set in motion and seem to promise big improvements at some unspecified future date. One of the many pitfalls of those large-scale efforts is they demand time and effort from participants long before they give any value in return. And the fact that they have large, general goals means they are much less likely to ever produce useful results than more focused modest efforts.

Other people at Goddard were already playing around with wikis and collaboration tools. The action I took was to not shut things down or assume a command and centralize approach, except in areas of IT commodities such as search capability. The more local efforts the better, and the more grassroots sharing and learning the better. Whenever possible, I encouraged and showcased good things others were doing. In the government, there is often an assumption that things need to be hidden or cost-cutting managers will whack whatever is not part of their own agenda. Clearly, that kind of approach would not work for knowledge management, which is supposed to be about sharing and openness.

Create Demand and Encourage Knowledge Management Converts and Evangelists

Participants in successful knowledge activities who tell their peers how those events helped make their projects successful are your greatest allies—their stories will do more to promote your knowledge management work than any arguments, presentations, and advertising you offer. Encouraging others to "sell" knowledge management for you helps make up for the fact that a chief knowledge officer only has so many hours in the day and can't do it all alone.

On a similar note, the best way to ensure that valuable knowledge management activities become a robust and persistent part of how your organization does business is to "reproduce" yourself. Start investing in people who can take over significant parts of what you do as early as possible. You don't want to be the sole source on knowledge management energy and therefore a single point of failure.

… RELATIVELY MODEST INITIATIVES ARE MUCH MORE LIKELY TO DEMONSTRATE THEIR VALUE AND WIN CONVERTS THAN BIG SYSTEMS THAT TAKE MONTHS OR YEARS TO SET IN MOTION AND PROMISE BIG IMPROVEMENTS AT SOME UNSPECIFIED FUTURE DATE.

Ten Myths About Knowledge Management

These positive lessons about making knowledge management work suggest why some of the commonly held beliefs about knowledge management *don't* work. Here is my top-ten list of false assumptions about knowledge management. Think about them as recipes for failure that should be avoided.

10. Culture can be mandated from the top.
9. Collaboration can be "purchased" or sharing can be rewarded.
8. Knowledge management can be outsourced.
7. Anybody (who isn't busy) can do knowledge management.
6. Knowledge management can be done by buying the right software.
5. Knowledge management can be independent of the business process.
4. Communities of practice can be established by the top.
3. Knowledge management is about centralizing knowledge content to use it more efficiently.
2. Knowledge management is really about databases.
1. Knowledge management is an IT function and should be given to the chief information officer.

As simple as these errors are, they are repeated over and over by people who hope that those failed approaches will work this time. If anybody ought to learn these lessons, it should be the people whose job is sharing lessons learned, but that is sadly often not the case. A main source of these repeat failures is the assumption that myth number seven doesn't apply. Over the years, I have met dozens of knowledge management managers in various government agencies with no relevant experience who were assigned to "go do knowledge management" and given budgets to do it. One scientist-turned-knowledge-management-expert told me she had a $2 million budget and no idea what knowledge management was but was eager to find out. Another told me confidently, "I've got knowledge management all figured out. It's just a matter of getting the right software systems in place." Ten million dollars and five years later, this same person told a public meeting, "We now know that knowledge management is 80 percent people and only 20 percent software"—which he could and should have known at the outset. This is an expensive way to educate government leaders.

The Knowledge Management Journey

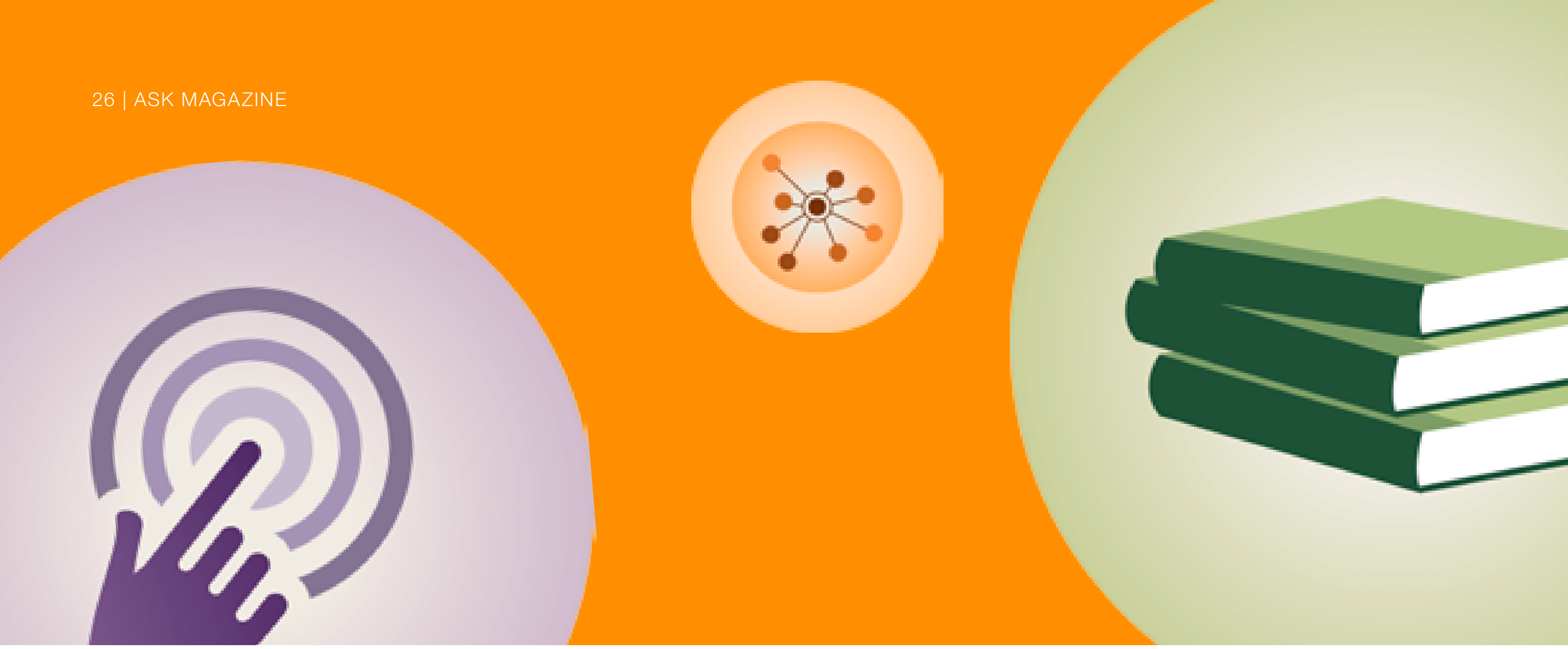
At the outset, I described my ten years at Goddard as a journey of discovery. Some might say I haven't accomplished much by their metrics. I am the first to admit I haven't accomplished all I wanted to do. When people go on a journey they often notice different things. It depends what you're looking for. What I'm looking for and what I see is NASA as a vibrant, dynamic, pulsating organization—almost a living organism that needs to stay healthy. Knowledge management is an ongoing effort. When you join a gym, it's not buying a membership that gets you in shape—you actually have to go there to work out and keep doing it. I set out to create exercises that would help Goddard be a stronger and healthier knowledge organization over time. I feel confident that those exercises are paying off and improving Goddard's knowledge fitness. ●

EDWARD W. ROGERS is the chief knowledge officer at Goddard Space Flight Center. He joined NASA in May 2003 as the center's chief knowledge architect, working first in the Safety and Mission Assurance Directorate and then in the Office of Mission Success. He became the chief knowledge officer in 2006 and subsequently moved to work for the center director.

Creating NASA's Knowledge Map

BY MATTHEW KOHUT AND HALEY STEPHENSON

Need to understand something about engine cutoff sensors, the physiological impact of extended stays in low-Earth orbit, or how to drive a rover on Mars? That kind of specialized expertise exists at NASA, and often nowhere else. But where does that unique know-how live? How and where is it captured and shared? NASA's interactive knowledge map serves as a springboard for helping practitioners find what they don't know and share what they do.



To paraphrase science-fiction writer William Gibson, NASA's knowledge is not evenly distributed. Sometimes the people who know something and the people who need to know it don't connect. NASA's missions continue to increase in complexity, teams become more distributed, and technology advances. At the same time, Apollo and shuttle generations are disappearing. All these factors make knowledge-sharing connections critical to organizational success.

THE KNOWLEDGE COMMUNITY DECIDED TO DEVELOP A COMPREHENSIVE INDEX OF THE SERVICES AVAILABLE ACROSS THE AGENCY.

While learning from its successes and failures is at the core of NASA's work, its track record for doing so is also unevenly distributed; the agency has done better in some instances than others.

Developing a more consistent knowledge capability across the agency was part of what motivated the Aerospace Safety Advisory Panel, a Congressionally established advisory group, to recommend that NASA "establish a single focal point (a chief knowledge officer) within the agency to develop the policy and requirements necessary to integrate knowledge capture across programs, projects, and centers."

In response, newly appointed NASA Chief Knowledge Officer Ed Hoffman convened the first meeting of NASA's knowledge community—individuals identified by center directors and mission directorate associate administrators as chief knowledge officers or points of contact—in January 2012. Their discussions revealed an abundance of knowledge work happening across NASA's centers, mission directorates, and cross-agency organizations: forums, lunches, case studies, databases, online expert-locator systems, and more. Some activities were well established and well known, while others were just getting started.

This big picture was an eye-opener. The knowledge community decided to develop a comprehensive index of the services available across the agency. And so began their initiative to create an interactive map—a knowledge map—that made NASA's knowledge services findable to all.

It Started with a Spreadsheet

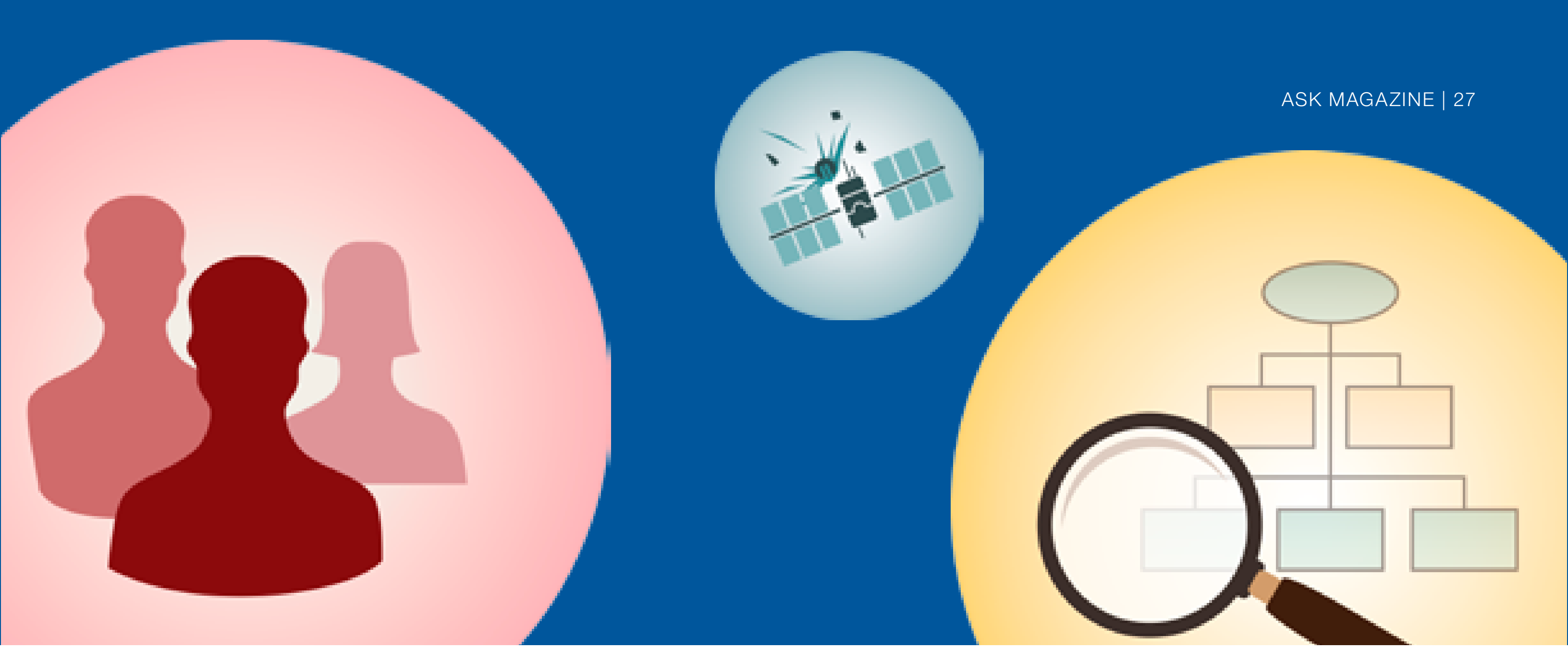
After the inaugural meeting, Mike Lipka, the knowledge point of contact for NASA's Safety Center, took the initiative to document the services community members had described at the initial meeting. He organized what he'd captured in a simple matrix that paired each NASA organization with the knowledge services provided, using an ad hoc taxonomy to categorize those services by type (for example, online portals versus publications).

Lipka's initial exercise laid the groundwork for a more systematic data-gathering effort to create a dynamic, online tool for visualizing and engaging with NASA's knowledge resources and services.

Each knowledge organization subsequently participated in in-depth interviews about the work within their organizations over the next several months. The resulting data set was impressive and large. The community needed a structured way to communicate about the great work going on across the agency.

A Vocabulary for Knowledge at NASA

Unsurprisingly, the knowledge services described by the chief knowledge officers and knowledge points of contact in their interviews took many forms. Some activities were "self-service,"



such as typing a query into a search box or watching a video. These services work well for explicit knowledge that doesn't require a lot of context or personal judgment. For instance, the fundamentals of earned value management can be codified, broken down, and expressed as a series of concepts without requiring a world-class subject-matter expert.

At the other end of the spectrum, some activities emphasized tacit knowledge, which is dependent on context and personal judgment. This kind of sharing usually requires social interaction. A master practitioner's knowledge about how to interpret ambiguous test data or make a go or no-go launch decision cannot be transferred through a Google search. Though technology can helpfully extend the reach of a personal story, it doesn't provide the full experience of face-to-face communication or hands-on learning.

The community agreed upon a set of categories to describe the range of knowledge activities taking place across NASA.

Online Tools. Any online knowledge tools, including but not limited to portals, document repositories, collaboration and sharing sites, and video libraries.

Search/Tag/Taxonomy Tools. Dedicated search engine for knowledge (e.g., Google Search Appliance) and any initiatives related to meta-tagging or taxonomy.

Case Studies/Publications. Original documents or multimedia case studies that capture project stories and associated lessons learned or best practices.

Lessons Learned/Knowledge Processes. Any defined process that an organization uses to identify or capture knowledge, lessons learned, or best practices, including the Lessons Learned Information System vetting process, organization-specific lessons-learned processes, benchmarking, use cases, knowledge-sharing recognition programs, knowledge product validation processes, and communications about expectations related to knowledge sharing.

Knowledge Networks. Any defined knowledge network, such as a community of practice, expert locator, mass collaboration activity, or workspace specifically designed to enable exchanges and collaboration.

Social Exchanges. Any activities that bring people together in person to share knowledge (e.g., forums, workshops, Lunch and Learn/Pause and Learn). The reach of these activities can be multiplied through online tools such as videos and virtual dialogues.

The categories are not the only ones that could have been created, and they are not a perfect fit for every knowledge activity at NASA, but they provide a means for making useful distinctions among different activities. The knowledge community decided to adopt these categories in January 2013, agreeing that this terminology could be improved in the future.

This vocabulary provided the knowledge community with a foundation for talking about their services, tools, and activities with each other, the practitioners they serve, and the agency's stakeholders. For instance, online tools such as the Jet Propulsion Laboratory's *Wired* wiki or Marshall Space Flight Center's ExplorNet satisfy different knowledge needs than the lessons learned and knowledge processes at Goddard Space Flight Center or the Human Exploration Operations Mission Directorate. The community wanted to do more than just talk about these services, however—they wanted to see them.

Visualizing Knowledge at NASA

Seeing is believing, and visualizing a knowledge landscape can promote increased sharing.

The data the knowledge community aggregated serves as a starting point: what is happening, who is doing it, and how can others access it? The community recognized that their data would change and grow over time. Creating a visualization that could accommodate that evolution meant thinking beyond

THIS INTERACTIVITY WOULD ALLOW USERS TO BROWSE THE COMMUNITY'S DATA SET AS IT CURRENTLY EXISTED—BY KNOWLEDGE CATEGORY, CENTER OR ORGANIZATION, AND KNOWLEDGE POINT OF CONTACT—AND AS IT COULD EXIST IN THE FUTURE—BY DISCIPLINE, TOPIC, ACCESSIBILITY, OR ANY OTHER VARIABLE.

what the word "map" usually brings to mind: subways, floor plans, theme parks, and possible buried treasure.

Instead, the map needed to be a kind of Rubik's cube, allowing the data to be sliced in multiple ways as the data set became richer and larger. This interactivity would allow users to browse the community's data set as it currently existed—by knowledge category, center or organization, and knowledge point of contact—and as it could exist in the future—by discipline, topic, accessibility, or any other variable.

Just as the community wanted its data openly displayed on the map, it also wanted the map itself to be broadly accessible online. This meant the map needed to be "platform independent": it shouldn't matter if a user had an iPhone or an Android tablet. Their access to the data and experience with the map should be the same. To satisfy this requirement, the map development team decided to build the map using HTML5, a coding language that achieved the vision of making the map accessible across all platforms. If you have an Internet connection and a browser, you can browse the current map of NASA's knowledge services at km.nasa.gov/knowledge-map.

Where the Map Leads Next

The NASA knowledge map represents a step forward in NASA's evolution as a learning organization. It is the first online tool of its kind that aggregates the knowledge work happening across NASA, making it a springboard for NASA practitioners and stakeholders to access resources to find answers and solve problems.

It demonstrates a commitment and dedication to greater transparency about the knowledge services available across the agency. While some resources remain protected behind firewalls, the community has identified the services available within each organization and provided points of contact.

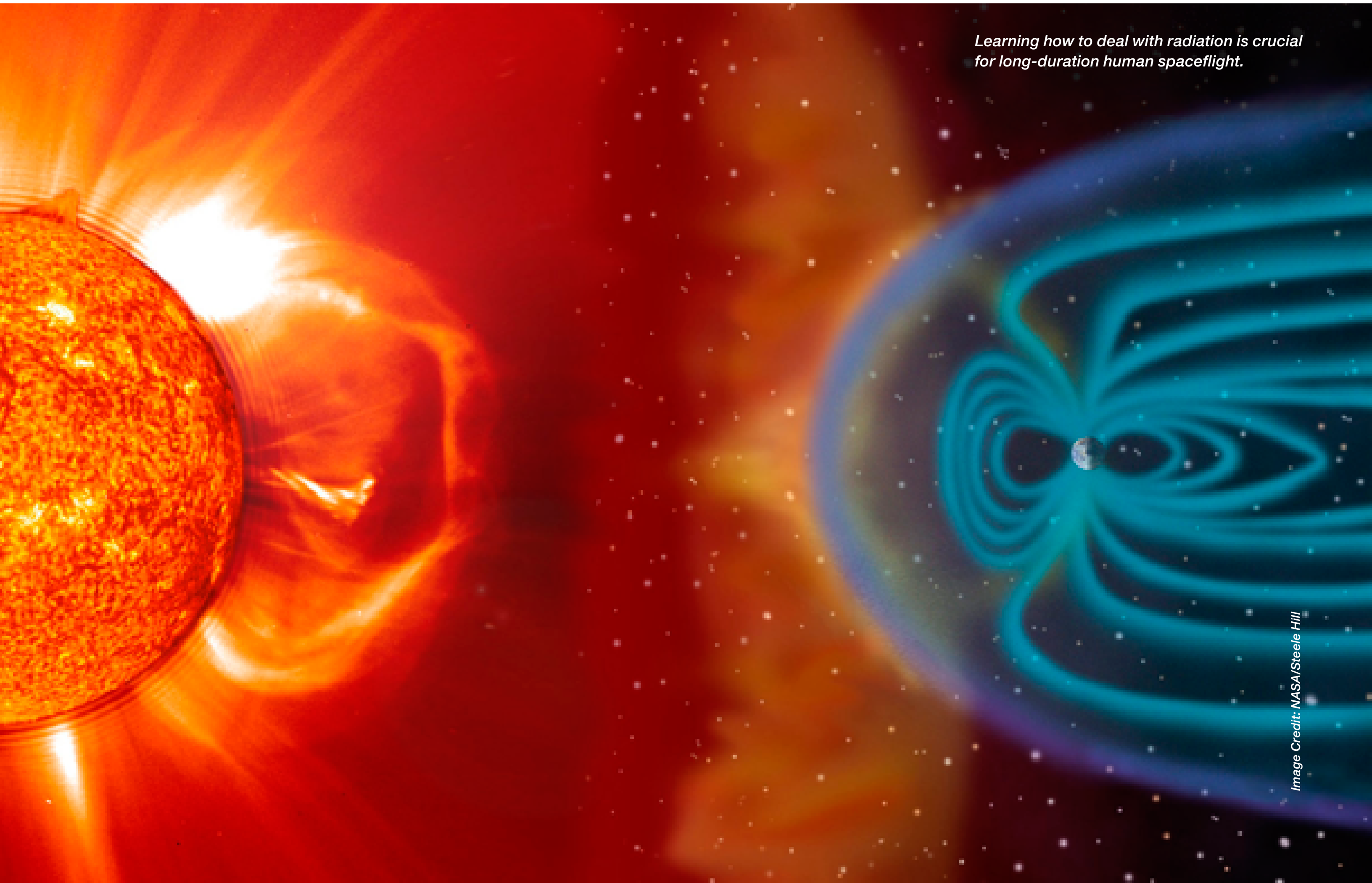
The map does not resolve the challenge of making knowledge universally accessible across organizational lines, but it is a step toward building more resilience into NASA's knowledge infrastructure. There's plenty left to do. Half the NASA workforce is eligible for retirement and could walk out the door with critical knowledge that has not yet been passed on to others. Young professionals at the other end of the career path have had fewer opportunities than previous generations at NASA to get hands-on experience.

In short, the 2013 NASA knowledge map is a beginning, not an ending. It will continue to grow as other organizations within NASA share their knowledge resources and as the knowledge needs of NASA practitioners evolve. ●

Lessons on Leadership: The Evolution of the Radiation Protection Project

BY KEITH L. WOODMAN AND DEBI TOMEK

Occasionally, you get the rare, pleasurable experience of watching a project flourish even when confronted with seemingly insurmountable challenges. The Radiation Protection Project started as a vague idea on how to address one of the largest inhibitors to maintaining long-duration human presence in space. This project survived multiple transitions, including having the work split between two organizations. In overcoming these odds, it has become an excellent example of how to formulate, stand up, and run a multicenter, mid-technology readiness level (TRL) project integrated across different organizations.



Learning how to deal with radiation is crucial for long-duration human spaceflight.

Image Credit: NASA/Steele Hill

TOMEK'S INSISTENCE THAT "EVERYONE HAVING A VOICE" NO MATTER THEIR ROLE OR CENTER AND THE TRUST GAINED FROM TEAM MEMBERS THROUGH HER INTEREST IN UNDERSTANDING IDEAS AND SOLUTIONS CREATED AN ATMOSPHERE OF TRANSPARENCY AND TEAMING THAT ENCOURAGED COLLABORATION INSTEAD OF COMPETITIVENESS BETWEEN CENTERS.

Lesson One: It Starts with the Right Leadership

In 2009, the Exploration Technology Development Program (ETDP) was considering Langley Research Center to lead a new project focused on the development of radiation-protection technologies for human space exploration. Looking at potential candidates to replace the lead of a different ETDP project, the program interviewed Debi Tomek.

During the course of this interview, it became obvious that Tomek possessed considerable leadership capabilities, including being able to multitask between concurrent projects and build agencywide teams. Though she was interviewing for a different position, she was a better fit for the Radiation Protection Project. The collective thought on Tomek after her interview was, "Here's someone who could build something out of nothing." The interviewing panel proposed starting the Radiation Protection Project a little early and putting Tomek as the lead instead of letting her slip away. The program agreed, and Tomek took the role as the Radiation Protection Project manager.

She had her work cut out for her from the start. The radiation community across the agency and academia is a diverse and disparate group with many different theories about how best to address space-radiation problems, such as solar-particle events and galactic cosmic rays. Tomek's background was not in radiation, but this turned out to be an asset as it brought her into the discussion with no preexisting opinions.

To build her understanding of the various issues and theories, Tomek put out a call for white papers across the agency to get a sense of what ongoing work was already out there, who the players were, and what role each center played. This not only provided great insight into the strong technical expertise within the agency but also shed light on the disparate nature of this community.

The complex nature of this technical discipline meant that there were widely varying opinions on how to approach and frame a new radiation project. In order to promote a more collaborative approach to this discipline, Tomek followed up this white-paper call with a workshop held at Langley where the white-paper authors could present in an open forum. During this workshop, Tomek opened the proceedings by telling the audience that, given the complexity of this technical problem, no one center could solve it alone. Centers would have to find a way to work collectively to enhance NASA's expertise.

This face-to-face meeting was critical. Those who wanted to participate in the project were able to make their cases. At the same time, Tomek and the other project leaders were given enough information to start making informed choices on which technologies needed to be funded in order to meet agency and programmatic goals. The collaborative "kick-start" this workshop produced was evident when Tomek was pulled aside during one of the breaks by a well-known scientist familiar with the usually argumentative radiation community. This scientist pointed out two individuals speaking at the back of the room. He said, "Those two scientists have refused to talk to one another for ten years, and now they are discussing how to collaborate!" While this was a great start for the new project, encouraging the cultural shift needed to promote collaboration, a huge problem was just over the horizon.

Lesson Two: Fight for What's Right

In 2010, the human exploration program decided to shut down ETDP and create the Exploration Technology Development and Demonstration (ETDD) Program, a completely new program under new management. During the formulation of ETDD, the human exploration program also decided that Radiation Protection would not be its own project but a technical element under the Life Support and Habitation (LS&H) project.

Many involved in the effort felt this was a major miscalculation. They knew that the enormity of the radiation-protection problems warranted a separate project. However, a new project could not be funded due to budgetary constraints, so the Radiation Protection Project transferred as a technical element under LS&H. This presented additional challenges in

Above Bear Lake, Alaska, the Northern Lights, or aurora borealis, are created by solar radiation entering the atmosphere at the magnetic poles.

trying to maintain the portfolio of radiation technologies that were under development within a project grouping that was not related to radiation protection.

The umbrella project was understandably very concerned about maintaining the full complement of their portfolio and having to share funding with the now embedded radiation work. Considerable negotiation, persuasion, and soft skills were required to restore project funding to its original levels. This involved conversations with individuals at centers and NASA Headquarters and "telling the story" of radiation protection: how driving toward a solution in support of long-duration human spaceflight involved focused funding and collaboration across the agency. The project could not afford to lose the ground that had been gained. Even with reduced funding at the inception, then delayed funding because of the budget environment, the project team still managed to hit all their milestones and embark upon building the foundation for radiation protection.

"THOSE TWO SCIENTISTS HAVE REFUSED TO TALK TO ONE ANOTHER FOR TEN YEARS, AND NOW THEY ARE DISCUSSING HOW TO COLLABORATE!"

Lesson Three: Work to Reach Concordance

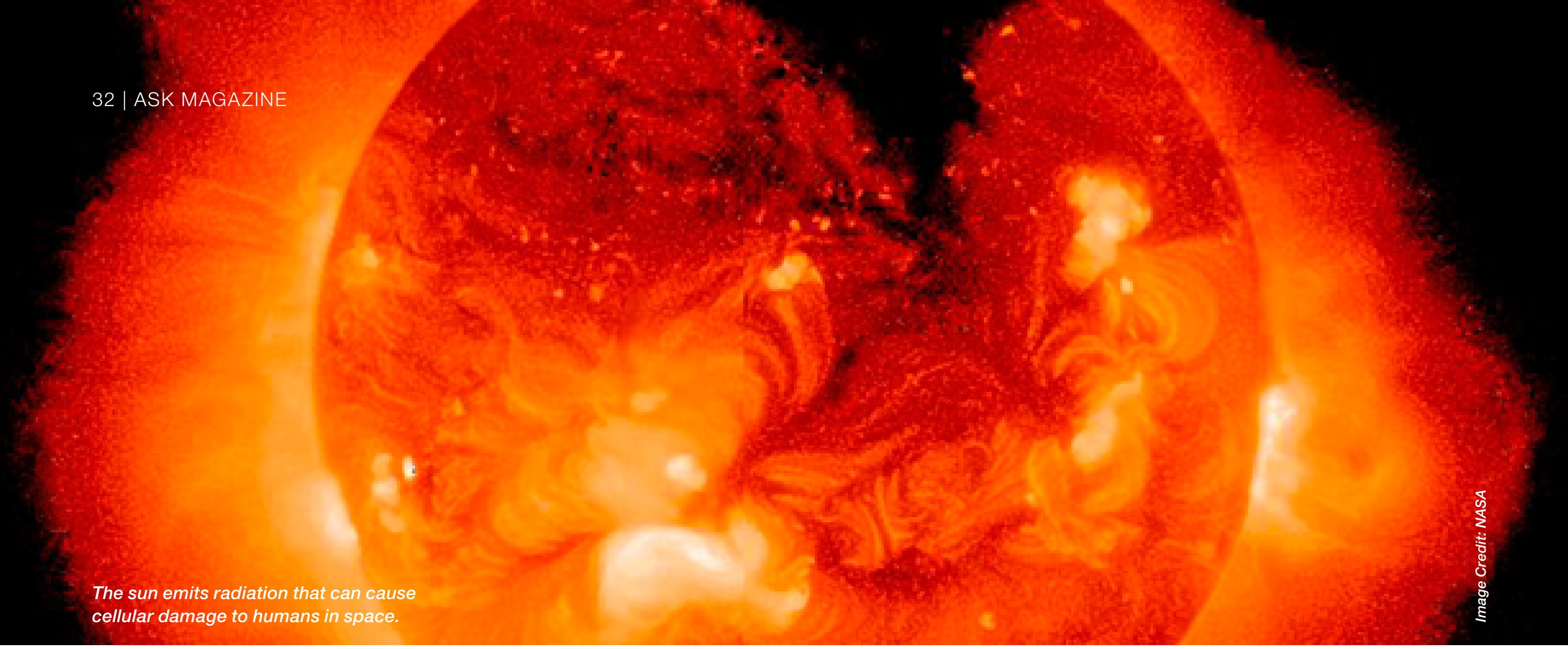
The radiation work was off to a great start, even considering the embedded nature of the work, but faced a new challenge. The Exploration Technology Development projects would again face transition, this time due to the replacement of ETDD with the Advanced Exploration Systems (AES) Program and the Space Technology Program (STP) Game Changing Office. Tomek had spent considerable time arguing the importance of a focused project addressing this vital technical area, and so programmatic AES managers pulled the radiation work out from under another project and stood Radiation Protection up as its own project.

At the same time, a portion of the existing portfolio was moved to the STP Game Changing Office as the Advanced Radiation Project (ARP). Tomek was selected as the project manager of this newly emergent project, but now the original ETDP project had been split between two different mission directorates.

Because of NASA programmatic and full-time employee constraints, the decision was made that the AES project would be led out of Johnson Space Center with Tomek as the deputy project manager. Johnson then selected a very experienced and talented project manager from the now canceled Constellation program, Bobbie Gail Swan, to serve as the project manager.

While switching the project from Langley to Johnson could have created tension within the team, both Swan and Tomek strove to maintain continuity and synergy within the existing team. Swan met with, talked to, and, most importantly, listened to Tomek and the team members who had been working on the project the previous two years. They discussed at great length the project's history and its way forward. These initial meetings helped the two leaders build a deep mutual understanding and respect. This concordance was evident to all team members during meetings, setting the tone of highly effective collaboration between centers. Team members saw the leaders exhibiting synergy and taking what could have been interpreted as a negative for the technical discipline into a positive. This, in turn, promoted a spirit of collaboration and freedom to share ideas among the whole team. The project now had two fine leaders who were working hand in hand.

During this same period, Tomek, as ARP project manager, was able to develop a portfolio of work within this sister project that was complementary to the work being done in the AES project. The thought was that as these STP radiation technologies matured, they could potentially be infused into the



The sun emits radiation that can cause cellular damage to humans in space.

Image Credit: NASA

AES project for further development and integration into flight vehicles and/or habitats. As project manager of the STP project and the deputy project manager of the AES project, Tomek was able to oversee a successful integration between the projects.

This good working relationship between the project managers seemed to permeate and influence the rest of the project. Langley's primary responsibility is the design and development of various types of protection shields for solar-particle events. This team includes various research scientists, systems and vehicle analysts, developmental engineers, technicians, and resource analysts. It was amazing how quickly this diverse group came together and started producing.

Tomek's insistence that "everyone having a voice" no matter their role or center and the trust gained from team members through her interest in understanding ideas and solutions created an atmosphere of transparency and teaming that encouraged collaboration instead of competitiveness between centers. Tomek encouraged the team to think beyond traditional methods of radiation protection. As a result, they have made great strides in furthering protection technologies. The project will soon fly its radiation dose-measurement technology (dosimetry technology) on EFT-1. It has already flown to the International Space Station for ongoing crew testing.

Lesson Four: Replace Good Leadership with Good Leadership

In 2012, Tomek was selected for NASA's Mid-Level Leader Program (MLLP). As part of this program, she was also selected to serve a detail to NASA Headquarters, working with Associate Administrator Robert Lightfoot, that has resulted in her using her strong leadership skills to assist in a restructuring of technical capabilities across the whole agency. Swan, Tomek, and Langley management decided that David Moore, who was the systems engineer for the shielding work, would replace Tomek as the Radwork's acting deputy manager and as the acting project manager for the Advanced Radiation Project. Although Moore's background and experiences were different from Tomek's, they shared a vision of the success of the radiation projects and what it would take to get there. The transition was seamless.

With Moore taking on these leadership roles, the projects continued to meet or exceed their programs' expectations with the development of new dosimetry and shielding technologies. Upon completion of the MLLP, Tomek was selected as technical advisor to Langley's Center Director's Office, so the position for the Radworks deputy manager and the Advanced Radiation Project manager was advertised. Moore competed and was selected. Now officially in the position, he is facing challenges because of budget cuts caused by the sequestration. As all good leaders do, he is adapting, rescoping, and focusing on mission success. ●

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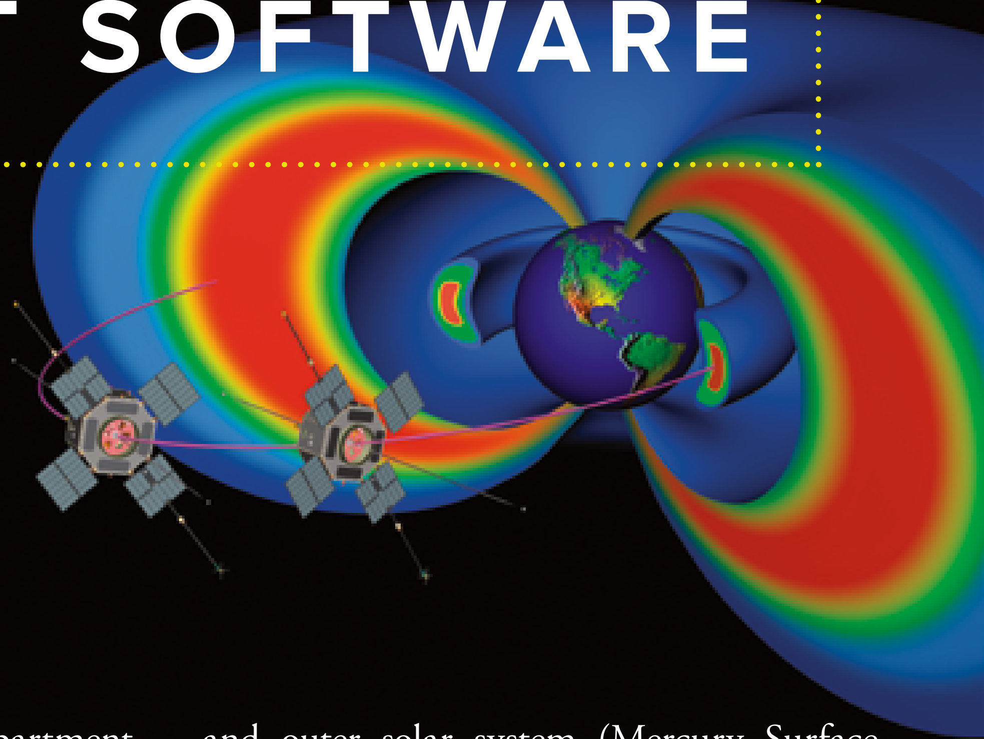
DEBI TOMEK is an aerospace engineer at Langley Research Center.

THE ROAD TO THE NEW FLIGHT SOFTWARE

BY CHRISTOPHER KRUPIARZ



In 2004, my group in the Space Department of the Johns Hopkins University Applied Physics Laboratory (JHU/APL) was presented with a critical opportunity and challenge. We had successfully developed and deployed spacecraft flight software on a number of NASA missions over the previous decade. They included the Advanced Composition Explorer, a spacecraft at a point of Earth–sun gravitational equilibrium almost a million miles from Earth; an Earth orbiter (Thermosphere, Ionosphere, Mesosphere Energetics, and Dynamics mission); the Near-Earth Asteroid Rendezvous spacecraft; the twin Solar Terrestrial Relations Observatory probes; and missions destined for the inner and outer solar system (Mercury Surface, Space Environment, Geochemistry, and Ranging spacecraft and New Horizons). Over the course of that decade, our flight software had become tightly coupled, with changes in one application affecting others. We were able to reuse the software during this time, but doing so depended on reusing the same avionics and the same personnel. When teams or hardware changed, the software was difficult to apply to new missions without substantial modification. It was clearly time to revamp our core architecture, but we wanted to do it in a way that preserved many of our existing applications while modernizing the overall structure.

Image Credit: NASA

Cutaway model of the Earth's Van Allen radiation belts with the two satellites from NASA's Van Allen Probes, the first mission to fly the new Applied Physics Laboratory flight-software architecture.

The Robotic Lunar Lander fires its onboard thrusters to carry it to a controlled landing using a pre-programmed descent profile. Guidance and control (G&C) development at the Applied Physics Laboratory is a collaborative effort between the flight-software group and the Marshall Space Flight Center G&C analysts' group.

Photo Credit: NASA Marshall Space Flight Center/David Higginbotham

Bruce Savadkin, my group supervisor at the time, recognized this need. Through proposals to the JHU/APL Internal Research and Development board, he successfully acquired funds to work toward this goal. Our first step was to identify software that would decouple our software architecture and allow individual applications to operate independently. This study led us to select an architecture developed by NASA Goddard Space Flight Center, called the Core Flight Executive (cFE).

Integrating the Core Flight Executive

CFE is a suite of software that provides multiple services to flight-software applications. A key to these services is a software communication bus, or transfer interface, that makes a modular, decoupled architecture possible. Instead of individual applications calling functions within other applications and creating intractable dependencies among them, cFE communication occurs via message passing. An application publishes messages and subscribes to messages on a software bus, providing a single input source to the application. With a well-defined message dictionary that various applications can understand, this provides a straightforward way to plug and play new applications into a system.

Once that middleware was selected, we began adapting our flight software to the cFE concept. Transitioning to a new architecture took a significant amount of rethinking. We had been working with our current architecture for years; we fully understood its idiosyncrasies, its advantages, and its limitations. The new architecture required a new way of thinking. Additionally, some in the group were reluctant to change. Their reluctance came with strong arguments, including, "We just launched a probe to Mercury. Why change a successful architecture?" and "Why not wipe the slate clean and rebuild from the bottom up?" (The answer to the first question was, "We need to improve our ability to reuse code to lower costs," and to the second, "Too expensive.") So our development process was not only technical. It included a necessary series of discussions to bring those who were reluctant to change onboard.

As the initial lead on the project, it was my responsibility to handle these questions and to find a way forward for the design. Leading a team on a research effort this large was a new experience for me. Unfortunately, I quickly learned lessons on how not to do it. Whereas my previous efforts with large teams had specific requirements and goals, this research effort was much more open ended; we had to answer the question, "What is good?" before we could build the software. So my usual project management method of trying to reach an agreement on small issues while we all agreed on the larger purpose immediately ran into trouble. Not surprisingly in hindsight, when you ask a group of experienced flight-software engineers what a good architecture is, you get multiple answers. As a result, we had many false starts that resulted in slower progress than I had originally hoped.

To address the problem, we identified a couple of key personnel who had strong technical reputations within the group as well as extensive flight-software experience and asked them to define a path forward. While it would not meet the impossible goal of unanimous consent, we knew that their experience and the trust they inspired meant it would be well received. At the end of the effort, the team had encapsulated enough of our heritage code in cFE applications to demonstrate that we could have the best of both worlds: a modular architecture that leveraged our past success. We had shown that cFE was adaptable to our architecture. Now we just needed a mission to prove it.

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As it happened, we had two: the Radiation Belt Storm Probes (now called the Van Allen Probes) and the Robotic Lunar Lander program.

The Van Allen Probes

The Van Allen Probes are twin spacecraft studying the Van Allen radiation belts. They are also the first mission to fly the new JHU/APL flight-software architecture based on cFE. Mark Reid, flight-software lead for the mission, was instrumental in advancing the architecture. He began his prototyping work in Phase A, working closely with the mission operations and integration and test teams—the ones who interact most with our software.

Naturally, they were accustomed to operating a spacecraft in a certain way. Familiarity with institutional procedures from mission to mission is a key to the success of our spacecraft. When introducing cFE, Mark focused on ensuring it would not disrupt those procedures. He avoided cFE features that fit Goddard's operational model but would have been too disruptive of APL's procedures. Mark also did early benchmark testing of cFE operations to understand their impact on resource utilization. We expected to see an increase in processor and memory usage, since we understood that cFE is more complex than directly coupling software. Mark's team's measurements showed that cFE would work within the computing constraints of the spacecraft. He also found that focusing on software that was not dependent upon external communication made it possible to reuse a significant amount of our code base while transitioning to the new architecture.

On the whole, the cFE integration was a success. The primary difficulties the team encountered were not with the code itself. Auxiliary tasks that come with managing a large body of code—for instance, version control, bug fixes, and updates—caused the greatest difficulties. Because Goddard was developing its own spacecraft while also supporting cFE, it was understandably difficult for them to respond to requests from outside the organization. Fortunately, Mark and his team developed strong personal relationships with Goddard personnel, which ensured focused responses to our needs.

The Robotic Lunar Lander

The Robotic Lunar Lander development article is a joint effort between JHU/APL and the Marshall Space Flight Center. To understand how cFE operated within the lander, I exchanged e-mails with Gail Oxton, who was the flight-software lead through a significant part of development. She and her team were responsible for developing the guidance and control algorithms that would fly on the test vehicles. Marshall developed the command and data-handling functionality and sensor interfaces.

Guidance and control (G&C) development at APL is a collaborative effort between the flight-software group and the G&C analysts' group. The analysts develop G&C models via MATLAB to accommodate the constraints and requirements of a given mission. Once that work is complete, they turn to Simulink to auto-generate flight code that is then delivered to the flight-software group and integrated into our flight software. For the robotic lander, Gail devised an initial plan to deliver the auto-generated C code for the G&C models directly to Marshall. But as Gail remarked, "That can be a challenge when the G&C analysts and the software team are on different floors, let alone in different states."

She decided instead to implement G&C as an entire cFE application so the interface between Marshall and APL would be solely over the software bus. Needing to define only a small set of messages for communication removed potential

NOT SURPRISINGLY IN HINDSIGHT, WHEN YOU ASK A GROUP OF EXPERIENCED FLIGHT-SOFTWARE ENGINEERS WHAT A GOOD ARCHITECTURE IS, YOU GET MULTIPLE ANSWERS.

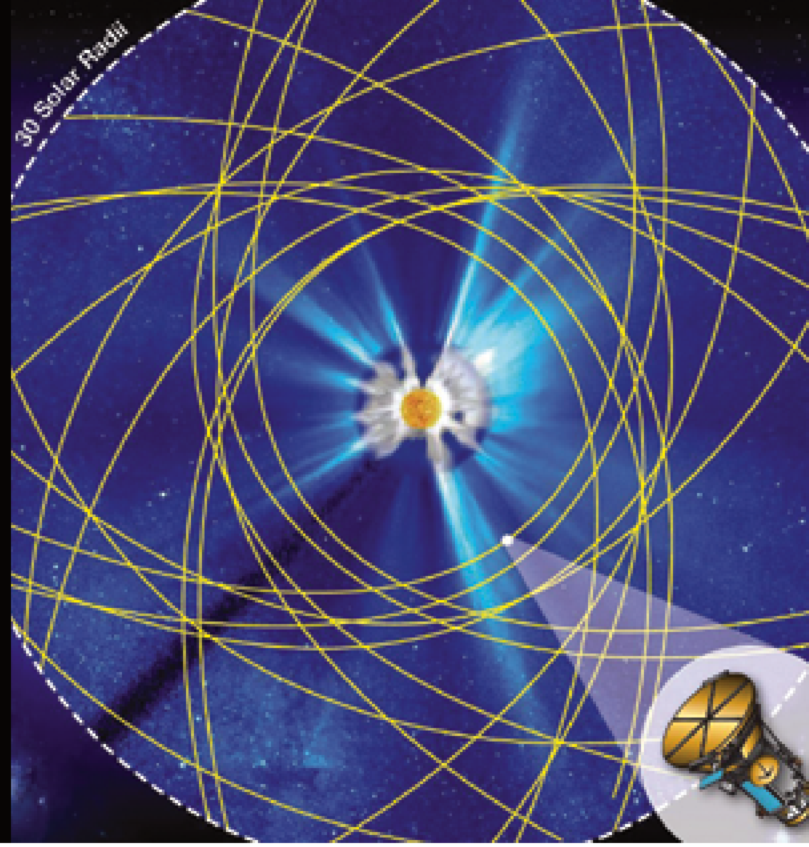


Image Credit: NASA

A simulated view of the sun illustrating the trajectory of Solar Probe Plus during its multiple near-sun passes. The Applied Physics Laboratory is flight-software lead for the project, working to further the Core Flight Executive architecture.

dependencies within the code. This was a step forward in both collaboration and software reusability; it would be the first time we delivered a cFE application externally.

To achieve this solution, Gail developed an interface control document that defined all software bus traffic. This involved a range of data including clock ticks, sensor input, and commands from Marshall's command and data handling to APL's guidance and control, and thruster fire commands, attitude data, and other telemetry from G&C to command and data handling. Over the next few months, each team separately developed and tested their applications. When the APL G&C application was delivered to Marshall, the Marshall team successfully integrated the G&C application in literally a few hours. Gail had one brief, over-the-phone debug session to identify an array indexing problem on day two, but after that the software worked flawlessly. Over time, Gail's team delivered algorithm improvements to Marshall. Each delivery was similarly smooth. The Robotic Lunar Lander continues to have many successful test flights.

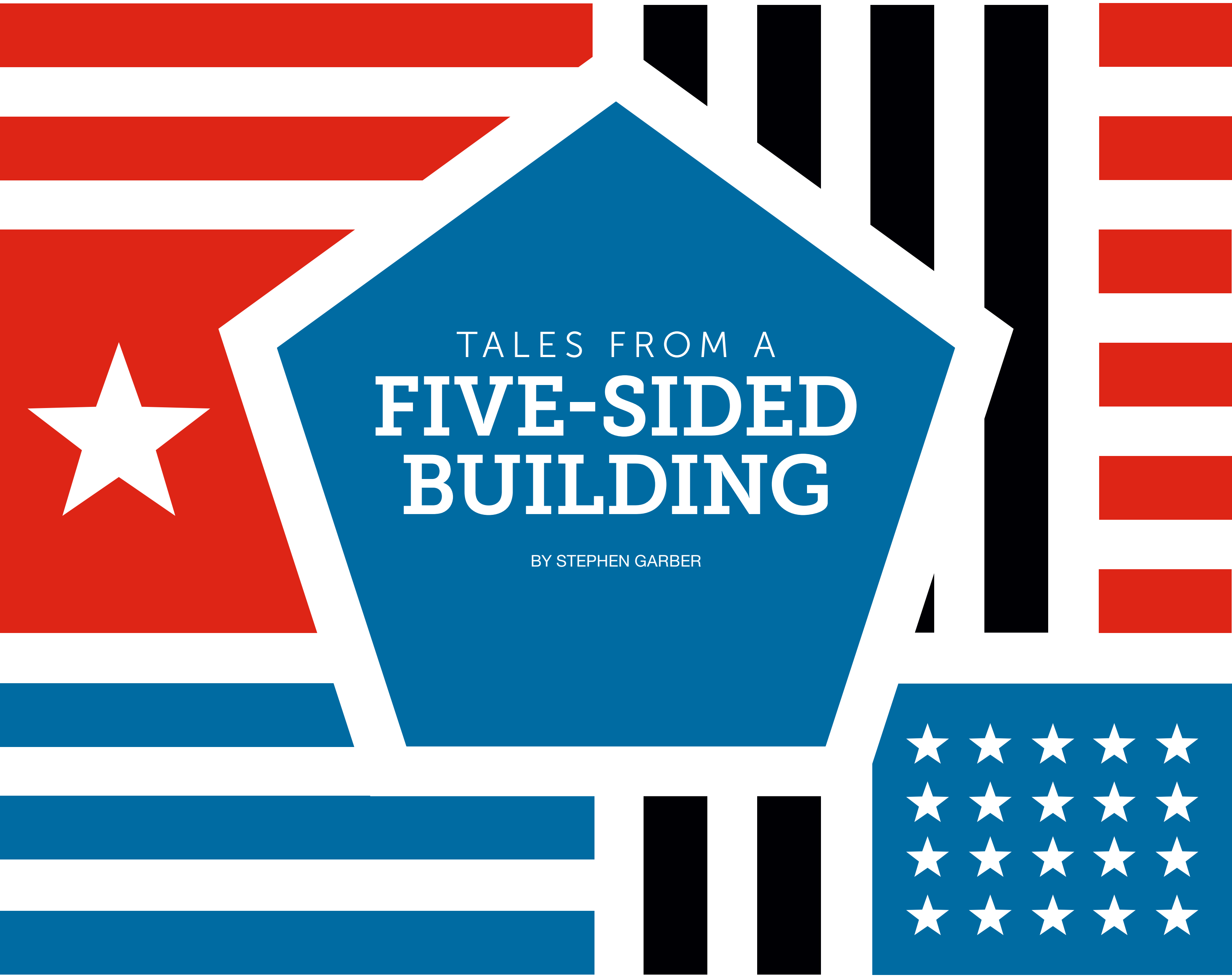
When asked about the experience, Gail summed it up this way: "We had no prayer of getting this to work in the timeframe and funding we had without cFE."

Solar Probe Plus and the Future of cFE

As flight-software lead for the Solar Probe Plus project, I am working with my team to further the architecture. We are striving to make the software even more reusable and cost effective through configuration values, parameters, and tables that can reduce the amount of rework from mission to mission, relying instead on configuration variables to modify the software. We are also working with the Van Allen team to avoid some procedural difficulties encountered on that project.

CFE and Goddard's larger Core Flight System, of which cFE is a part, continue to achieve recognition outside Goddard. It is not only performing flawlessly on the Van Allen Probes and the Marshall lander, but it is also being used on projects such as Johnson Space Center's Morpheus effort, the Ames Research Center's Lunar Atmosphere and Dust Environment Explorer, and Goddard's Lunar Reconnaissance Orbiter, Global Precipitation Measurement spacecraft, and the Magnetospheric Multiscale mission. CFE can work for an organization that has no existing flight-software experience or architecture; it can also work, as we showed, for an organization with an existing architecture. CFE and the Core Flight System have the potential to serve as a basis for other NASA missions, reducing costs and simplifying the process of developing software for the full fleet of NASA spacecraft. Currently, Goddard has to turn to individual missions to improve cFE on a mission-by-mission basis. What the Van Allen experience has shown us is that Goddard (and NASA in general) has a strong product available for use by the NASA community. As the user base grows, we hope institutional support will grow with it.

CHRISTOPHER KRUPIARZ is a member of the Johns Hopkins University Applied Physics Laboratory (JHU/APL) principal professional staff. He is currently the assistant group supervisor of the JHU/APL Embedded Applications Group and flight-software lead for the Solar Probe Plus mission.



TALES FROM A FIVE-SIDED BUILDING

BY STEPHEN GARBER

What is it like to work at the Pentagon? From November 2012 to April 2013, I was fortunate enough to do a six-month "detail" there. I worked in a policy office within the Office of the Secretary of Defense, which is roughly analogous to NASA Headquarters as an agency-level organization that oversees military services and numerous smaller agencies. It was a rewarding experience where I learned every day. Not only did I learn a great deal about the two main policy issues I had in my portfolio, I also observed the different organizational culture at the Department of Defense's (DoD) headquarters. Although the atmosphere wasn't much different from what one might expect, I found some details interesting and potentially relevant to other organizations, including NASA.

One stereotype that turned out to have validity is that military people follow directions well, as opposed to many civilians who often don't follow directions, even when it's in our best interest. One morning I dropped off a prescription at the commercial pharmacy in the Pentagon. The pharmacist said she'd check if it was in stock and notify me. She left a voice message that afternoon, saying the medicine was in stock and that I should print out a coupon for a discount. When I listened to the voice message, I didn't really understand what she meant about the coupon. Most people might have given up there to save themselves some headache, but I Googled the medicine and found a web site for it with a coupon for first-time patients. When I gave the coupon to the pharmacist, she explained that it allowed me to receive the medicine for free, saving me about $70. The pharmacist told me that in other locations where she'd worked, patients typically wouldn't print such coupons, even though it was in their best interest. DoD people (and not just those in military uniforms) take direction well. Perhaps this illustrates a common foible of human nature outside the military—we are often too proud to accept advice.

Another well-known facet of military services is that service members rotate among assignments frequently. In addition, there is considerable turnover among civil servants and contractor staff. Perhaps that's inevitable, since there are more than 20,000 people who work at the Pentagon. Not surprisingly, defined structures and work processes are key when personal institutional memory may be lacking. Cross-training government employees to do different kinds of work is usually mutually beneficial, allowing the organization to reduce single failure points and motivating and engaging employees. Given the constant churn of personnel at DoD, leaders there tend to view cross-training as more essential than at NASA.

When I first arrived at the Pentagon, I had a couple of weeks with a military officer on our team who I knew would soon retire. After he gave me two neat, chronologically organized binders with materials on a policy issue I would soon take over for him, I asked him for copies of his relevant electronic files. He responded that all his work files, like those of others in the office, were stored on a shared drive with a file structure that turned out to be easy to understand. Before my detail, I had made sure to copy all my NASA work files to a shared drive, but many of my file folders were arbitrarily named. At least in the Office of the Secretary of Defense Space Policy, the electronic file structure was self-evident and thus fairly straightforward for employees to find needed documents. When I returned to NASA, one of the tasks my boss asked me to work on was pulling together documentation for our various contract history projects in a way that all members of our office could easily access. Because people often stay for long periods of time in their jobs at NASA and thus acquire substantial detailed subject-matter expertise, if a subject-matter expert is out of the office for any reason it sometimes becomes a single point of failure. We at NASA likely could do better in terms of "knowledge management" to avoid this problem.

The fact that people move around so much at DoD, perhaps combined with respect for hierarchy, yielded another notable organizational culture facet: a strong implicit emphasis on teamwork. While working on various aspects of two space-policy issues, I interacted with people from a variety of organizations who brought different perspectives and expertise. Underlying our interactions was the notion that regardless of where we worked or our specific backgrounds, we each had something to contribute to the issues at hand. Thus everybody worked together cooperatively. I didn't witness any bureaucratic "steamrolling" or people trying to pull rank, presumably because the hierarchy was clear. Also, people rarely asked for others' personal perspectives; we all represented a particular office or institutional perspective. At NASA, I've seen more latitude for individual personalities and ways of doing business, which can be a pleasant form of teamwork or it can be dysfunctional.

Relatedly, virtually everybody I encountered at DoD was respectful of other people. This is hardly a surprise, but the manners I saw exhibited on a daily basis were instructive. In an orientation class, one presenter cautioned that we should not refer to a superior by his or her first name in casual conversation unless we'd feel comfortable addressing that superior by first name to his or her face. Two colleagues refused to call me anything but "sir" even after I suggested a few times that we call

THE FACT THAT PEOPLE MOVE AROUND SO MUCH AT DOD, PERHAPS COMBINED WITH RESPECT FOR HIERARCHY, YIELDED ANOTHER NOTABLE ORGANIZATIONAL CULTURE FACET: A STRONG IMPLICIT EMPHASIS ON TEAMWORK.


Photo Credit: Department of Defense/Master Sgt. Ken Hammond, U.S. Air Force

The Pentagon, headquarters of the Department of Defense.

each other by our first names. (I suppose I technically outranked them, although I don't think they knew that.) I began calling others at work "sir" or "ma'am" and found this encouraged me to be polite, especially when dealing with frustrating customer-service situations outside work. This was a change of pace from NASA, where the administrator, a retired general, asks employees to call him by his first name. Presumably long ago, NASA Administrator Charles Bolden wisely adapted to NASA's more informal culture, but I've always addressed him as "sir" when I see him in the hallways.

Although there was good-natured teasing among my team at DoD, people rarely talked disparagingly about a person who wasn't in the room. Initially, I didn't consciously realize this admirable aspect of DoD's culture. Even at NASA, with a deserved reputation as a "can do" organization, sometimes we waste emotional energy and time complaining about people or things we don't like. Not everything was or is perfect at DoD, but I find focusing on the positive to be a helpful tactic in many practical ways.

Another way in which mutual respect is demonstrated at DoD is people don't check their phones during meetings. The reason for this is simple: such portable electronic devices are prohibited from almost all offices and meeting rooms in the Pentagon for security reasons; this has the added benefit of ensuring respectful attention to speakers.

DoD employees multitask in another way, however: using classified and unclassified systems almost simultaneously. Everybody has at least a secret clearance and uses at a minimum two separate computers: one classified and one unclassified. For security reasons, these computers connect to separate systems. Thus everybody has at least two e-mail addresses. Since most of my work was on the unclassified system, I could ask colleagues who sent me messages on the classified network to let me know via phone or unclassified e-mail to check my secure e-mail. Conversely, I asked my boss to give a specific colleague, who spent most of his time on a highly classified system to which I didn't have access, a heads up when I'd sent him an unclassified e-mail. While a little cumbersome, this informal system sufficed to keep work flowing in separate channels. Because the vast majority of NASA employees, even those with security clearances, do not have such computer setups, this arrangement isn't usually necessary at NASA.

Another aspect of my experience that I keep coming back to is that policy has a significant footprint at DoD. The Undersecretary of Defense for Policy oversees perhaps one thousand people who are divided into various geographical and functional offices. The Space Policy Office, a group of about twenty people divided into three branches, has significant influence despite its relatively small size, and it is only one of several DoD players in space policy. There is

An illuminated American flag is displayed at the Pentagon near the spot where American Airlines Flight 77 crashed into the building on September 11.

Photo Credit: Department of Defense/Petty Officer 1st Class Brandan W. Schulze, U.S. Navy another office called the DoD Executive Agent for Space that also deals with space-policy issues. Then there are other people in a number of staff offices who work on space policy from various angles (e.g., various air force components, legal, and procurement). DoD is much larger than NASA, so it makes sense that there are more people working on space-policy issues at the Pentagon.

In practice, only a small number of people do policy analysis at NASA, and these people are forced to cover many issues. In fact, the term "policy analyst" seems to have different meanings at DoD and NASA. I was heartened to see the number and range of DoD people thinking about the complex space-policy issues that both civilian and national security (and often commercial as well) space communities face. Sometimes my head would spin a bit after sitting in on discussions about internal DoD directives or DoD perspectives on national space-policy issues, as it seemed people were debating how many angels would fit on the head of a pin. Yet people had time to think through the issues, and people in the field paid attention to the carefully crafted language in these policies. Simply put, words matter. Ideally it'd be nice if there were at least a few more NASA policy people at Headquarters to help think through similar various perspectives.

Another facet of DoD's organizational culture that was apparent is there seems to be more administrative support at the Pentagon than at NASA Headquarters, and most of these positions are filled by contractors. This may seem like a luxury to NASA people who are accustomed to more minimal support, yet these highly capable administrative professionals increased the efficiency of workflow. In particular, schedulers made arranging meetings vastly easier and freed the "principals" to do other things. More administrative support seems like a relatively small investment that's worth it whenever possible because it yields great benefits in operational efficiency.

As a sidelight, I was also impressed with one administrative-support contractor who helped me numerous times and basically ran the office. He had a terrific "let's get it done" attitude. Although he expressed interest in working at NASA, this former sailor was awarded with a fairly high-level civil-service job in another DoD office. He is truly a standout who typifies the best of enthusiastic, capable employees at both DoD and NASA.

Of course, leadership and management are all about the people. Beyond the exciting, important missions that NASA and DoD have, an organizational culture focused on setting the conditions for employees to thrive makes all the difference. Reflecting on the different natures of the two organizations and missions, it is heartening to see that both DoD and NASA strive to take care of their people. We have much to learn from each other. ●

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STEPHEN GARBER has worked in the NASA History Program Office for a number of years and recently completed a six-month detail at the Department of Defense. Read more about his experiences at the Pentagon and during a six-month detail in NASA's Office of Legislative and Intergovernmental Affairs in the 2013 third-quarter issue of *NASA History News and Notes* at history.nasa.gov/histnews.htm.

The Knowledge Notebook

Big Data—The Latest Organizational Idea-Movement

BY LAURENCE PRUSAK

Since the Second World War, something like forty-five major idea-movements have swept through both public and private organizations. They include early time-and-motion studies, the quality movement, reengineering, human potential, and many, many others. Some of these movements promulgate genuinely new ideas; some recycle old approaches under new names. I am quite certain every reader of this column who has spent more than a few years in an organization has been the beneficiary—or the victim—of at least one or two of them.

What accounts for the often disruptive change that seems to erupt every few years (the new ideas then either becoming embedded in the way we work or forgotten forever)? Well, for one thing there is money to be made from selling new ways to make organizations more efficient, innovative, or profitable. Consultants, technology vendors, motivational speakers, and the like all need new ideas to gain audiences and keep them interested. The same is true of the business press. It isn't always possible to fill a journal with compelling stories every month or even every quarter unless there are new ideas to discuss or develop.

Some other factors contribute to the phenomenon. The boredom experienced by many managers who yearn for something new to try is one that reinforces their genuine desire to actually produce useful results for their organizations. There is also the pure uncertainty faced by all who try to improve the performance in their work life—and increasingly their home life as well. There is little real science to guide organizational behaviors; the "science" of organizations lacks the clarity and testability of engineering or biology. Therefore, one can make a substantial case for an organizational improvement idea on more specious grounds than the purer sciences allow. Cases, logic, and rhetoric all play their roles in persuading people to follow the latest idea. Because those things are easier and less costly to develop than the findings of real science, there are virtually no barriers to entry. Finally, the fact that so many of the movements that promise so much in principle deliver so little in practice (except disappointment) drives people to latch on to the next great new idea and hope that this one will live up to the hype.

Now we have big data, or "business analytics" as it is sometimes called. It addresses issues of capturing, storing, organizing, and interpreting large quantities of data and extols the benefits of those efforts. This movement is just about at the height of its influence, in my opinion. It is more global in scope than some of the others I have mentioned, due to the increasing globalization of the market for business ideas as well as the almost total dissemination of information technology know-how across the developed and most of the developing world.

Like the quality movement, big data has much to recommend it. Analytic software has been used to do everything from studying baseball dynamics to predicting customer preferences. You can read and hear many stories of how those analyses uncovered new opportunities and supported good decisions. New applications for data combing, analytics, and gaming are being developed every day.

There is still the question, though, of what one does with all this analyzed data. Some of the proponents of big data suggest that the software itself can tell you what to do, but in fact the results of these analyses are almost never self-evident. Human judgment and experience-based knowledge are still called for to understand and give meaning to the data and decide what to do with it.

If this were not the case, we would barely need human managers at all—just let the machines run our organizations. In fact, the plethora of data being produced by all the new monitoring and social-media usage require more—not less—human intervention in running any organization. Without human reflection and interpretation, the data remain inert and ambiguous. Doing what the data itself "tells" you to do—or seems to tell you—can actually cause harm.

The dream of self-running organizations, organizations where little human intervention is needed and so-called objective data itself continuously optimizes performance, is a long-standing fantasy that should be limited to sci-fi literature but can be found in business magazines, books, and schools.

So, like some other movements, big data seems to have some real potential but also the potential to be misused and overpraised. Maybe it is not possible at this point to determine the proportion of good to bad. The one thing we do know for sure is that some other movement will come along to replace it within a few years. ●

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NASA in the News

NASA announced a Grand Challenge focused on finding all asteroid threats to human populations and knowing how to deal with them. Grand Challenges are ambitious goals on a national or global scale that capture the imagination and demand advances in innovation and breakthroughs in science and technology. The challenge is a large-scale effort that will use multidisciplinary collaborations and a variety of partnerships with other government agencies, international partners, industry, academia, and citizen scientists. It complements NASA's recently announced mission to redirect an asteroid and send humans to study it. To read more about the challenge and respond to NASA's request for information, visit www.nasa.gov/asteroidinitiative.

Mars 2020

NASA has announced plans for a new robotic science rover set to launch in 2020. Designed to advance high-priority science goals for Mars exploration, the mission would address key questions about the potential for life on Mars. The mission would also provide opportunities to gather knowledge and demonstrate technologies that address the challenges of future human expeditions to Mars. NASA's plans include openly competing the opportunity for the mission's specific payload and science instruments. Learn more about the 2020 plan and the current science definitions for the mission at mars.jpl.nasa.gov/m2020.

NASA Apps

If you're looking for another way to keep up with NASA news on the go, the agency has a collection of apps tailored for general overviews and updates, photos, missions, on-demand video, International Space Station tracking, and more. Check out all the latest apps at www.nasa.gov/connect/apps.html.

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