National Aeronautics and Space Administration

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The NASA Source for Project Management and Engineering Excellence | APPEL

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Image courtesy of the Image Science and Analysis Laboratory, NASA Johnson Space Center

ON THE COVER

The view of Earth from space continually reveals new aspects of our planet, aiding scientific research and increasing human understanding about how the "blue marble" developed and how it changes over time. The cover image shows the dynamic force of high winds across the earth's surface. When wind speeds attain sufficient velocities, sand particles are transported in the lower atmosphere, causing a dust storm such as the one that is pictured here in the Djourab Sand Region of central Chad.

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The Academy of Program/Project and Engineering Leadership (APPEL) and *ASK Magazinee* 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.

For inquiries about APPEL Knowledge Sharing programs and products, please contact the Knowledge Sharing Project Manager, Rosie Robinson, ASRC Management Services, 6303 Ivy Lane, Suite 130, Greenbelt, MD 20770; rosie.robinson@asrcms.com; 301-768-5744.

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In This Issue

Several articles in this issue of *ASK* give essentially the same important advice to project managers and engineers. In one way or another, they say, "Step back and look at the big picture."

That is certainly the message of Nancy Leveson's "An Introduction to System Safety." She explains why paying attention to the interactions of the system as a whole (not only the hardware and software but people and processes, too) is much more likely to ensure safety than focusing on the reliability of individual components. And Michael Hall's discussion of "The Optimized Project Portfolio" argues that leaders need to keep their eyes on the big picture to make sure that the projects they approve and support actually help the organization achieve its aims.

"Nothing Weak About It," by Keith Woodman, describes the work of "center focals" for the Constellation program at Langley almost entirely in terms of their ability to step back and understand center capabilities and project needs as a whole. Then they use that knowledge to negotiate balanced and effective use of the center's resources. Toshifumi Mukai, the chief engineer of JAXA, the Japanese space agency, recalls his experience on a Japanese–American project to talk about what makes international projects work. Here, too, the broad view is important: working toward the overall success of the project rather than the local preferences of one group or the other. In international projects, looking at the big picture also means stepping back from the purely technical demands of the job to understand differences in language and culture and make them work for rather than against the project. In more general terms, "What's Ahead for Project Management," a roundtable discussion, considers the multiple abilities and breadth of vision project managers will need to manage complex, international projects.

Taking a step back also means finding new perspectives and new sources of knowledge that provide new ways of solving stubborn problems (and often a better understanding of what the problems are). The Operation Burnt Frost team used informal social networks to get the knowledge they needed to intercept a falling satellite. At Johnson Space Center, Dustin Gohmert took home what the astronaut seat team had been learning and turned it into a prototype that helped move the project to the next level. NASA and Capitol College found one solution to two problems—insufficient funding to continue monitoring a satellite and students' need for hands-on experience—by turning over the tracking job to the college.

The value of new, broader sources of knowledge motivates the CoLab project, which has created an online environment where people within and outside NASA can share ideas. It underlies Ed Hoffman's advocacy for a diversity of perspectives and Laurence Prusak's advising people to get out of their offices and learn something. Too often, we equate serious work with bending over a computer or workbench, with intense focus on the task at hand. But standing up and looking around, taking a walk, or having a conversation are also part of work, and sometimes the most important part.

Don Cohen
Managing Editor

From the APPEL Director

Don't Trust Anyone Under Thirty?

BY ED HOFFMAN

I recently participated in a panel discussion about next-generation challenges and strategies for aerospace. Such sessions have become common as we worry about the ability of the future workforce to assume responsibility for the science, engineering, technology development, and management of our future aerospace missions.

You often hear that members of Gen X and Y do not have the work ethic, commitment, or attention span of their elders. In one session, someone commented that "research had determined" that the new generation has an attention span of a few seconds. (I wondered how they crossed the street without being run over.) The few hundred attendees at the conference were skewed significantly toward maturity and long experience. Whenever I appear on a panel devoted to next-generation work issues, I see few representatives of the target community there to keep us honest.

This is nothing new. Twenty years ago, getting ready to facilitate a strategic diversity planning session, I was struck by the complete lack of diversity on the work team, which consisted entirely of middle-aged white males. We spent the day wondering what could be done to improve workforce diversity and how to understand the needs of a diverse workforce. But the most obvious resource—a diversity of perspectives—was missing.

We have a tendency to work a problem without including the people who know it best. Perhaps it is natural to invite the people you know, but assumptions made on behalf of those who are missing are often flat wrong. One such assumption is that the next generation is not ready to take over, but little evidence is offered to support it. Every generation takes over a world that is more complex than what came before, and so far every generation has outdistanced its predecessors. I remember Gene Kranz indicating at a NASA event that the average age of the Apollo workforce was twenty-seven. Evidently youth was not a hindrance to landing a man on the moon.

I have also been told that this new generation is not as dedicated or committed as past generations. That is not what I see. In many respects the next-generation workforce seems far better prepared. They are more open to diversity, working in teams, international collaboration, information technologies, and continuous learning, to mention just a few potential strengths. As far as motivation and commitment are concerned, spend a few minutes with a new co-op student. The enthusiasm and dedication are unmistakable.

At that recent conference, I asked for a show of hands to determine how many in the audience were under thirty. Five hands went up. I watched their reactions at different points of the panel discussion. They sat and listened while they heard theories about the next-generation workforce. Theories about how they learned. Theories about how they worked. Theories about how prepared they were to enter the workforce. Theories about their loyalty. Theories about their professional passion. During some of the discussion they seemed to nod their heads in agreement. At other times, they seemed to laugh at the conjectures and concerns. Despite their small numbers, they were active participants, asking questions and offering ideas. They made their voices heard. What they said loud and clear was, "We are here, and we are ready."

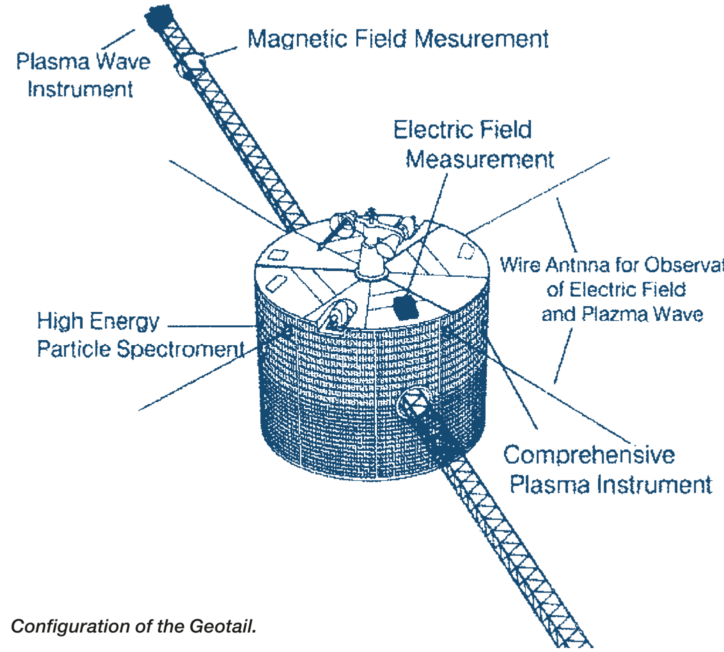
The Akebono (EXOS-D) and Geotail missions observe Earth's magnetic field.

Image Credit: Japan Aerospace Exploration Agency

INTERNATIONAL COOPERATION: When 1 + 1 = 3

BY TOSHIFUMI MUKAI

The hope in international projects is that one plus one will equal three—that the diverse resources, skills, and technologies of the partners will add up to more than the sum of their parts. To get those benefits, however, project teams need to successfully manage the challenges that arise when different countries with different languages and cultures collaborate on a complex project. Successful project management always involves effective communication and negotiation to coordinate the activities of various groups to achieve the shared goal. This coordination is all the more challenging when the groups work in countries halfway around the globe from each other and must overcome potential cultural and linguistic barriers.



Configuration of the Geotail.

Image Credit: Japan Aerospace Exploration Agency

One successful international project I worked on was Geotail, a joint effort of the Institute of Space and Astronautical Science (ISAS), which is part of the Japan Aerospace Exploration Agency (JAXA), and NASA. ISAS developed the spacecraft and about two-thirds of the science instruments while NASA provided the launch vehicle, about one-third of the science instruments, and tracking support.

Geotail was designed to study the structure and dynamics of the Earth's magnetotail, the part of the magnetosphere pushed away from the sun by the solar wind of charged particles. To explore this vast tail region, the Geotail spacecraft traveled in a highly elliptical orbit ranging from 8 to 210 earth radii. Its measurements of plasma and electric and magnetic fields have contributed to the understanding of the physics of interactions between Earth and the sun, and have made it a valuable part of the International Solar-Terrestrial Physics program.

One reason for the project's success is that the scientists working for the international program had a clear common goal. That is a feature of every successful science project, the necessary foundation for success. As important as that commonality is, though, it does not eliminate the potential for cross-cultural misunderstanding and confusion.

What kinds of difficulties do cross-cultural programs face? Language is the toughest one between the United States and Japan, but we also had to think about (and find common ground) in regard to our different decision-making processes and meeting styles. We also had to deal with communication across many time zones as well as funding and legal issues (including liability and ITAR, the International Traffic in Arms Regulations that limit access to some American technology and knowledge).

English was the official language of the project. (One of my American friends said there are only two languages in the world, English and FORTRAN.) But only a few of the Japanese members spoke English fluently, and we faced many misunderstandings and much confusion during our discussions.

English and Japanese are very different not only in their vocabularies but in their structures, differences that reflect dissimilar values and ways of thinking. For example, look at the English sentence, "I am not supporting this idea," and its Japanese equivalent:

The various elements of the statement appear in a very different order in the two languages. Notice that the negation is located at the very end of the Japanese sentence—something that may reflect a cultural reluctance to express a negative opinion in Japan. The language differences are not just a matter of vocabulary. They extend to how language and—to a certain extent—how thinking are structured.

The most important first step toward resolving this and other cultural issues is to recognize that the differences exist and to respect each other's cultures and traditions. In the case of the language problem, both groups recognized the likelihood of misunderstanding and took steps to minimize it that included repeating and paraphrasing, slowing down the conversation, and frequently confirming that the discussion was being understood by all parties. Some American participants took Japanese lessons, which was important in several ways:

- It showed their respect for the Japanese language and culture.
- Trying to learn Japanese made clear to the Americans how challenging it is for the Japanese to work in English.
- Even a rudimentary understanding of Japanese helped the Americans understand some of the likely sources and types of misunderstandings the language differences could cause.

A Delta II rocket carrying the Geotail spacecraft lifts off at Launch Complex 17, Kennedy Space Center.

Photo Credit: NASA

One of the Geotail principal investigators, Roger Anderson from the University of Iowa, has identified these language lessons as one of the reasons for the team's successful collaboration. He also noted that the Japanese practice of seeking consensus is quite different from American and European ways of working and points to other important lessons from the Geotail experience:

- In international cooperation it is important that one side not dictate requirements to the other side.
- Diplomacy is very important. It is much better to guide your colleagues in the direction you want them to go than to make demands.

Dr. Anderson and Dr. Mario Acuna of NASA also have called Geotail an "outstanding success" and commented that "the development of a mutual trust relationship between the partners was perhaps the most critical element of all for success."

Mutual respect, trust, and recognition that cultural differences exist, matter, and must be explicitly dealt with are requirements of successful international projects. In summary, I would suggest these principles for the success of international collaboration:

- Two (or more) teams share the same goal and seek the overall optimal result, not the local optimum.
- Each team should clearly recognize and value the other party's different culture and traditions.
- The single most important word in international projects is **trust**. Team members earn trust by being sincere, honest, and open-minded.

These principles apply especially to international projects but no doubt the same principles contribute to the success of any challenging project in which team members work for different organizations or in different locations. ●

DIPLOMACY IS VERY IMPORTANT. IT IS MUCH BETTER TO GUIDE YOUR COLLEAGUES IN THE DIRECTION YOU WANT THEM TO GO THAN TO MAKE DEMANDS.

TOSHIFUMI MUKAI is senior chief engineer at the Japan Aerospace Exploration Agency.

A NEW ASTRONAUT SEAT:

TEAMWORK AND INDIVIDUAL INITIATIVE

BY DUSTIN GOHMERT

The Advanced Crew Escape Suit (ACES) fit in the Orion concept seat is evaluated. ACES was used as the reference suit for the anthropometric guidance provided for seat design.

Photo courtesy Dustin Gohmert

As Orion seat subsystem manager, I had been working with contractor Lockheed Martin for approximately a year and a half on the design of an astronaut seat for the new crew exploration vehicle, Orion. The seat would have to protect astronauts from the "high landing loads," or g-forces, of landings on water or land, including those where problems like one of the parachutes not opening or high crosswinds would expose the crew to higher-than-expected loads. Even a perfect landing is what you might call a "controlled crash."

We knew that an effective seat would be one that spread those forces evenly over the astronaut's body and constrained motion to avoid the harm done to limbs or head flung in any direction. Given the tight quarters of the six-person capsule and payload considerations, the seats would have to be compact, lightweight, and easily storable when not in use. We decided early on that the solution the Russians used on Soyuz—custom seats molded to every astronaut—would not work for us. Among other things, they could not be folded for storage and would create problems when astronauts took shifts on the International Space Station (and would presumably have to keep their seats with them).

By December 2007, Lockheed Martin had a seat that was set to meet the myriad requirements specified early in the project. While this seat was a good overall solution, NASA faced a dilemma: it was built to requirements specified before the team fully understood the extent of potential landing injury problems and how to solve them. That often happens when you're designing something new: you discover things in the process of doing the work that you needed to know to define the requirements, but couldn't have known at the time the requirements had to be written.

Since that time we had learned a lot, especially from the technologies auto racing had developed to protect drivers. Years of experience and experiment had gone into seats designed for NASCAR, Indy, and Monster Truck racing. Monster Truck drivers repeatedly experience forces as great as 18 G's—comparable to some of the worst impacts the astronauts could experience. NASCAR and Indy racers routinely survive impacts of greater than 50 G's with little or no injury. The veteran racing designers shared their knowledge with us freely and enthusiastically. We also got valuable information from Apollo astronauts and vehicle design teams. Solutions used on Apollo were shared by the folks who have done this work before us; for instance, they used heel clips to help immobilize the astronauts' legs during reentry and landing. That helped provide a solution to our potential leg-flail concerns.

So we had a much better idea now of what the seat needed to do and how we might give it those capabilities, but the Lockheed Martin and NASA seat team already had a viable design that fulfilled the requirements laid out in black and white. To upgrade the requirements and rewrite contractual agreements could delay us several months in the critical time approaching our design reviews.

Do Try This at Home

As people discussed the seat during team meetings on impact safety, I found myself thinking, "that's a good idea," or, "that probably won't work." Those judgments reflected what we were learning together and also my own earlier work on the orange pressure suits the shuttle crew wear during launch and reentry. Those suits are the "interface" between the astronaut and the chair, so understanding how they are constructed was essential to understanding the seat. One problem with the existing design, clearly, was that the seat was flat and people are not. And we hadn't fully solved the problem of adjusting for different leg lengths to provide continuous support. I began to have a good sense of what the seat should look like. As I've mentioned, though, we were not at a point where we could stop work and start over from scratch.

I decided I would try to come up with something at home over the Christmas–New Year's holiday that might help put us on the right track, thinking that if I came up with a design that worked, NASA might support it and Lockheed Martin might be able to take it to the next level without further contract negotiations.

There were some other reasons the idea appealed to me. I liked hands-on work; I grew up on a ranch in Texas where you needed to know how to fix things and build them from scratch. And I'd recently gotten some new tools that I wanted to try out. So I walked up and down the aisles of the local Home Depot, thinking, "I'll probably need this." I spent $200, which I hoped I'd eventually get reimbursed for.

The first thing I did was ask my fiancée to draw the outline of my body on big sheets of cardboard. That gave me a template

Isometric view of the seat adjusted to accommodate 99th percentile operator.

I could use to shape the chair, designing, most importantly, a curved, adjustable lower part of the seat that matched the curve of the buttocks. Of course we had done computer modeling to try to fit body shapes to chair designs, but computer models tend to be too rigid when designing for the ultimate non-rigid interface: the human body. One model, for instance, showed that the fit between suit and seat would be too tight when in actual fact it left space that needed to be filled. I worked ten ten- to twelve-hour days in my garage. (At 10:30 p.m. on New Year's Eve, my fiancée said, "So, are we going out?" We did.) At the end of that time, I had a full-size working prototype made out of wood, metal, and fabric. Its main new features were the adjustable, curved lower section and spacers of various sizes that could make a snug fit between the seat and astronauts' shoulders and hips.

Why Build a Prototype?

There were good reasons for building a prototype rather than just sketching my ideas. For one thing, you learn by touching the hardware. It teaches you that sometimes what looks good on paper is impossible to make—every piece of hardware is a compromise between an idea and the realities of physical materials. Also, the hardware shows you things you couldn't guess from diagrams. When I tested my prototype with people of very different heights and leg and arm lengths, I was surprised to find that everyone's hands always ended up near their knees. That gave me the idea of putting the controllers near the knees on the sides of the flight crews' chairs, thereby eliminating the complication of separate armrests for the hand controllers.

The other reason for building a prototype is that I knew that sketches can easily be dismissed for lack of clarity or understanding (or can lead to long discussions about whether or not the design would work in the real world). Everybody has sketches, but not everybody has a full-size working prototype. In other words, the squeaky wheel gets the attention, and I squeaked as loud as I could. Because I knew the impression the prototype made would be important, I spent time sanding edges and painting the wooden parts to make it look as professional as possible.

Back to Teamwork

After the holidays, I took the prototype and a PowerPoint presentation I had created "on the road" to numerous boards and meetings of groups overseeing the project and to my Lockheed Martin colleagues. I didn't present the seat design as my brilliant idea, because it wasn't. It was a product of a lot of learning that the whole team had done and of contributions from many sources: the Lockheed Martin design team, race-car engineers, suit designers, former astronauts, and others. Building the seat was really an exercise in integration, not an exercise in invention. I specifically designed the new seat features as an upgrade to the already existing good design, not as a replacement for it. That made it easier to foster team commitment to the changes without significant impact or rework on the sound foundation that had already been laid.

From there the teamwork continued. For instance, I had struggled to find a good way to have the leg and foot support slide in for storage; I never found a satisfactory answer. The Lockheed Martin guys quickly saw that it would be easier and better to have that part of the seat fold over. It was an obvious solution, but I hadn't seen it. I also worried that a bar at the end of the footrest would stick up when the seat was in the stored position. I stopped worrying when an astronaut looked at it and liked the bar that way, saying, "I can tuck my toes under here on orbit."

Lockheed Martin fairly quickly built an improved metal version of the prototype seat, while incorporating new creative solutions in the design. As I write this, it is scheduled for impact-sled testing with crash-test dummies at Wright-Patterson. I'm sure we will learn things that influence the final design of the seat, but we seem to be on the right track. I'm proud of the contribution I made by spending those ten days incorporating what we had learned into a prototype, but this has truly been a team effort and will continue as one for years to come as we work to provide the safest seats ever ridden to space and back. ●

DUSTIN GOHMERT is the seat subsystem manager at Johnson Space Center for NASA's new crew exploration vehicle, Orion.

INTERVIEW WITH

Neil deGrasse Tyson

BY DON COHEN

Photo Credit: © 2006 Chris Cassidy for NOVA ScienceNOW

Neil deGrasse Tyson is an astrophysicist with the American Museum of Natural History in New York City, where he also serves as the Frederick P. Rose Director of the Hayden Planetarium. In addition to writing for many professional publications, Tyson has written popular science books, including his memoir, *The Sky Is Not the Limit: Adventures of an Urban Astrophysicist,* and *Death by Black Hole and Other Cosmic Quandaries.* He is the host of PBS's *NOVA ScienceNOW* and has served on presidential commissions studying the future of the U.S. aerospace industry and the implementation of the United States' space exploration policy. Don Cohen talked to him in New York.

COHEN: How does NASA affect your work as head of the planetarium?

TYSON: In two fundamental ways. One relates to the public's appetite for the cosmos, stimulated by discoveries and missions conducted by NASA. Since there are hardly any NASA facilities in the Northeast—hardly anyone knows about GISS [Goddard Institute for Space Studies]—it has no direct presence in the hearts and minds of New Yorkers. For many people, the Rose Center for Earth and Space and the Hayden Planetarium are the closest they'll ever get to NASA in this region of the country. So we closely monitor missions and frequently design programs around NASA science.

“IF NASA IS SO VISIBLE that people think IT’S 10 PERCENT OF the federal budget WHEN IT’S SIX-TENTHS OF ONE PERCENT, SOMEBODY’S doing something right.”

COHEN: For example?

TYSON: We recently had our annual Isaac Asimov panel debate on “Mining the Sky”—what to do about the natural resources of space scientifically, culturally, morally, and ethically. I had an engineer from NASA Marshall, Curtis Manning, who specializes in *in situ* resource utilization. I got Cassie Conley, the head of the planetary protection group at NASA, to talk about what it means to go into space in search of resources, either in support of space-based activities or to bring back here. We also had a mining geologist to ground everyone, figuratively and literally.

COHEN: What’s the other way NASA connects to your work?

TYSON: We apply for support money from NASA for programs we run. Our most visible NASA-supported programs are space shows. In the old days, the planetarium director would stand up with a microphone and recite what constellations were visible that season. That doesn’t play anymore, nor should it. We know too much about the universe and the universe is too dynamic, too broad and deep, for anyone to believe that pointing out objects in the night sky constitutes astronomy any more. So we identify various cosmic objects and take the viewer there visually. We’ve enjoyed NASA support for each of the shows that we’ve produced over the past eight years.

COHEN: How would you characterize public response to NASA?

TYSON: People are generally completely supportive. Those who grumble about science and space don’t tend to visit us.

Our visitors are self-selected, of course, but the numbers have gone up. We get families, kids, international visitors. We show them the universe as it is and how we've come to learn our place in the universe. We give it context. We are fundamentally linked to the geological sciences, to the anthropological sciences, to the archaeological sciences. Context matters when someone says, "Let's go to space!" and someone else says, "Well, why?"

COHEN: Context matters because …?

TYSON: Often the "why" isn't, "Here's the answer." The why is, "Here's the landscape in which this activity is unfolding." Once you understand the landscape, it's self-evident why we are undertaking these activities. So I see almost complete support for our space activities.

COHEN: What kind of effect has NASA had on you personally?

TYSON: I was born the same week NASA was founded, so we're the same age and feel some of the same pains, joys, and frustrations. But the Apollo program had no effect on me.

COHEN: Why no effect?

TYSON: Because the astronauts were military pilots. They had crew cuts. Their skin was many shades lighter than mine. That was not an adventure that at all considered me as one of its participants, so I couldn't consider myself as one of them. It's not that I didn't appreciate what NASA was doing. I was as excited as the next person that we landed on the moon. It was a great engineering feat, a great technological feat. It just didn't influence my ambition to become a scientist. My interest came about entirely separate from that.

COHEN: Where did it come from?

TYSON: From my first visit to Hayden Planetarium, where I saw the night sky as never before, as undreamt of actually, because I grew up in the Bronx and I was sure the night sky was maybe eight stars, ten on a good night—not the thousands they were showing me. I thought it was a hoax. A couple of years later, I looked up with binoculars and the universe looked really different than it did with the naked eye. I realized that maybe what I was seeing from the Bronx was not the real thing. So NASA was going into low-Earth orbit and then to the moon and back, and my interest was being forged on the large-scale universe.

COHEN: In 1968, a year or so before the moon landing, I heard a talk by [astronomer] Fred Hoyle where he said space exploration was all well and good, but it would never replace looking through a telescope.

TYSON: Unless you figure out how to get to the place the telescope sees. I think he's right for the large-scale universe, but I bet he would not have imagined what we would glean just from our own planetary system from space probes that have been as far out as Saturn. Now we know that the moons are in many ways more interesting than the planets themselves. I don't think he could have imagined that at the time. So space travel is replacing telescopes. No one is saying, "Give me a good telescopic view of Saturn." No, we just call Cassini and say, "What have you got for me today?" So Hoyle was half right.

COHEN: What do you think our relative investment in robotic and human space exploration should be?

TYSON: I wear two hats. As a pure scientist, I would say, "Just send robots." For every astronaut you send up, you could send ten or more robots to ten different places. Very few scientists, given that specific choice and given the relative cost of the two, would say, "Send people instead of robots." But I also spend a good part of my professional life interacting with the public. I'm a public educator and a public scientist. In that capacity, I'd say there is no question that human exploration of space has no substitute. Nobody names high schools after robots. People have said, "Look at the interest shown in the Mars rovers." That's undeniable, but let's go back forty years. There were robotic missions to the moon. Does anyone remember them who wasn't directly involved in them? Of course not, because people were going to the moon.

There's no substitute for the thrill of having one of your own explore, without specific reference to a scientific goal. We've been doing it from the very beginning, and I see no reasons why we wouldn't want to continue. For many people, it is *the* motivation for the exploration of space, because we can explore vicariously through the eyes of an explorer who can experience, who can feel, who can emote. People criticize the golf ball that was hit on the moon, but I celebrate that, because it's something a human would do. A robot follows your commands; humans can be a little naughty now and then. When you send one of your own, you can track that person, you can ask, "What school did they go to? What's their hometown?" There will be headlines on them, and every chapter in their past lives will be captured and celebrated by the press. You'll create role models. Robots just don't make role models.

If you want a nation to have space exploration ambitions, you've got to send humans. So if you catch me on a science day, I'm going to tell you, "Leave the people home." Then there's the reality check and I say, "We need to have people reaching the frontier of space exploration. That makes the headlines." History has shown that and the future will bear it out. You don't contrast rovers and shuttle missions; that's not the right comparison. When you spend all your time "driving around the block," where one mission is no more ambitious than the previous one, headlines do not follow—unless of course there's a disaster, like *Challenger* and *Columbia*. You've got to compare Mars rovers to human exploration of some place where humans have never been. Then find out who's getting the headlines.

COHEN: In one of your essays in *Death by Black Hole*, you say robots are only good at finding what you know you're looking for.

TYSON: I think a robot can find something unexpected but, yes, it's true you program a robot for what you expect to see. You program it to climb over a particular kind of rock, to look in a certain spectral band, to dig in a certain way. Something *completely* unexpected could go unnoticed.

COHEN: What do you think was the most significant accomplishment of NASA's first fifty years?

TYSON: People like to say it was landing on the moon. I'd phrase it in a different way. The most significant accomplishment was *saying* we would put someone on the moon and then doing it. I think we would eventually have put someone on the moon but to say it and then do it speaks to a high level of ambition. In some ways, the landing was the easy part. What you had to do to get to that point was the hard part. The Mercury missions and Gemini missions were steps toward landing on the moon: the one astronaut, the two, the three, the spacewalk, the docking—all of those were proving grounds. That's where the cross-pollination of the various engineering disciplines came in. The aerospace engineering, the material engineers, the scientists had to come together with a single mind. It's not often you get that for small projects, much less large ones, much less ones that are government-agency mandated. I think without question that's the greatest achievement.

COHEN: What would you like to see NASA commit itself to next?

TYSON: I'm not naïve enough to think that just because we went to the moon we're automatically going to land on Mars. What drove the moon landing was a flow of money commensurate only with times of war, because we were at war with the Soviet Union.

COHEN: NASA got 4 percent of the federal budget then.

TYSON: That was a war budget, and when you're at war you spend money. I think the greatest challenge now is to ask what else can drive the expenditure of money. One of the big drivers is the promise of the growth of wealth. So I think space tourism, which for a while was considered a fringe activity, may be the most important source of capital for the future of space exploration. Yes, one job of a government with foresight is to invest where capital markets have yet to tread, but then the government needs to open those pathways for others to create the market, allowing space travel to become routine.

COHEN: We're at the beginning of that process.

TYSON: You can smell it in the air. The entrepreneurs who are out there—the X PRIZE, Space X—have the goal of making space exploration cheap enough to attract tourists. Once you have an industry, you invite competitors that will continue to drive the price down and create more opportunity. I'm a big supporter of that notion. I think many futurists of the Apollo era were naïve. Nearly all of them said things like, "We're on the moon now, we're explorers, we're discoverers. Mars is next. We'll be on Mars by 1985." Reality check, please. Somebody is paying for this. Who? It's Congress. Why? Because of the communists. It wasn't because Congress thinks exploration is a great thing to do.

MARS ONCE WAS wet and fertile. IT'S NOW bone dry. SOMETHING BAD HAPPENED ON MARS. I WANT TO KNOW what happened on Mars SO THAT WE MAY PREVENT IT FROM HAPPENING HERE on Earth.

In fact the history of exploration across nations and across time is not one where nations said, "Let's explore because it's fun." It was, "Let's explore so that we can claim lands for our country, so that we can open up new trade routes; let's explore so we can become more powerful." It was never, "Let's explore so that we can understand science better." I wish it were, but there's no history of that. Maybe the explorers themselves felt that way, but somebody had to sign the check, and the people signing the check did not share those philosophies.

COHEN: Are there good ways to demonstrate the value of NASA to the public?

TYSON: I think one of the greatest ways to assess the value of an agency to a nation is to do the following experiment: ask people how much money they think an agency gets. When they do it for NASA, they think it's something like 10 percent of the federal budget. Then you tell people how much money they actually get. The ratio of those two numbers is the magnifier impact of every dollar spent. So the fact that everybody thinks NASA's budget is ten to fifty times larger than it is tells you how successful NASA is at what it does. That should be celebrated. If NASA is so visible that people think it's 10 percent of the federal budget when it's six-tenths of one percent, somebody's doing something right. There ought to be a government index that ranks agencies by how much money people think they're getting. I bet NASA would come out at the top. I think the public needs to understand more than technology spinoffs. I think much too much has been made of spinoffs.

COHEN: Although people are not aware of how much useful technology NASA has developed.

TYSON: That's true, and that story should be told no matter what. But I think NASA has a bigger story, a more noble story to tell. The exploration and research conducted by NASA have the potential to circumvent problems that right now we're simply running away from.

COHEN: Like what?

TYSON: Mars once was wet and fertile. It's now bone dry. Something bad happened on Mars. I want to know what happened on Mars so that we may prevent it from happening here on Earth. Venus has a runaway greenhouse effect. Something bad happened on Venus, too. It's an experiment that has already run its course there; we don't have the luxury of performing that experiment here on Earth. There are cosmic hazards that we were all ignorant of but certainly existed in 1900. We learned of them because of space exploration. For instance, asteroid impacts. One slammed into Earth 100 years ago this June in Tunguska, Siberia. We're cataloguing asteroids so that if a big one is headed this way, we can go out and deflect the damn thing rather than build shelters and try to run away from it. Without a space program, you end up running away from problems, when in fact we have scientists, engineers, clever people who can actually stop the thing in the first place. That's what vaccination was all about: instead of treating your symptoms, let's prevent the disease in the first place. That's taken for granted when it's done by medicine. But with other dangers, people might say, "This tornado is big, we need a better shelter," or, "I'll build a levee so that I don't get flooded next time," rather than stopping the storm system in the first place. A great thing about science is that you can control many things once you understand them. You can't just run away from problems all the time. Space exploration is a means of coming to understand our place in the universe because the universe is not always a garden of Eden. Sometimes it's hostile. So I see this investment as buying into our space security.

COHEN: One or more of the presidential candidates has talked about using most of NASA's money for Earth-related missions.

TYSON: You want some money on the earth, but if you always concentrate on the earth, you miss the stuff coming in from outside. Not only that. Discovering that which was unknown to the generation before you is a noble quest. Only the greatest of civilizations have had the luxury to do that. America is the country I want to live in because that is the kind of legacy we have enjoyed. I recently gave a talk to 900 people and the last question of the day was, "Suppose, in the new administration, everyone votes to cancel all science projects and devote the money to programs that help people. If you were given the choice of one and only one science project to have happen, what would that be?" You know what I'd do? I'd use that money to build a boat and sail to a country that's investing in science projects. America would no longer be the country I grew up in, the one that believes we'll have a tomorrow different from today because we've funded creative people whose goal in life is to make a better world. ●

Operation Burnt Frost:

THE POWER OF SOCIAL NETWORKS

BY LUCAS STEINHAUSER AND SCOTT THON

Photo Credit: U.S. Air Force/Airman 1st Class Jonathan Olds

Maj. Santos Munoz, Joint Functional Component Command for Space, and other Vandenberg leadership give farewells to airmen boarding a C-5 Galaxy headed to McGuire AFB, NJ, on February 15. Thirty-six airmen from the 30th Space Wing were deployed in support of Joint Task Force Burnt Frost.

On February 20, 2008, a single Standard Missile 3 (SM3), fired from the USS *Lake Erie* in the Pacific Ocean, shot down a National Reconnaissance Office satellite that was falling out of orbit and potentially posing danger to people around the globe. The ailing satellite's fuel tank contained nearly 1,000 lbs. of highly toxic hydrazine fuel. President Bush tasked U.S. Strategic Command with seeking a way to mitigate the danger to people around the world, and Operation Burnt Frost was born. The mission required the collaboration of more than two dozen federal agencies whose personnel were spread around the United States.

Coordination, communication, and knowledge sharing were major challenges, yet they were critical to the mission's success. Social networks played key roles in the successful outcome of the operation, connecting people and their knowledge.

Sociologists define social networks as connections among people, the informal personal relationships based on trust and reciprocity. In other words, they are made up of the people you know (and some of the people *they* know) who can be relied on to offer knowledge and assistance when you need them and who expect you to return the favor when and if the need arises.

This is one story of how social networks contributed to the success of Operation Burnt Frost.

Social Networks at Work

It was late one evening in December 2007. Colonel Michael Carey, deputy director of global operations for U.S. Strategic Command, and his team had been working all day to find an expert in modeling the orbit of space objects. Col. Carey got out his notebook of contacts and called an old colleague at home: "Hey, Jeff, I need your help real quick …." Jeff didn't know the answer, but he was able to give Col. Carey the name of an engineer he knew at NASA who was an expert in the area.

The challenge of intercepting a rapidly spinning, bus-sized satellite as it hurled through space at 17,000 mph was daunting and unlike anything the team had done before. The complex problem required expertise to calculate the necessary trajectory and to understand the likelihood of success. Finding the expert at NASA so quickly—through a couple of phone calls—was a huge benefit to the tightly scheduled mission. His involvement proved critical to mission success. He provided invaluable knowledge through analytical modeling and planning, information that fed operational plans and supported the decision briefing that went to the president of the United States.

The mission's success might have been jeopardized if Col. Carey hadn't been able to reach out and connect with the appropriate subject-matter experts. Leveraging expertise through individual social networks was a huge factor in the success of the operation. Many organizations were capable of supporting various critical tasks, but knowing and being able to contact the many subject-matter experts saved time, increased confidence, and improved mission effectiveness.

When it was over, Col. Carey recalled the numerous valuable contacts he and his team had accumulated, and the wealth of talent, skills, and specialized expertise they provided. Looking back, he expressed his desire to maintain the contacts and relationships made during the operation, contacts likely to prove fruitful for new missions and new challenges. And Col. Carey can now count himself as a member of all the social networks of all the subject-matter experts that he came in contact with during this operation.

FINDING THE EXPERT AT NASA SO QUICKLY—THROUGH A COUPLE OF PHONE CALLS—WAS A HUGE BENEFIT TO THE TIGHTLY SCHEDULED MISSION.

A Recognized Asset

Most of us have informal networks we can call on for information and assistance. Engineers, scientists, project leaders, and managers in many organizations rely on those contacts for expertise and advice. Some organizations—Whirlpool, Halliburton, Sanofi-Aventis, Chevron, and Caterpillar, for example—have made explicit efforts to support and strengthen the social networks

Photo Credit: U.S. Navy

The USS Lake Erie *launched a Standard Missile 3 at a non-functioning National Reconnaissance Office satellite as it traveled in space at more than 17,000 mph over the Pacific Ocean.*

of their employees. Frequently including relationships that go beyond their organizational boundaries, these connections can promote cross-cultural, global collaboration by connecting individuals who share similar interests.

These personal connections can center on a common passion or profession—for instance, space launch or a technical discipline—or shared experience, like attending school together. Research has shown that high performers typically have especially robust connections outside their unit or organization.

Networks can be supported by a wide range of communication media; face-to-face interactions are powerful and important builders of trust and understanding, but telephone, e-mail, and Web-based collaboration tools also help maintain social networks. New social networking tools such as LinkedIn and Facebook help people stay in contact as they move to new organizations or new job responsibilities.

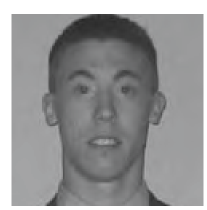
FOUR WAYS TO STRENGTHEN YOUR SOCIAL NETWORK

1. **Actively participate in communities of practice.** In many organizations, formal and informal communities bring together people with shared interests and related experiences. Such communities excel at knowledge sharing and developing professional and personal contacts.
2. **Contact the author.** If you read an interesting article, blog, or Web page, follow up with the author to share ideas and learn more.
3. **Participate in organizational social functions.** These events allow you to establish relationships with individuals outside your branch or division and give you access to diverse knowledge and experience.
4. **Join professional organizations and attend conferences.** These activities provide opportunities to extend your networks beyond the boundaries of your organization and to get new perspectives on your own knowledge.

Networking and Collaboration = Success

On February 20, the SM3 streaked skyward. Moments later, the efforts of hundreds of subject-matter experts, linked together by their personal and professional connections, paid huge dividends 150 miles above the earth as the missile slammed into the falling satellite, smashing it to pieces that would harmlessly burn up in the atmosphere. This impressive technical accomplishment was an equally impressive organizational accomplishment. Extensive social networking played a key role throughout the operation and was a major part of the successful intercept. ●

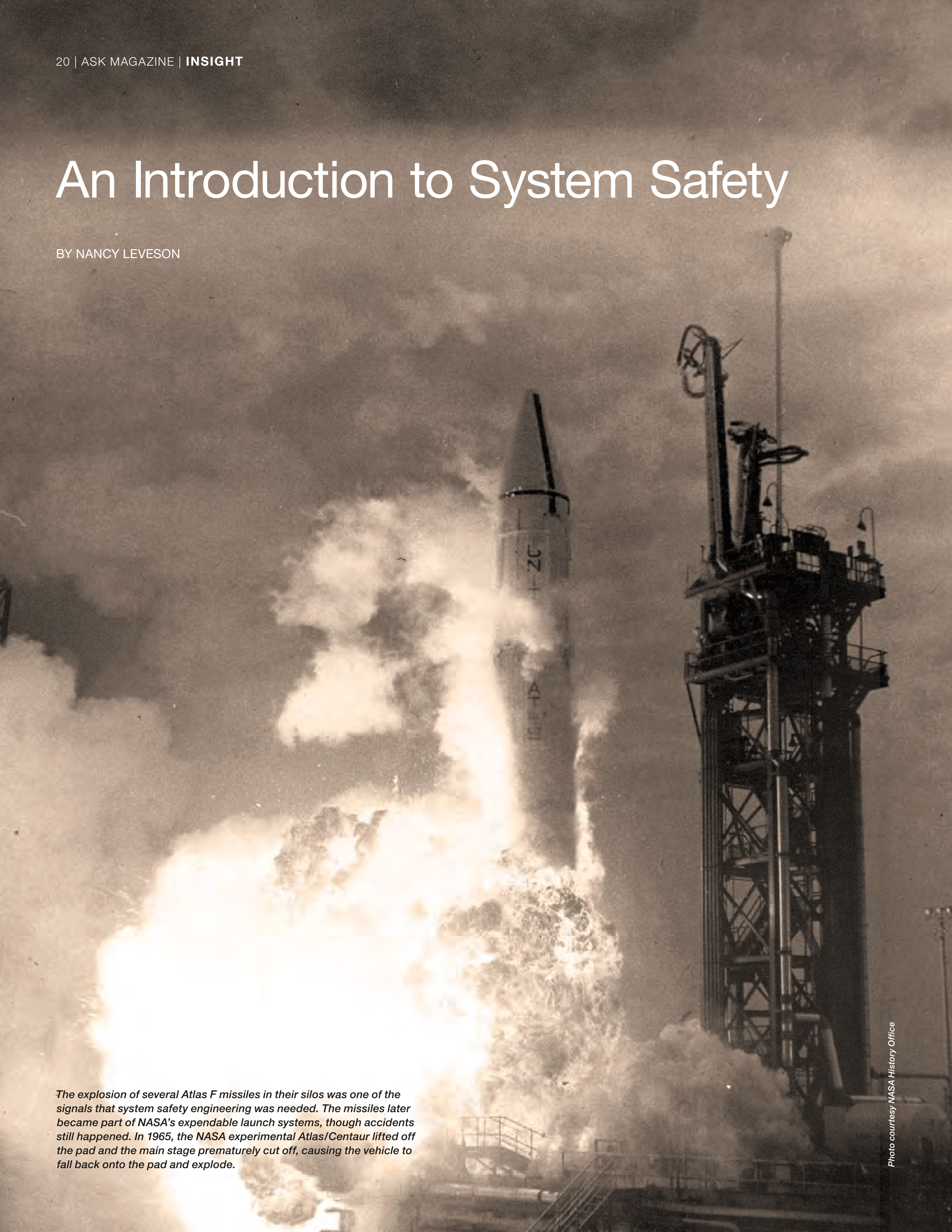
LUCAS STEINHAUSER is the deputy chief of the Knowledge Transfer Office at U.S. Strategic Command. He recently received a doctorate in information systems and technology from the University of Nebraska at Omaha. His research focuses on the use of collaborative work practices that are enabled through information technology.



SCOTT THON leads the Knowledge Transfer Office at U.S. Strategic Command. He is dedicated to implementing innovative knowledge transfer concepts that leverage social and human capital within the Command. A graduate of the U.S. Army War College in Carlisle, Pennsylvania, he holds a BS in business from the University of Minnesota and an MS in logistics from the Naval Postgraduate School in Monterey, California.

An Introduction to System Safety

BY NANCY LEVESON



The explosion of several Atlas F missiles in their silos was one of the signals that system safety engineering was needed. The missiles later became part of NASA's expendable launch systems, though accidents still happened. In 1965, the NASA experimental Atlas/Centaur lifted off the pad and the main stage prematurely cut off, causing the vehicle to fall back onto the pad and explode.

Photo courtesy NASA History Office

System safety uses systems theory and systems engineering approaches to prevent foreseeable accidents and minimize the effects of unforeseen ones. It considers losses in general, not just human death or injury. Such losses may include destruction of property, loss of mission, and environmental harm.

A Little History

Rigorous, defined approaches to safety engineering mostly arose after World War II, when the Atomic Energy Commission (and later the Nuclear Regulatory Commission) were engaged in a public debate about the safety of nuclear power; civil aviation was trying to convince a skeptical public to fly; the chemical industry was coping with larger plants, increasingly lethal chemicals, and heightened societal concern about pollution; and the Department of Defense (DoD) was developing ballistic missile systems and increasingly dangerous weapons. These parallel efforts resulted in very different approaches, mostly because the problems they needed to solve were different.

While the nuclear power, commercial aircraft, chemical, and other industries have taken a conservative approach to introducing new technology, changing designs slowly over time, defense and space systems have pushed the technology envelope, developing tremendously complex, novel designs that stretched the limits of current engineering knowledge, continually introducing new and unproven technology, with limited opportunities to test and learn from extensive experience. In response, a unique approach to engineering for safety, called system safety, arose in these industries.

When the Atlas and Titan intercontinental ballistic missiles (ICBMs) were being developed in the 1950s, system safety was not yet identified and assigned as a specific responsibility. Instead, each designer, manager, and engineer was responsible for the reliability of his particular component or subsystem. As a result, many interface problems went unnoticed until it was too late. Within eighteen months after the fleet of 71 Atlas F missiles became operational, four blew up in their silos during operational testing. The missiles also had an extremely low launch success rate. The air force had typically blamed most accidents on pilot error, but these new liquid-propellant missiles had no pilots to blame and yet blew up frequently and with devastating results. When these early losses were investigated, a large percentage of them were traced to deficiencies in design, operations, and management. The importance of treating safety as a *system* problem became clear and, as a result, systems engineering and system safety (a subdiscipline of systems engineering) were developed.

The Minuteman ICBM became the first weapon system to have a contractual, formal, disciplined system safety program. At first, few techniques that could be used on these systems existed, but specialized system safety practices evolved over time. Particular emphasis was placed on hazard analysis techniques, such as fault trees, which were first developed to cope with complex programs like Minuteman. While these techniques were useful for the technology of the time, new technologies, particularly digital technology and software, have made many of them no longer appropriate for the increasingly complex, software-intensive systems we build today. Unfortunately, recognition of these limitations has been slow. Attempts to apply techniques developed for the simpler and primarily electro-mechanical systems of the past continue, with only partial success.

The space program was the second major area to apply system safety approaches in a disciplined way. After the 1967 Apollo 1 fire that killed three astronauts, NASA commissioned the General Electric Company at Daytona Beach, among others, to develop policies and procedures that became models for civilian space flight safety activities. Jerome Lederer was hired to head safety at NASA. Under his leadership, an extensive system safety program was set up for space projects, much of it patterned after the air force and DoD programs. Many of the same engineers and companies that had established formal system safety defense programs also were involved in space programs, and the systems engineering and system safety technology and management activities were transferred to this new work.

But as time has passed without major new manned space flight development projects at NASA, many of the very effective NASA system safety practices have been replaced by reliability engineering and approaches to safety used by industries with very different requirements. For Constellation to be successful, traditional system safety practices will need to be reemphasized and extended to handle new technology, particularly extensive use of software and computers.

What Is System Safety?

The primary concern of system safety is the management of system hazards as opposed to emphasis on eliminating component failures in reliability engineering. Borrowing Thomas Huxley's definition of science, in 1968 George Mueller described the then-new discipline of system safety engineering as "organized common sense." It is a planned, disciplined, and systematic approach to identifying, analyzing, eliminating, and controlling hazards by analysis, design, and management procedures throughout a system's life cycle. System safety activities start in the earliest concept development stages of a project and continue through design, production, testing, operational use, and disposal.

Although system safety is a relatively new and still-evolving discipline, some general principles hold for its various manifestations and distinguish it from other approaches to safety and risk management.

- **System safety emphasizes building in safety, not adding protection features to a completed design.** System safety emphasizes the early identification of hazards so action can be taken to eliminate or minimize them in early design decisions; 70 to 90 percent of the design decisions that affect safety are made in concept development, requirements definition, and architectural design. The degree to which it is economically feasible to eliminate or minimize a hazard rather than to control it depends on the stage in system development at which the hazard is identified and considered. Early integration of safety considerations into the development process allows maximum safety with minimum negative impact. The usually more expensive and less effective alternative is to design first, identify the hazards, and then add on protective equipment to control the hazards when they occur. A recent demonstration project for the Jet Propulsion Laboratory showed how safety can be designed into a spacecraft (an outer-planets explorer, in this case) from the early concept formation and trade study stages. New hazard analysis approaches that include software were used. (See http://sunnyday.mit.edu/papers/IEEE-Aerospace.pdf.)

- **System safety deals with systems as a whole rather than with subsystems or components.** Safety is an emergent property of systems, not components. One of the principle responsibilities of system safety is to evaluate the interfaces between the system components and determine the effects of component interaction. (The

The Minuteman ICBM became the first weapon system to have a formal, disciplined system safety program. Here, a Minuteman II launches successfully.

Photo Credit: U.S. Air Force

FOR CONSTELLATION TO BE SUCCESSFUL, TRADITIONAL SYSTEM SAFETY PRACTICES WILL NEED TO BE REEMPHASIZED AND EXTENDED TO HANDLE NEW TECHNOLOGY, PARTICULARLY EXTENSIVE USE OF SOFTWARE AND COMPUTERS.

set of components includes humans, machines, and the environment.) Safety is an *emergent system property*. It is not possible to determine whether a spacecraft design is acceptably safe, for example, by examining a single valve. In fact, statements about the "safety of the valve" without information about the context in which it is used are meaningless. Conclusions can be reached about the *reliability* of the valve (defined as the probability that the behavior of the valve will satisfy its specification over time and under given conditions), but safety can only be determined by the relationship between the valve and the other spacecraft components, in the context of the whole.

- **System safety takes a larger view of hazard causes than just failures.** A lack of differentiation between safety and reliability is widespread at NASA and elsewhere. Hazards are not always caused by component failures, and all failures do not cause hazards. Reliability engineering concentrates on component failure as the cause of accidents and a variety of techniques (including redundancy and overdesign) are used to minimize them. As early missile systems showed, however, losses may arise from interactions among system components; serious accidents have occurred when the system components were all functioning exactly as specified. The Mars Polar Lander loss is an example. Each component worked as specified but problems arose in the interactions between the landing leg sensors and the software logic responsible for shutting down the descent engines. Reliability analysis considers only the possibility of accidents related to failures; it does not investigate potential damage that could result from *successful* operation of individual components. Software, ubiquitous in space systems today, is an important consideration here. In most software-related accidents, the software operates exactly as intended. Focusing on increasing the reliability with which the software satisfies its requirements will have little impact on system safety.

  Reliability and safety may even conflict. Sometimes, in fact, increasing safety can decrease system reliability. Under some conditions, for instance, shutting down a system may be an appropriate way to prevent a hazard. That increasing reliability can diminish safety may be a little harder to see. For example, increasing the reliability (reducing the failure rate) of a tank by increasing the burst pressure–to–working pressure ratio may result in worse losses if the tank does rupture at the higher pressure. System safety analyses start from hazards, not failures and failure rates, and include dysfunctional interactions among components and system design errors. The events leading to an accident may be a complex combination of equipment failure, faulty maintenance, instrumentation and control inadequacies, human actions, design errors, and poor management decision making. All these factors must be considered.

- **System safety emphasizes analysis in addition to past experience and codes of practice.** Standards and codes of practice incorporate experience and knowledge about how to reduce hazards, usually accumulated over long periods of time from previous mistakes. While the use of such standards and learning from experience is essential in all aspects of engineering, including safety, the pace of change today does not always allow for such experience to accumulate. System safety analysis attempts to anticipate and prevent accidents and near misses *before* they occur, in addition to learning from the past.

- **System safety emphasizes qualitative rather than quantitative approaches.** A system safety approach identifies hazards as early as possible in the design stage and then designs to eliminate or control those hazards. At these early stages, quantitative information usually does not exist. Although such information would be useful in prioritizing

Photo Credit: NASA

Seated at the witness table before the Senate Committee on Aeronautical and Space Services hearing on the Apollo 1 accident are (left to right) Dr. Robert C. Seamans, NASA deputy administrator; James E. Webb, NASA administrator; Dr. George E. Mueller, associate administrator for Manned Space Flight; and Maj. Gen. Samuel C. Phillips, Apollo Program director. In an effort to prevent another such tragedy from occurring, NASA commissioned the General Electric Company and others to develop policies and procedures that became models for civilian space flight safety activities.

hazards, subjective judgments about the likelihood of a hazard are usually adequate and all that is possible when design decisions must be made. In addition, probabilistic risk analyses that exclude potential causes of an accident, including interactions among non-failing components, design errors, software and hardware requirements errors, and poor management decision making, can lead to dangerous complacency and focusing engineering efforts only on the accident causes for which those measures are possible. If enough were known about factors such as design errors to define a probability for them, then safety would be more effectively enhanced by removing the design error than by measuring it in order to convince someone that it will never cause an accident. In the case of the Mars Polar Lander, if the scenario that unfolded had been known and could have been included in a probabilistic risk analysis, then the engineers would have had enough information to change the software so the unsafe control command would not be issued.

- **System safety is more than just systems engineering and must incorporate management and safety culture concerns.** System safety engineering is an important part of system safety, but the concerns of system safety extend beyond the traditional boundaries of engineering. In 1968, Jerome Lederer, then the director of the NASA Manned Flight Safety Program for Apollo, wrote:

> System safety covers the total spectrum of risk management. It goes *beyond* the hardware and associated procedures of system safety engineering. It involves: attitudes and motivation of designers and production people, employee/management rapport, the relation of industrial associations among themselves and with government, human factors in supervision and quality control, documentation on the interfaces of industrial and public safety with design and operations, the interest and attitudes of top management, the effects of the legal system on accident investigations and exchange of information, the certification of critical workers, political considerations, resources, public sentiment, and many other nontechnical but vital influences on the attainment of an acceptable level of risk control. These nontechnical aspects of system safety cannot be ignored.

Using these general principles, system safety attempts to manage hazards through analysis, design, and management procedures. Key activities include analyzing system hazards from the top down, starting in the early concept design stage to eliminate or control hazards and continuing during the life of the system to evaluate changes in the system or the environment; documenting and tracking hazards and their resolutions (establishing audit trails); designing to eliminate or control hazards and minimize damage; maintaining safety information systems and documentation; and establishing reporting and information channels. ●

For more information see the following:

- *http://sunnyday.mit.edu/papers/jsr.pdf*
- *http://sunnyday.mit.edu/accidents/safetyscience-single.pdf*
- *http://sunnyday.mit.edu/ESMD-Final-Report.pdf*

NANCY LEVESON is a professor of aeronautics and astronautics at Massachusetts Institute of Technology. She has been associated with NASA for more than twenty years, was a member of the NASA Aerospace Safety Advisory Panel at the time of the *Columbia* loss, and was a consultant for the *Columbia* Accident Investigation Board. She is a member of the National Academy of Engineering.

Featured Invention:
NASA Spinoff Technology Helps Detect Cardiovascular Disease

BY DANIEL LOCKNEY

Photo courtesy NASA Spinoff

ArterioVision measures the thickness of the first two layers of the carotid artery wall using an ultrasound procedure and advanced image-analysis software.

For decades now, NASA has been sending spacecraft throughout the solar system. Once in space, many of these craft use advanced cameras to create images of corners and crevices of our universe never before seen and then transmit these pictures back to laboratories on Earth, where scientists then ask: *What exactly are we looking at?*

That question is often answered at NASA's Jet Propulsion Laboratory (JPL) in the Image Processing Laboratory, founded in 1966 to receive and make sense of spacecraft imagery. There, NASA-invented VICAR (Video Image Communication and Retrieval) software has, through the years, laid the groundwork for understanding images of all kinds. The original software, created by a JPL team of three—Robert Nathan, Fred Billingsley, and Robert Selzer—is still in use today, although with improvements that offer greater accuracy and effectiveness.

The imaging division at JPL has grown increasingly sophisticated over the years, developing new processes and technologies to handle increasingly complex acquisitions from NASA science missions, from the Voyager images of Saturn and Jupiter taken in the 1970s to new imagery captured by the Mars Reconnaissance Orbiter in late 2006 that suggests water still flows on Mars, opening the possibility that the red planet could perhaps support life.

Partnership

Selzer, from the original VICAR team, has made the NASA imaging technology his life's work, spending forty-six years as a NASA employee and continuing to work on its advancement even after his retirement from JPL. He received many NASA awards for technical achievement, including the prestigious Technology and Application Program Exceptional Achievement Medal. During the last fifteen years of his career as a government scientist, he led the JPL Biomedical Image Processing Laboratory, working on medical applications of the imaging technology.

The project began when the imaging team developed the idea of using the VICAR software to analyze X-ray images of soft tissue. Typically, X-rays are not effective for this purpose, but researchers thought the imaging software might change that. The results were interesting, but too much quality was lost in transferring the pictures into a digital format for useful analysis. Still, the idea seemed promising, so, with several grants from NASA, the testing continued.

Selzer's JPL team, partnering with scientists from the University of Southern California under the direction of the late Dr. David Blankenhorn and Dr. Howard Hodis, director of the Atherosclerosis Research Unit at the school's Keck School of Medicine, began to image X-rays of arteries. Achieving only marginal success, they hit upon the idea of applying the software to ultrasound imagery, which was already digitally formatted. The new approach proved successful for assessing plaque buildup and arterial wall thickness, direct predictors of heart disease. Testing continued, and the team, buoyed by its successes, began looking for outside funding and methods of distribution. At this point, Gary F. Thompson entered the picture.

Thompson has a history of heart disease in his family. The first male in many generations to live past age fifty, and the last living male in his family line, Thompson comes from a long line of active, athletic men who, with no prior symptoms, suffered fatal heart-related events. A lifelong athlete who had boxed in the New York City Golden Gloves tournament in his youth and ran his first marathon in 1975, Thompson was understandably concerned, but feeling confident, when he approached his fiftieth birthday. He had the family history working against him, but he was also in prime shape. To celebrate his half-century mark, he planned to run three marathons—Los Angeles, New York, and Boston—and he underwent a battery of medical tests, all of which confirmed that he was in perfect health, without any signs of cardiovascular disease.

Seven days after his birthday, Thompson ran the Los Angeles marathon. At the fifteenth mile, he started experiencing

Photo courtesy oNASA Spinoff

ArterioVision uses a proprietary database and JPL-developed algorithms to show percentile of risk for atherosclerosis.

back pain. By the twentieth mile, it became so excruciating that he stopped running. Later, at the hospital, doctors confirmed that he had suffered a moderate heart attack and lost 48 percent of his heart muscle. Modern medical testing, he realized, had failed him. Luckily for Thompson, having 52 percent of his heart working was the equivalent of 127 percent for men of his age, because he was so athletic.

Months later, at dinner with David Baltimore, then president of the California Institute of Technology, Thompson asked about new heart-related breakthroughs and was surprised to hear that there was, indeed, a new technology that had been developed at JPL: a noninvasive diagnostic system with the ability to accurately predict heart health. Baltimore offered to set up an appointment for Thompson at the University of Southern California hospital where this new method was being tested, but Thompson declined.

THIS NEW DEVICE HAD MANAGED TO FIND WHAT ALL THE OTHER TESTS HAD MISSED.

Instead, he went in on his own, unannounced, and without revealing his family history or heart attack. Despite his recent heart attack, he gave every impression of great health. A technician performed an ultrasound scan on either side of his neck, the location of the carotid arteries. When the results were in, the technician told Thompson that he needed to meet with the doctor immediately. The test showed that Thompson had the thickest artery walls of the more than 3,000 people tested, a clear indicator that he was in danger of a heart attack or stroke.

Thompson was impressed. This new device had managed to find what all the other tests had missed. Thompson, a hard-charging entrepreneur, met with the researchers Selzer and Hodis and told them that they needed to get this technology into the hands of physicians. They agreed. Thompson developed a business plan, secured an exclusive license for the JPL-developed technology from Caltech, and invested his own money to start Medical Technologies International Inc. (MTI) in Palm Desert, California. Selzer now serves as the company's chief engineer.

Product Outcome

MTI licensed fourteen research institutions around the world for pre-U.S. Food and Drug Administration clearance and research-only use of the analysis software, and incorporated feedback from these groups into the new clinical product it was developing. It patented the new developments and then submitted the technology to a rigorous review process at the FDA, which cleared the device for public use. MTI also filed with the American Medical Association to have the device given a dedicated Current Procedural Technology (CPT) code for insurance purposes, thus encouraging more doctors to offer this test to patients.

The patented software is being used in MTI's ArterioVision, a carotid intima-media thickness (CIMT) test that uses ultrasound image-capturing and analysis software to noninvasively identify the risk for the major cause of heart attack and strokes: atherosclerosis, a buildup of cholesterol and fatty substances in the arteries, combined with arterial hardening. Atherosclerosis, referred to by the American Heart Association (AHA) as the "silent killer," initially has no discernable symptoms until one or more of the arteries becomes so congested that these major, sometimes fatal, problems occur. The AHA estimates that two out of three unexpected cardiac deaths occur without prior symptoms.

Using ultrasound image-capturing and analysis software, ArterioVision noninvasively identifies the risk for the major cause of heart attacks and strokes.

In fact, astronaut Edward White, the first astronaut to ever perform a spacewalk and one of the three space pioneers to die during the Apollo launchpad tragedy in 1967, was thought by most to be in perfect health, having successfully passed the rigorous astronaut testing. An autopsy directly after the accident, though, revealed that he had extreme thickening of the arteries and showed most signs of heart disease.

Unlike CT scans, which are expensive and pose some radiation risk, the NASA-based technology poses no risks, and it is relatively inexpensive. The imaging technology can distinguish between 256 different shades of gray and differentiate nuances at a subpixel level of interpolation, making it the most accurate in this field, and it is compatible with all existing ultrasound machines, making it readily accessible to physicians.

While ArterioVision is not the only FDA-cleared CIMT tool on the market, it is the only one that offers a predictive report for the physician and patient. It explains the significance of test results using a proprietary database and JPL-developed algorithms and can extrapolate to show percentile of risk.

One particular feature of the report is the revelation of arterial age. It can show the patient that while he may be fifty years old, his arteries may be the equivalent of patients seventy-five years old. This real-world number is something patients can identify with and helps promote compliance with drug therapies and other forms of treatment—one of the most difficult aspects of preventing and treating heart disease. Physicians often lament that they stress the importance of lifestyle changes to their patients, but since heart disease does not initially come with symptoms, but instead with potentially fatal events, it is often difficult to impress upon the patients the urgency of taking care of their hearts. The ArterioVision patient report provides a significant warning sign and gives concrete examples.

Currently, the technology is being used in all fifty states and in many countries throughout the world. MTI is continuing to push this lifesaving technology and is rapidly expanding its sales force in an effort to live up to its company credo, "Making a Positive Difference Every Day."

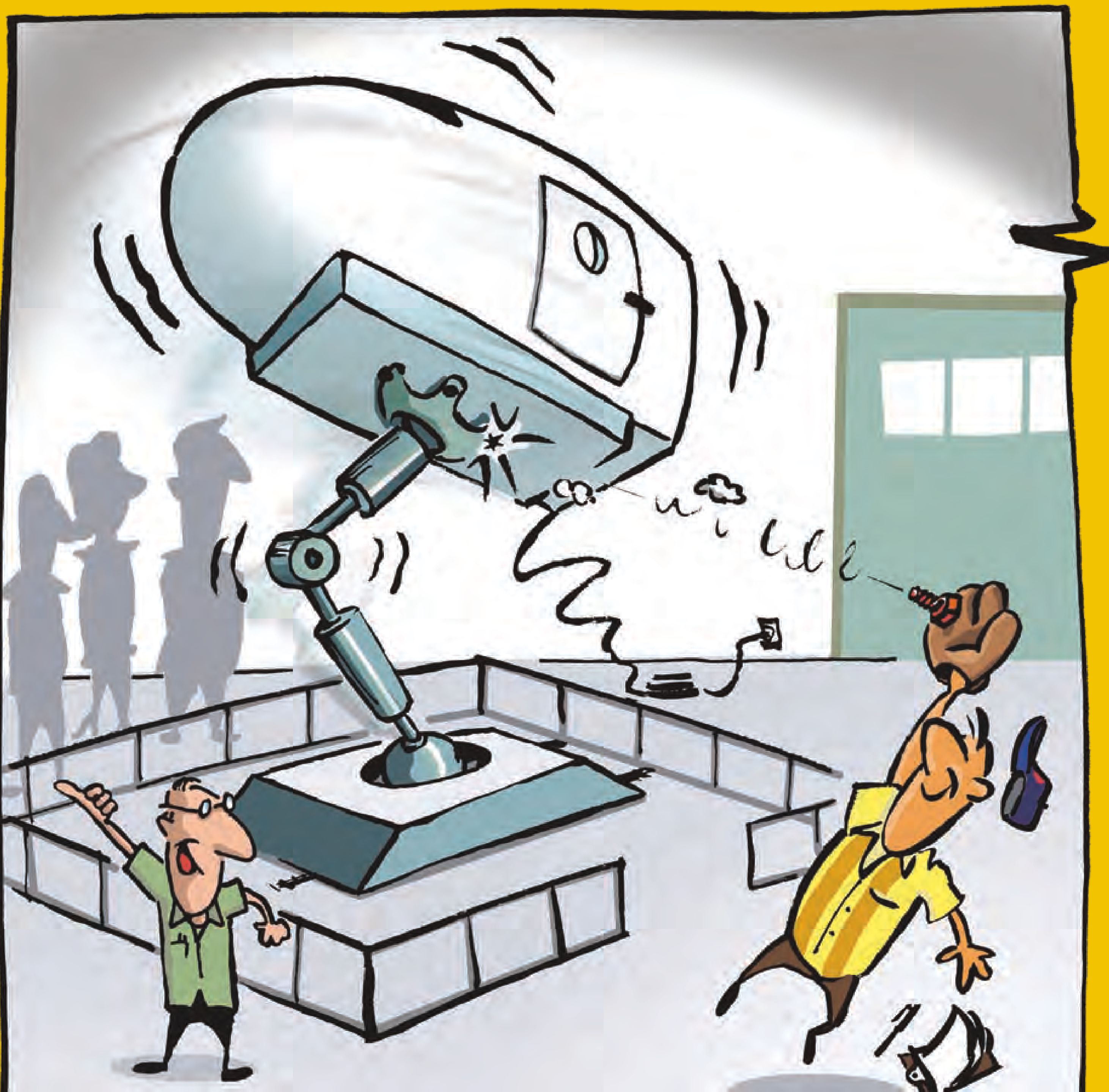
In April 2008, this NASA spinoff technology was inducted into the Space Technology Hall of Fame. Without the researchers' dedication to finding new applications for their imaging software and a vigilance for testing the result in the field, this medical innovation may never have made it outside JPL's walls. ArterioVision's success shows more than what's inside the heart; it shows how creative thinking and communication can make a difference in the health and well-being of others. ●

This article was originally published in NASA's Spinoff 2007 *(http://www.sti.nasa.gov/tto).*

DANIEL LOCKNEY is editor of the NASA publication *Spinoff,* which shows the practical, tangible benefits of the nation's investment in aerospace research. Since 1976, *Spinoff* has documented more than 1,600 NASA-derived technologies in the categories of medicine, transportation, safety, environmental resource management, computers, and manufacturing technology.

Staying Motivated During TOUGH TIMES

BY JENNIFER COLE



Our team was working with the Department of Homeland Security (DHS) on one of those rare projects that is just big enough. In other words, we had just enough experts on board to be effective yet flexible. I was the youngest as the chief engineer. Although I'd been chief engineer on a project or two before, this was my first time working directly with another government agency. I was relatively new to working with my NASA team, which included seven engineers and pilots. Our team was diverse in terms of experience, skills, and personalities, but we had one thing in common: we really enjoyed the task at hand.

That task consisted of figuring out how to safely control and land an airliner using just the thrust from the engines. This is called throttles-only control (TOC). We weren't allowed to modify the airliner in any way, given the time and cost involved, and we had to use a "stock" airliner with line pilots. The idea was to give the pilots an emergency checklist that would provide them with the most useful information in the shortest time to learn how to fly TOC. Homeland Security was interested in expertise Dryden Flight Research Center gained from the earlier propulsion-controlled aircraft (PCA) project, which demonstrated the feasibility of the idea with an automatic MD-11 landing using just engine thrust for all axes of control. Although that project employed extensive modifications to the aircraft and engines, the concept of throttles-only control was researched extensively, in both airplanes and simulations.

Dryden didn't have in-house simulations of the airliner, and our test pilots are probably far from being representative of line pilots. So DHS made arrangements with an airline to get access to their simulations and their pilots and carry out a test flight with their airplanes. We research engineers are used to working with simulations rife with every parameter imaginable, delivered in a standard format and at a specified data rate. An airline simulation, however, is used for pilot training and certification. Our first challenge was to set up a conversation with the airline's simulation engineer to identify the common ground between the limitations of the training simulation and our engineering needs. The simulation data was going to form the foundation of our flights, so the quality, format, and type of data were of critical importance.

Initially, this presented a challenge from both sides as we tried to make a training simulation into an engineering simulation. We struck common ground when we were finally face to face and could explain what we needed and what the airline could provide without significant modifications. As we worked together, the simulation engineer suggested improvements that helped us out a lot. By the way, that conversation continued until the very last day of our work, as our parameter list evolved and the last data set was produced. It is clear now that this open, solid communication link with our simulation engineer was a critical aspect of the project's success; it enabled us to get the best and most consistent data set possible.

Next was scheduling time in the simulation. Because of their intended use, airline simulations are tightly scheduled in multihour blocks around the clock. Although the airline was getting paid for our time in the simulation, we didn't exactly outrank the captains, who got the prime spots. We usually had the 6:00 a.m.–10:00 a.m. slot, but once or twice we got bumped to the 10:00 p.m.–2:00 a.m. slot. I felt especially bad for our simulation engineer, who remained essentially "on call" during our simulation times in case we crashed it (as one might crash a computer), couldn't reset it, or realized we'd left a parameter or two out of our required list. We strove to maintain a good working relationship with him by giving him as much lead time as possible to make modifications. In the beginning, both entities set clear expectations, which helped establish a good working foundation. Throughout the project, we treated his support of our work in the simulation with top priority.

We had a limited number of simulation hours, and a limited amount of travel money, so we meticulously planned every last minute of those simulation visits, which took us one time zone and three states away from California.

We were in the zone, so to speak, getting great data. We had one flight under our belt and had established an excellent working relationship with both Homeland Security and the airline. We kept all our customers in the loop on our progress, and we didn't sugarcoat it. When we had a concern, we made sure to communicate it in the context of how it would affect the final product, and we communicated it to the appropriate level and with a workable solution, if we had one.

As with any engineering endeavor, our team had to make certain simplifying assumptions to stay within the scope of the task. As we progressed further into the research, we kept a running list of our unknowns and key assumptions. Some time after the first flight, we had identified plenty of areas for further research. Together, we organized and prioritized several key areas that we felt warranted further study, from validating our simplifying assumptions to exploring the checklist's application to other airframes, and presented our ideas to DHS. Because we already had the group identified and working together, it made sense to build the foundation necessary to explore these other areas now to simplify our efforts later, if DHS wanted to fund further work. Then we ran into a big brick wall.

The DHS program office that was supporting us had its funding redirected due to new priorities. Almost overnight, our current work and certainly our future work were in jeopardy. Our small group took this rather hard as there is nothing worse than pouring your heart and soul (and weekends!) into a project and then getting the rug yanked out from under you. Although we had all experienced this before in our aerospace careers, this one stung especially hard, perhaps because we were such a small, flexible group and were giving the customer exactly what they wanted. Although we weren't cheap, we were conducting research effectively and efficiently, the way all projects intend. As the technical experts, we were given the authority to make technical decisions, even big ones. If we had a question about project scope or aircraft capability, we had the phone number of the person who could answer it.

As the chief engineer, I served largely as "management" when we were on travel, so I learned firsthand about problems and successes. Now, it was incumbent upon me to keep us moving toward our goal, doing as much as we could for as long as we could, without getting mired in the muck of why this had to happen and also searching for a reason we understood.

First things first: we refocused on the task at hand. There was a possibility that we wouldn't get a second flight, which meant that we had to reprioritize our simulation times. We had to strike a balance between pilot availability and simulation time; if pilots weren't available at the same time as the simulation, we had a prioritized list of research maneuvers to do instead with the rest of the research team. When the pilots were there, we focused more on refining the checklist. Either way, we functioned as a well-oiled machine, quickly moving from one maneuver to the next. Every person in the simulation (and for the flights) had a specific role, from pilot to flight test engineer to qualitative data recording.

ONCE THE TEAM HAD ITS SIGHTS SET ON WHAT WE COULD STILL DO, WE STOPPED WASTING ENERGY ON THE THINGS WE COULDN'T CONTROL.

IT WAS THE LITTLE THINGS—THE OATMEAL BREAKFAST BEFORE THE SIMULATION SESSION AND THE TURKEY SANDWICHES AND APPLE PIE AFTERWARD, THE COMPLIMENTARY HOTEL COFFEE, THE *SIMPSONS* JOKES, AND THE VORTEX OF ACTIVITY THAT ALWAYS FOLLOWED ONE PARTICULAR TEAM MEMBER—THAT KEPT US GOING DURING THE TOUGH TIMES.

Once the team had its sights set on what we could still do, we stopped wasting energy on the things we couldn't control. We communicated our tweaked "replan" back to DHS and the airline to make sure our priorities still aligned. We kept the conversation focused on the minimum level of support we needed to still deliver a product and what that product would look like. All the players were in the room, and everyone had a stake, operating just as we had since the beginning. Ultimately, we were able to get everyone's concurrence, and DHS gave us the approval to proceed.

We headed back to the simulations. It was difficult to get remotivated, sitting in the simulation before the sun was even up and gearing up for another four hours in close quarters. Our jokes turned sarcastic, and we had some exhausted faces at dinners. Generally speaking, I am a rather happy person who always tries to look on the bright side of things, but even I was really disappointed.

Rather than try and be the lone ray of sunshine, I concentrated on keeping our group on schedule. We still had breakfast at the cafeteria every morning before our sessions and lunch afterward. We still had dinners in the local restaurants, we still met for coffee in the hotel lobby, and we always met during our long afternoons to discuss what we'd learned that day and how it affected the next day's work. This helped to keep the group together as we moved forward.

Remember the diverse set of personalities mentioned earlier? The potpourri of people on this project really helped to keep us going and smiling. One member of the group seemed particularly susceptible to adventures during travel, from getting upgraded to first class because of purported center-of-gravity issues to taking off before the rest of the group and somehow landing after us. His stories provided much needed humor and a sense of anticipation as we all wondered what the story was going to be *this* time. Another engineer had to be talked into joining us for our simulation sessions. I pseudo-bribed him into going with us by loaning him seasons from my collection of *The Simpsons* DVDs. This became a running joke, as we ran out of simulation sessions before I ran out of *Simpsons* episodes. We learned that pilots enjoy eating almost as much as they enjoy flying, and our simulation engineer became known as God, as only he could bring us back from a failed maneuver or save our data.

It was the little things—the oatmeal breakfast before the simulation session and the turkey sandwiches and apple pie afterward, the complimentary hotel coffee, the *Simpsons* jokes, and the vortex of activity that always followed one particular team member—that kept us going during the tough times. We finished our simulation sessions, received permission to do our final flight, obtained one-of-a-kind data, and finished the year with our final report to Homeland Security. Two years later, we are still fielding requests for presentations and the occasional interview, and our team's collective efforts have been recognized with a NASA Group Achievement Award. ●

JENNIFER COLE is chief of the Research Aerodynamics and Propulsion Branch at Dryden Flight Research Center in Edwards, California.

The Optimized Project Portfolio

BY MICHAEL A. HALL

Albert Burkholder is vice president of group operations for Griffin Systems, Inc. Sitting in a blazing hot office in the El Centro facility, he is reflecting on what he has heard and seen today during the operations meeting with Ed Cruz, the site operations director. Albert understands the importance of having a strategy. He also realizes many of the projects Ed just reported on will yield no measurable strategic results.

USING AN EFFECTIVE PORTFOLIO MANAGEMENT PROCESS PROVIDES THE MEANS FOR PEOPLE TO FOCUS ON THE CRITICAL FEW INITIATIVES THAT WILL DELIVER RESULTS AND REDUCE COMPLEXITY IN A GIVEN TIME.

Months earlier, Albert and the leadership team spent several days off site to formulate a two-year strategy and agreed on a list of twenty-one initiatives to achieve it. For the past four years, revenue has been in decline in every market they serve. On a brighter note, strategy implementation started ten months ago and a few of the initiatives increased revenue growth during the past three quarters. The most recent quarterly report shows a 5 percent increase last month and a 7 percent increase in year-to-date revenue. Increasing revenue for three straight quarters is a significant improvement, but contract delivery performance, part quality, and scrap rates are all tracking in the wrong direction. The strategy identified two of these areas—dedication to quality and "do what we say we will do"—as fundamental beliefs and outlined initiatives to address them.

Albert and the team are concerned that the sites cannot handle all the projects. How can the leadership team be sure the right things are being done? What can be done to make sure the organization's project teams are communicating clearly and understanding each other? Albert and his team were learning an important lesson about strategic success. Success is a function of the strategy's quality *and* the effectiveness and efficiency of its implementation.

Judging projects in terms of their contribution to strategic and operational objectives, organizations can develop a project- and program-selection process—or *project portfolio process*—to set priorities. Project portfolio management is like the process used to manage an individual's investment portfolio. Investors set objectives that are used to evaluate investment choices, ensuring proper emphasis and risk management. The same thinking guides project portfolio management. Establishing an optimal project portfolio aids success because pursuing the wrong projects (or too many projects with too few resources) can jeopardize both project execution and achievement of the organization's goals. While many variables influence the success of projects—including the experience of project managers, the organizational structure and how it supports projects, and the way projects are funded—setting priorities effectively ensures that successful projects will contribute to organizational success.

Project Priority Setting

Using a systematic, data-driven portfolio process to manage work involves an ongoing, iterative process that

- Eliminates confusion as to what projects are most important
- Has the right mix of strategic and tactical projects
- Minimizes risks connected to lack of project coordination and visibility
- Controls project size and scope
- Makes practical use of valuable resources
- Identifies important links to ongoing, long-term capital expenditures and other strategic initiatives
- Is systematic
- Is data-driven

Without a systematic process to manage a portfolio of projects, firms are prone to project proliferation and project scope creep (meaning projects grow into more than was planned or are outside the strategy). Using an effective portfolio management process provides the means for people to focus on the critical few initiatives that will deliver results and reduce complexity in a given time. This may be especially important for U.S. government and quasi-government agencies struggling to implement strategies given changes in leadership, administration, and suppliers.

NASA's strategic goals, laid out in its 2006 plan, define the breadth, depth, and complexity of what it is striving to accomplish. The challenge for NASA, as for any organization, is in the implementation. The project portfolio process helps automate data gathering and reporting so complex projects and missions can be managed effectively. An optimized portfolio includes a dashboard for leaders to monitor and assess resource needs and overall performance against specific measures. This minimizes project proliferation and scope creep.

As NASA continues to build an initiative portfolio, two key questions can help the Agency keep focus:

1. Given available resources and the need to not compromise ongoing operations, how many small/medium/large initiatives can we take on?
2. How can we ensure that we are working on the highest-priority initiatives?

Effective project portfolio management means knowing the relative value and risk associated with every project that has been proposed or is under way. It means knowing how resources are deployed across projects and what resources are available for new projects. Most of all, it means making tough decisions about which projects will be done and when, based on a shared understanding of each project's potential for adding value to the organization.

The work environment plays a pivotal role in getting results from project portfolio management. This includes making sure that people have the right expectations and resources, and that obstacles are removed. It includes people clearly understanding the "what's in it for me" of achieving success. And it includes making sure people know how, specifically, their work advances—or retards—both the project and the overall portfolio. Finally, it includes making an accurate assessment of the cross-project impact of actions, so that what supports one project does not derail another.

Developing an optimal project portfolio is usually a collaborative process between our consulting firm, Kepner-Tregoe, and clients, and we work with them to establish a process for ongoing project portfolio management. An effective portfolio management process can provide the means for people to focus on the "critical few" initiatives that deliver results.

PROJECT CONSISTENCY SUPPORTS PORTFOLIO MANAGEMENT

Project portfolio management works best when projects are managed in a consistent way. NASA employs a common project management framework for both contractor and NASA teams managing projects. Aligning project standards and practices with the Project Management Body of Knowledge (PMBOK) and supporting use of common project software are two ways to help create a shared project language and approach.

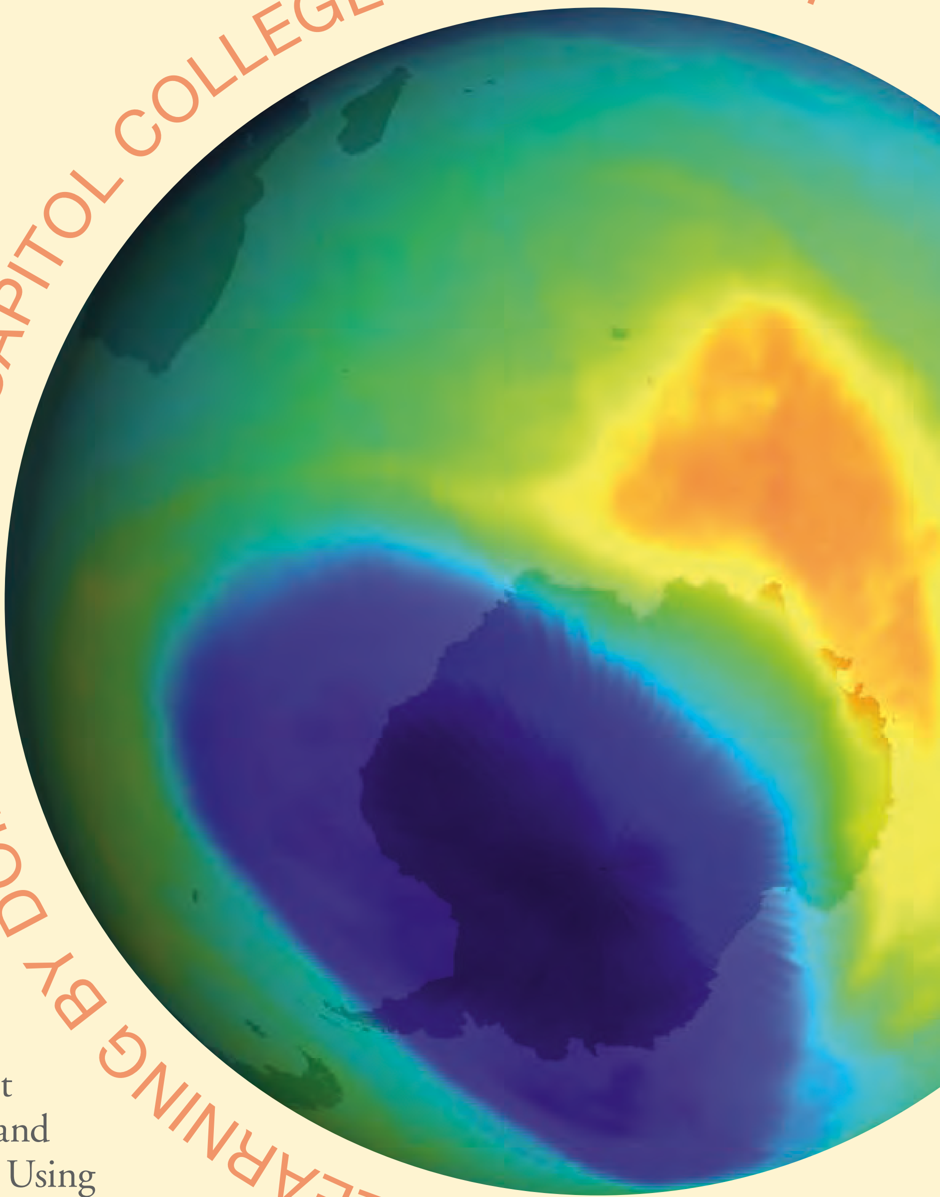
When NASA changed Lockheed Martin Space Operation's Science, Engineering, Analysis, and Test Operation (SEAT) to completion-form and performance-based contracting, Lockheed Martin SEAT, rather than NASA, was given the responsibility of project management. Kepner-Tregoe provided the SEAT program with training to help them gain the skills needed to manage projects, not just work on them. Kepner-Tregoe's project management process is taught in workshops, which focus on applying principles, and through a "learn and do" process, where our consultants act as project managers and trainers on actual projects. As the client project managers learn the process, they assume more responsibility. Armed with a powerful project management process, project managers and team members can better define and plan a project while nimbly anticipating and responding to issues during implementation.

MICHAEL A. HALL is an IP consultant at Kepner-Tregoe, Inc.

LEARNING BY DOING: A NASA–CAPITOL COLLEGE PARTNERSHIP

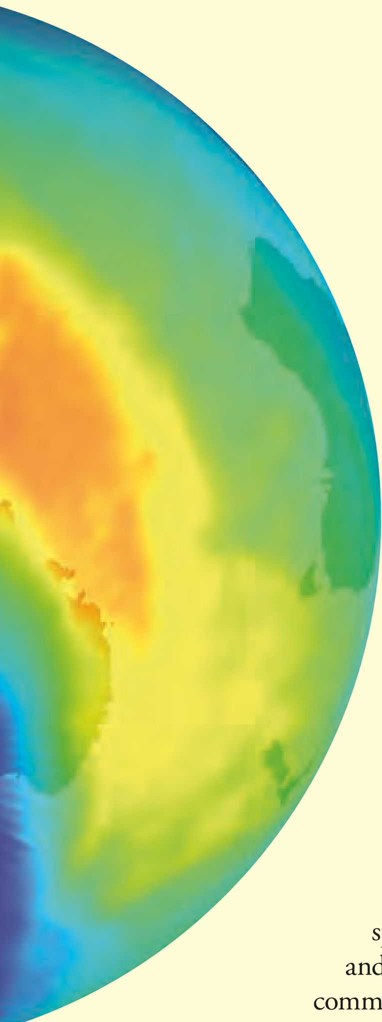
BY KEN DOLAN

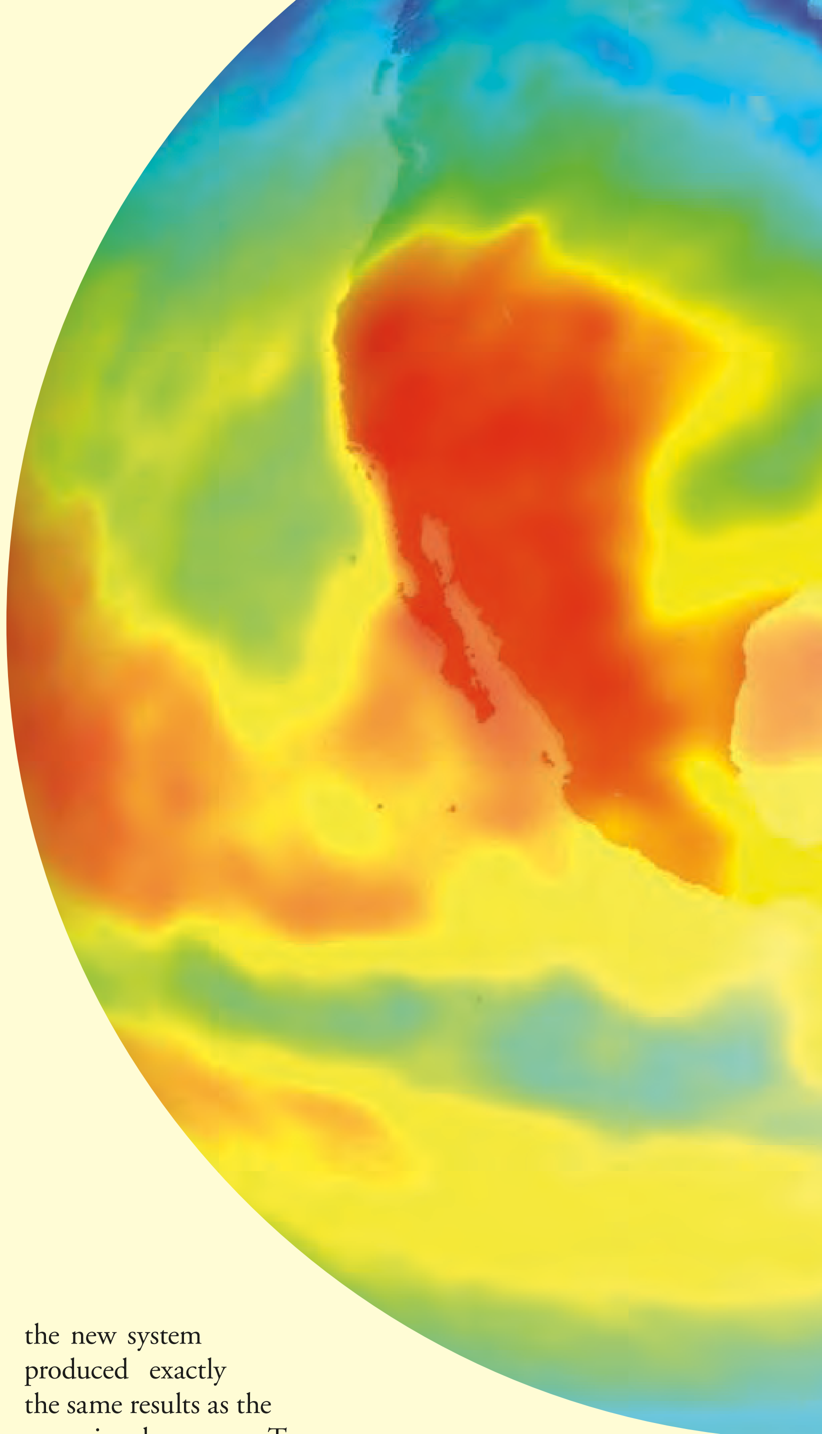
Launched in 1996, the Total Ozone Mapping Spectrometer (TOMS) satellite was expected to map and understand the magnitude of polar ozone depletion for two years. More than ten years later, it was still in orbit and providing valuable scientific data. Its life was extended thanks in part to a collaboration with Capitol College's Space Operations Institute (SOI), whose students became lead controllers of the NASA spacecraft in 2002, first from Goddard Space Flight Center and then from a control center on campus. Using students for TOMS mission support reduced NASA's operational cost from millions of dollars a year to a few hundred thousand dollars, making the extended mission operations possible. The partnership also gave the students an important hands-on learning experience. The Capitol College team demonstrated that a small contingent of engineering students could perform a number of complex technical tasks well with limited subject-matter expert supervision. Dave Wagner, Capitol College's Space Operations Institute director, described the arrangement as a "win-win situation," saying, "Students get to learn and NASA reduces its cost without increasing its risk."



Using data from NASA's Total Ozone Mapping Spectrometer (TOMS) instrument onboard the Earth Probe satellite, researchers can evaluate and compare current conditions over the South Pole to readings taken by other instruments in years past. This shows the Antarctic ozone hole in 2000.

Image Credit: NASA/Goddard Scientific Visualization Studio



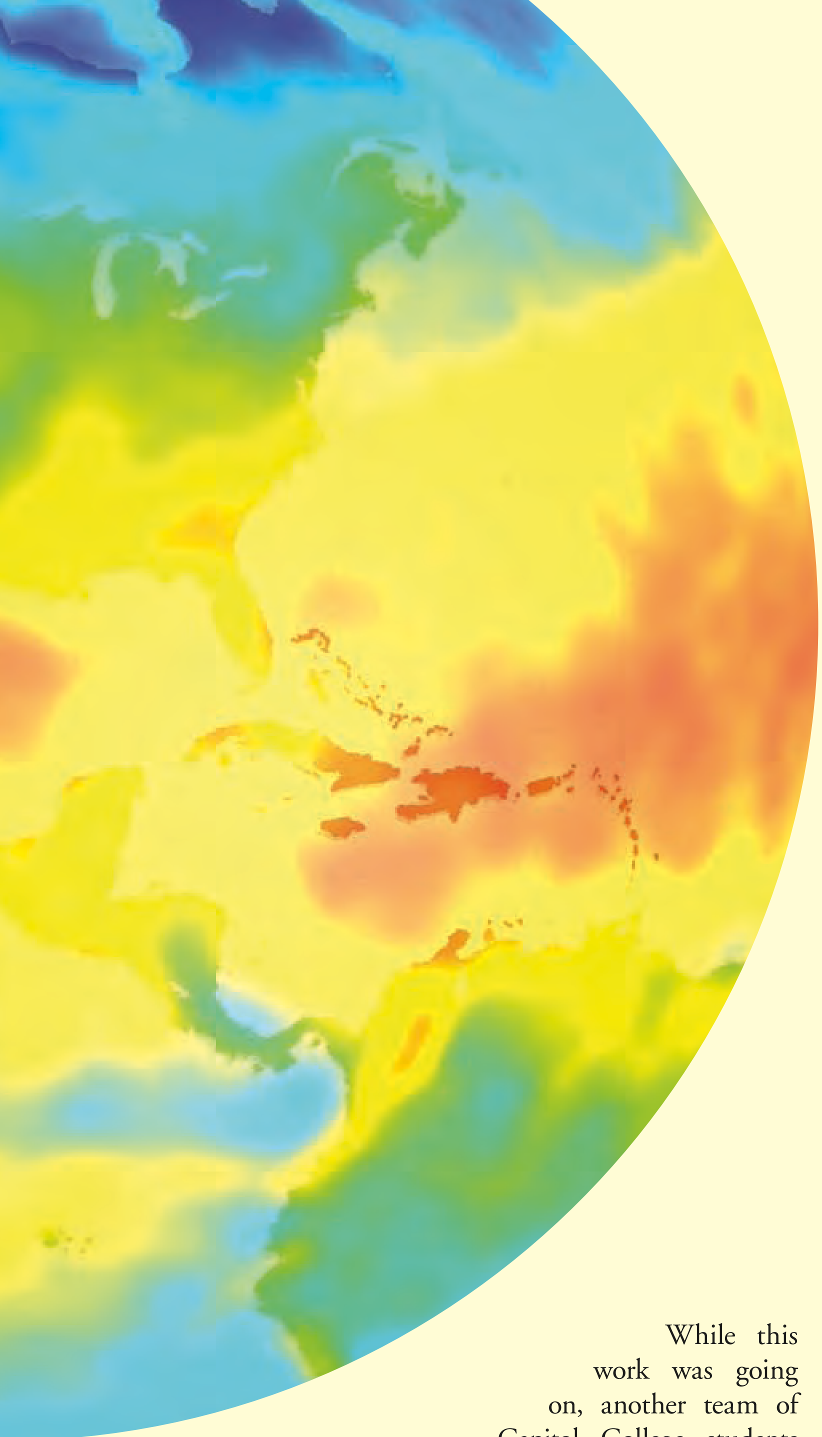


One task Capitol College students took on was redesigning the operations ground system for the satellite. With NASA contractors and college faculty serving as technical mentors, Noah Williams and Peter Fetterer put together a ground system that emulated the one being used for operations in the TOMS control center at Goddard. It was not a simple task. Among other things, the system had to capture data from the tracking station, separate spacecraft and science data, display spacecraft health and safety data, and provide spacecraft and instrument command capabilities.

Fetterer remembers, "Noah started with some spare hardware the school had lying around. We received some software and some incomplete instructions on how to install the software. Noah and I had to work though various issues and were able to get some answers to questions from the operations folks. As we grew more confident that the system was receiving telemetry correctly, we built a system using the newer IBM e-series servers." Williams adds, "On the security side, in some cases, the previously used software was swapped out for more secure, commercial software that provided more functionality."

As the work proceeded, Si Tran, a Capitol College student who had become a certified TOMS flight controller in the Goddard control center, came on board to verify that the new system produced exactly the same results as the operational system. Tran ran a complete set of functional tests, played data through the system, and verified system performance. Describing her overall experience with TOMS, Tran says, "It was overwhelming at first, but I'm really grateful for the chance to get this kind of experience."

In the summer of 2003, the Upgraded TOMS Ground System (UGS-1) was packed up and moved to the TOMS control center at Goddard. Once in place, it was again run through a set of successful systems tests. Then began a period of "shadow operations," the new system receiving the same data at the same time as the operational system and exactly duplicating its performance. After an operational readiness review, the system became the primary operational system in September 2004. This program was accomplished in eighteen months at the cost of some hardware, software, and student salaries. It was a great deal for NASA.



Data collected from TOMS during the year 2000 resulted in this view of the United States with red, denoting highest ground levels of ultraviolet radiation, covering the western portion and equatorial region.

Image Credit: NASA/Goddard Scientific Visualization Studio

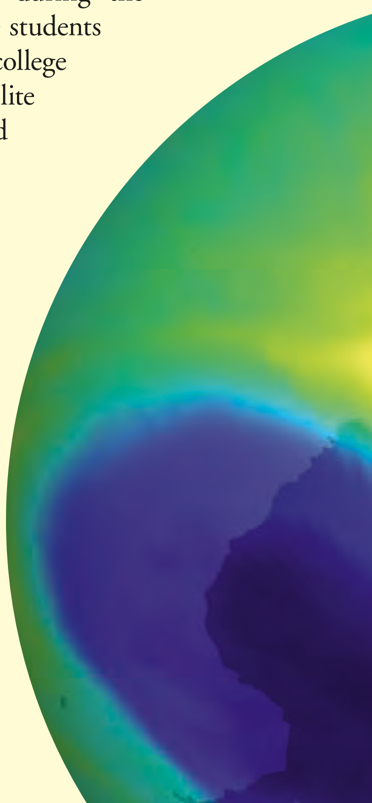
While this work was going on, another team of Capitol College students was redesigning the TOMS Flight Dynamics system. TOMS operations had been using Flight Dynamics products provided by the Goddard Flight Dynamics Facility. The college students, including Jason Tobiasz as one of the leads, designed a PC-based system that met TOMS requirements.

UGS-1 was so successful that NASA subsequently asked the college to build a second system and install it in a control center at Capitol College. Fetterer and Williams became mentors of a new set of college students who built and tested UGS-2. Sabrina Kirkley was one of the students who came on board to provide configuration management, verify system performance, and prepare and present the UGS-2 readiness review. This system went through the same process and was put together even more quickly than the first system.

Kirkley had this to say about the program: "I think the SOI program provides a great foundation in both practice and theory for anyone interested in pursuing a career in the space industry. My experiences as a ground segment intern helped me to understand how a control center is run and maintained and the importance of quality testing and documentation processes. I would not have been as successful in my current position without the knowledge that I gained through SOI and the Space Missions and Operations Specialist Certificate programs available through Capitol College."

In 2006, TOMS operations were moved to the Capitol College control center. From 9:00 a.m. to 5:00 p.m. weekdays, certified student operators or a faculty advisor monitored the satellite's passing in the morning and late afternoon, sent it commands, and collected data from it. A control center at Goddard tracked the spacecraft during the evenings, on weekends, and when the students were on break. Students with a college professor mentor operated the satellite without loss of data until the second TOMS transmitter failed and the mission was terminated in the spring of 2007.

A new cadre of students is currently working on a Tropical Rainfall Measuring Mission (TRMM) R&D project to provide TRMM an up-to-date, highly secure ground system to replace the aging system now in use. By December 31, 2008, they will have a new system checked out and ready for operations in the backup TRMM control center.



The fires that raged across southern Africa in August and September of 2000 produced a thick "river of smoke." NOAA's Advanced Very High-Resolution Radiometer measured the fires and TOMS measured the smoke index.

Image Credit: NASA/Goddard Scientific Visualization Studio

Besides the NASA grant, the Space Operations Institute at Capitol College has a number of subcontract tasks with NASA contractors. It normally employs about twenty-five students who work as control center operators, systems engineers, and software programmers and also perform other tasks. Students have tracked satellites as well as helped with launches, conducted research on battery systems, and redesigned upgraded ground systems. Overall, almost eighty students have been employed by the Institute. To date, forty-six have graduated, with more than 75 percent of them finding employment in the space industry.

Williams and Fetterer, who both worked on the TOMS operations ground system as students, now work for Honeywell at Goddard, as does Si Tran. Sabrina Kirkley has found work in mission development at Orbital Sciences Corporation, and Jason Tobiasz is a systems engineer at a.i. solutions, which develops orbit flight dynamics software.

When the initial contract with Capitol College expired in late 2005, NASA found additional money in its tight budget to continue funding SOI projects—a testament to the Agency's faith in the program and the success of the students. Edward Chang, the contracting officer's technical representative from NASA Goddard, has said, "When NASA says it wants to educate, this is as good a result as we can have." ●

Parts of this article first appeared in the Capitol Chronicle.

OVERALL, ALMOST EIGHTY STUDENTS HAVE BEEN EMPLOYED BY THE INSTITUTE. TO DATE, FORTY-SIX HAVE GRADUATED, WITH MORE THAN 75 PERCENT OF THEM FINDING EMPLOYMENT IN THE SPACE INDUSTRY.

KEN DOLAN is director of operations at Capitol College.

What's Ahead for Project Management: A Roundtable Discussion with the Project Management Institute

BY MATTHEW KOHUT

Matthew Kohut of *ASK the Academy* met with Project Management Institute (PMI) CEO Greg Balestrero, PMI Board Member Yanping Chen, Academy Director Dr. Ed Hoffman, and *ASK Magazine* Managing Editor Don Cohen for a wide-ranging survey of the project management landscape today.

KOHUT: What big trends are dominating the field of project management globally?

BALESTRERO: I'd say that globalization has changed the face of project management. It's difficult to think of a company or organization that doesn't feel the pressures and implications of globalization.

The Airbus A-380 is one example of the effects of globalization on the organization, and the challenge of having a common framework and understanding—as simple as a lexicon, as complicated as a common process—for project and program management. In the case of the A-380—1,500 suppliers, 24,000 projects cutting across thirty countries that have a variety of currencies—it's crucial to have a common understanding of what project deadlines mean to the project, what project scheduling is, and things like risk management.

Managing a project with the scale and scope of the International Space Station, where you have contractors, mission specialists, and control specialists all over the world, requires a sincere and deliberate effort to concentrate on a common standard, common practice, and a common approach. In something as highly visible as the space station, where the project's so costly and the accountability is great, communication becomes a crucial issue. Project communication is one of the nine knowledge areas in the PMBOK Guide™ (PMI's Project Management Book of Knowledge). The need to emphasize skilled communication is compounded when you go across geographic boundaries.

COHEN: Talking about communication, I'm concerned about how the knowledge needed to do the project successfully is, first of all, communicated among the parties of the project and, second, how things learned during the project are passed on for future project uses. What's the role of the project manager in making sure that happens, and do you know of approaches that solve that big knowledge problem?

On the International Space Station, the U.S.-built Unity node (top) and the Russian-built Zarya or FGB module (with the solar array panels deployed) were joined during a December 1998 mission. International collaboration has helped further space exploration and science.

Image Credit: NASA

BALESTRERO: As far as turning each project into a learning activity so that results can be passed on, one of the key processes is project closure. Project closure includes a learning exercise: what went right, what went wrong, and how do you transfer that information or distribute it so that the next person or project team will know what's going on.

With regard to knowledge, success starts with a clear definition of the scope of the project and what the expected outcomes are. That's not easy to do. I was reading a case study of the Atlanta aquarium. One of the criteria was a comprehensive study of all the animals and what their habitats had to include. As they made team decisions on meeting the deadline—on a $290 million, forty-four-month project—they'd sit down periodically and audit against the habitat. Were they creating the habitat that would allow these animals to survive? They had that from the very beginning of the project.

CHEN: There's the question of how to share program/project knowledge internally and also how to pass it from generation to generation. NASA and all the space agencies document knowledge and encourage sharing documents internally, but not across boundaries. That concerns me. NASA has been called to take the lead in human exploration of space. That's not a mission that one country can accomplish. It has to involve many nations, but it's difficult for the space agencies to share knowledge outside. There is also a kind of a spirit, an inspiration, that is often lost in the translation across the generations. So how can you capture that part?

HOFFMAN: One of the great things about NASA is that most of our missions are international partnerships. They go beyond international space agency partnerships—much of the work is done by industry, a large part is academic. You basically have an activity that pulls the whole world community together. The challenges are to find out what needs to be done and then find ways and formats for people to work together.

When international activities work well, you see examples of person-to-person relationships. I'm not a big fan of the database approach because I don't usually see that working; I believe people need to see each other and talk together. When you go to a different country, it's important to find out what that country is proud of, and what are some of the things that are important there, because it's the relationship that ultimately leads to the success of the mission. When you look at something like the International Space Station, it's natural to see the problems, the cost, and the technological breakthroughs. Look at what was accomplished in terms of the international community coming together. We went from the Apollo era when the Soviet Union was the enemy, to the Russians having a key part in the space station. That to me is the hope for space—it's something that can pull the community together.

COHEN: Greg, you talked earlier today about various kinds of diversity in these large projects—intellectual diversity and cultural diversity. Have you seen things people do to balance getting the diversity with keeping that common ground they need to work together?

BALESTRERO: There's work being done today in many aspects of developing leadership skills that looks at diversity in personality tendencies or in aspects of emotional and social intelligence to help solve problems in a disciplined way. For example, there are tools that are spinoffs of the Myers-Briggs personality-type indicators for decision making. Let's say you put people in a room to brainstorm that are unaccustomed to it. You will not achieve the results you expect. In the movie *Apollo 13*, I love that scene where they throw a whole bunch of miscellaneous materials down and say, "Start brainstorming." You can immediately see that some people were uncomfortable with that and others bought into it completely right away.

Great project team leaders try to seek and embrace diversity, encourage conceptual diversity, and encourage feedback. Today's world demands a project manager or program manager who can be sensitive to and encourage diversity of all kinds—especially conceptual diversity when it comes to problem solving—and yet be able to manage that diversity to give you the desired output. It is not only cultural and emotional diversity but intellectual diversity. You don't want constant conflict or brainstorming with no output.

HOFFMAN: I like your definition of diversity because it goes toward diversity of ideas, of different ways to approach something, of discipline backgrounds, of nations. Managing that diversity well gives you solutions and new approaches. From what I've seen, folks love working on NASA's international missions. It's partly about seeing the world through different eyes, and it's partly about finding new solutions through diverse ideas.

KOHUT: The Atlanta aquarium example you cited brings up the question of systems engineering. Could you say a little about the relationship between project management and systems engineering?

BALESTRERO: The aquarium is a classic case of looking at an entire system and how the elements of that system are going to interrelate. What project management does in a big way with systems engineering is focus on managing the interfaces. The systems engineer manages the interfaces among the subsystems. The project manager develops a full project plan that can be managed from start to finish. Both are absolutely essential in making the project successful. As you know, systems engineering as a discipline developed in the 1960s as part of the emerging

Whale sharks, sawfish, and stingrays swim overhead in the underwater tunnel at the Georgia Aquarium. The new aquarium opened in 2005 and has been a success in part because of a clearly defined project scope at its inception and frequent auditing against the criterion that all habitats had everything needed to ensure the animals survived.

space program. The Aerospace Corporation in the late 1960s created a body of work in systems engineering that had never existed before. It addressed the complexity of scale and scope in the new space program which did not exist before.

CHEN: When I was working in the Chinese space program, we used systems engineers to manage the space program. Systems engineering derived from the engineering community. It is project management of a sort, but it treats all the relationships as engineering components, so you have the system, the subsystem, the sub-subsystem, and then you have interfaces and configuration management. You put everything in the system into engineering concepts. A project manager uses a lot of the same methodology to manage a project.

HOFFMAN: A lot of complex projects are mismanaged because they lack a sense of the systems implications of what they're doing. Systems engineering asks, are you looking at the larger systems implications? Are you asking what can go wrong? Are you asking, what things aren't going to happen? Part of the challenge is that systems engineers define their job many different ways. Is it the design of the system? Is it looking across the boundaries? From a risk standpoint, is it anticipating what can go wrong ahead of time? If you look at Constellation, it's going to be different five years out in terms of new technologies. Have we built in the ability to think, adapt, and modify? Anytime you're at a project point where you're dealing with complexity, you need to factor in the systems implications.

COHEN: It also fits in with what Greg said earlier about getting clarity about the project goal. As in the case of the aquarium, the job of the systems engineer is to make sure that what's happening is focused on that goal and doesn't get sidetracked solving little, local problems.

HOFFMAN: What do you see as the biggest challenge in developing the next generation of project managers?

BALESTRERO: That's a great question, but it's difficult to answer because it's evolving. It's a very young discipline and even younger as a profession. It's like watching engineering form as a discipline 250 or 300 years ago. We're seeing things transform into first a discipline, a set of tools, and then people who take that on as a career path.

Society has to take some responsibility for educating those individuals. China saw it as a critical issue and immediately chartered ninety-six master's programs in project management at engineering schools throughout the country. The United

This is a technical rendition of the Space Shuttle Atlantis *docked to the Kristall module of the Russian Mir Space Station. The configuration is that of STS-71/ Mir Expedition 18, a joint U.S.–Russian mission completed in June 1995, and represents how having a common goal can help overcome project management and engineering challenges.*

States doesn't have that kind of centralized commitment or decision process. Our public school system is driven by local school districts with state funding.

COHEN: To what extent do you think someone who's well trained in project management but who doesn't have engineering or software expertise can be an excellent manager of a technical project?

BALESTRERO: The program manager who was in charge of developing the BMW Z4 came out of a business-consulting firm; he was from McKinsey. Some of the skills he needed to manage that project—understanding the technology that was being put into the vehicle, the manufacturing, dealing with a global supply chain—developed as he went along. He was highly successful. He's now vice president of Engineering Integration. I think leadership is not about having all the knowledge and being an engineer. It is about having the knowledge and skill to be able to make sure the project team has the knowledge it needs and having enough of what I would call professional skepticism to know how to challenge assumptions. Personally, I think it can be done. We've seen people leave IT and manage projects in health care and people from automotive engineering move to IT. It's an issue of having the right framework, understanding the lexicon for managing projects, and having a clear grasp of the associated processes, and then bringing together the people that are crucial to achieve the end result.

KOHUT: The critical thing is the project manager having the right counsel, the project team members he or she can draw on to get the hard technical facts and the appropriate level of skepticism, because the project manager does not necessarily know the detailed questions that need to be asked but will recognize them when they're raised by the project team.

BALESTRERO: How to mitigate the risk of a fire on the Mir space station is very different than mitigating the risk of a fire inside an automobile, but the approach to getting the team to address the risks is the same.

COHEN: I agree that having management expertise means you don't necessarily have to have the technical expertise, but if I'm an engineer and you don't know much about engineering, I may not respect you. Your perspective suggests a different mode of earning the respect of the people working for you, by saying, "You know these important things, but I know this other set of important things."

CHEN: This is about diversity. Not everyone should be an expert engineer in a specific area, because you'd only have that one engineering perspective. I am not an engineer. When I was managing China's astronaut space program, I had 200 projects, about 50 to 60 percent of them purely engineering projects. However, when I communicated with them, they knew how much I could contribute and how much they could contribute, so we had mutual respect as a diversified team. Another thing is that, as a program manager or a project manager, you trust the engineering ability of your team members and let them do their work. If you challenge them, of course they will say, "Which engineering school did you graduate from?" You don't do stupid things like challenge an expert. That's emotional intelligence. Meanwhile you need to show your expertise, what you can contribute to the team.

BALESTRERO: From an organizational point of view, project managers have to have a well-defined position. They have to be accountable for a specific result and have the authority to act. That means they've got to have great executive sponsors who are willing to go to the mat for them to get them what they need so they can build trust with their own team. A good way to cut off the legs of the project manager is not to give him the resources he needs to get the project done.

Then there's trust. Stephen Covey defines trust as being trustworthy as well as trusting. In order to build a bond of trust, you have to be trustworthy. When you make a commitment, you have to be able to deliver on it. And you have to be trusting. Once the individual on the team is given a task, you have to trust that they can do it. Anything that gets in the way of that has to be addressed, candidly, honestly, and openly, and in a way that respects the individuals. Otherwise you'll never build a bond of trust.

TODAY'S WORLD DEMANDS A PROJECT MANAGER OR PROGRAM MANAGER WHO CAN BE SENSITIVE TO AND ENCOURAGE DIVERSITY OF ALL KINDS—ESPECIALLY CONCEPTUAL DIVERSITY WHEN IT COMES TO PROBLEM SOLVING—AND YET BE ABLE TO MANAGE THAT DIVERSITY TO GIVE YOU THE DESIRED OUTPUT.

HOFFMAN: It goes back to the people again. Projects are team-focused. Do you have a team of individuals who feel included, who know that their roles make a contribution, so it's in their interest to build up the team and bring up problems as well as solutions? Is the team based on appreciation? Do they feel valued, which makes them work in a different way than if they don't? Do they feel that they're working off a set of shared values and doing something special together? High-performing teams have that essential human factor: appreciation, inclusion, values, clarity about the goal and the requirements, and constant communication.

KOHUT: When you talk about project management, you typically think cost, schedule, and performance. But the project manager has to be the most emotionally intelligent person on the project. It's absolutely critical to the respect needed. Trusting and being trustworthy are qualities of emotional intelligence.

BALESTRERO: It goes back to training and investing in the project. It's not just about picking somebody who likes details. What changes in going from project management as a discipline to a project management profession is investment in skills. Organizations don't think twice about investing in the right technology, but do they invest in project managers? NASA does—that's where APPEL [Academy for Program/Project and Engineering Leadership] comes in—but there are many organizations that won't invest.

Take our new program management certification. The certification process has three elements. Every application is screened by a panel to determine whether or not the individual qualifies to take the examination in terms of experience. If that individual passes, he or she takes a written examination of 170 questions. He or she will have a 360-degree evaluation of his or her capabilities as a program manager. Part of that assessment includes leadership ability. It's recognition that their peers must recognize their effectiveness as a leader in managing programs before they can be considered. The aim is to build a team leader who is strong in the human aspects. Those things sound squishy, but they are what makes for successful teamwork.

HOFFMAN: You're talking about assessing individual program managers and project managers. Let's face it—at the end of the day it's the team that either fails or succeeds. One of the things we do at APPEL is assess how the project team is working together. I think it needs to be done at the project kickoff. I've been on projects where from day one you knew it was going nowhere. On the other hand, I've been on teams where you knew it was going to work. How would we go about assessing the team?

BALESTRERO: That's a great question. We haven't discussed it at length, but project closure is a very sophisticated part of the success of a program. How well can they do a rigorous learning assessment? People always want to get done with the project and move on and won't take the time to do a truly rigorous assessment. But that's where the learning is—turning that project team into a learning organization. That's an area of opportunity. ●

PMI's PMBOK may be found and purchased online at http://www.pmi.org/Marketplace/Pages/ProductDetail.aspx?GMProduct=00100035801.

MESSENGER: BIG SCIENCE IN A SMALL SPACE

BY KERRY ELLIS

Photo Credit: NASA

Looking upward inside the mobile service tower on Launch Pad 17-B at Cape Canaveral Air Force Station, the MESSENGER spacecraft is lowered toward a Boeing Delta II Heavy rocket for mating.

The last time NASA visited Mercury was in the early seventies, when Mariner 10 made history as the first mission to explore two planets and the first spacecraft to use a gravity assist to change its course. In the thirty years since learning about the planet's large core, magnetic field, and mostly helium atmosphere, scientists and engineers have been researching ways to return and explore the planet in more depth. But the extreme temperatures caused by Mercury's widely elliptical orbit—about 450°C at noon on the equator when it's closest to the sun and a frigid -180°C at night—are a tough challenge for any spacecraft. Those extremes present additional difficulties for designing and testing a mission to the innermost planet in our solar system.

Studies from the Jet Propulsion Laboratory estimated that building a spacecraft and running a mission that could meet the challenge would cost well over $1 billion. When the Johns Hopkins University Applied Physics Laboratory (APL) proposed the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission for about $300 million, NASA's Discovery program approved it as the seventh of its lower-cost, scientifically focused projects.

APL had ambitious plans to create a lightweight spacecraft that could house the large amount of fuel needed to propel MESSENGER on a 4.9-billion-mile journey that included multiple trips around the sun and a series of flybys of Earth, Venus, and Mercury, a complex sequence of gravity assists needed to slow the vehicle enough so the craft's propulsion system could insert it into Mercury's orbit. The team needed to pack seven miniature science instruments into the small space not taken up by the propellant, which accounted for more than half of MESSENGER's mass at launch. Finding a place to house them was made even more difficult by the need to affix a sunshade to the spacecraft to protect it from the sun. This would be a blindfold for any observations and further limited where instruments could be placed.

In August 2004, the spacecraft successfully launched, and it has already completed its Earth flyby, two Venus flybys, and first Mercury flyby. Getting to that launch was not easy, however.

To gain a better understanding of the project and prepare for an impending preliminary design review, the lead systems engineer met face to face with the individual leads for each subsystem to ask them questions and capture requirements based on their answers. But for this tactic to work, he also needed to gain their trust. So the systems engineer focused on figuring out what everyone needed and how to meet those needs. This did more than build the trust he needed to succeed in a lead position; his foresight also set the stage for reciprocation when he might need a favor in the future.

After defining the requirements, a process that took two to three months to complete, the team then needed to figure out how to prove to everybody that the spacecraft could fly in an environment with light and heat as much as eleven times more intense than we receive on Earth. They had a great thermal engineer who used an illumination lamp at Glenn Research Center that could focus eleven times the sun's intensity into a small area. Because they couldn't take the entire spacecraft up to Glenn, they built a small mock-up of the sunshade and components to send to the Ohio center, where they blasted it for hundreds of hours to prove the spacecraft could handle the light. To prove it could also survive the heat, the team went to Goddard Space Flight Center with the full spacecraft and placed giant heaters in front of it. Showing how this spacecraft could survive an environment you can't really replicate on Earth was a big hurdle, but they overcame it.

Once the team proved the spacecraft could survive the mission, they had to tackle the mass challenge involved in making sure it would arrive at its destination. Because the Mercury orbit insertion maneuver is so complex, MESSENGER required a lot of fuel. In fact, about 54 percent of the spacecraft's final 2,400-lb. launch weight was propellant. To compensate, the team sought to lighten the load in other places, mainly in the body of the spacecraft itself.

Traditional spacecraft use an aluminum honeycomb with aluminum sheets encasing the structure. MESSENGER used a composite material, a graphite blend much like what you would find in the shaft of a golf club, because it was strong and, more importantly, very light. The team later realized that a majority of spacecraft subsystems rely on aluminum as a conductor for heat and electricity, and to ground components. To solve the challenge introduced by the lightweight composite, they placed copper sheets around the spacecraft to act as a conductor. After all their mass savings, they ended up adding mass back to get the grounding for the electricity, and then adding heat pipes to transfer the heat. Even with these additions, the main structure of the spacecraft was

SHOWING HOW THIS SPACECRAFT COULD SURVIVE AN ENVIRONMENT YOU CAN'T REALLY REPLICATE ON EARTH WAS A BIG HURDLE.

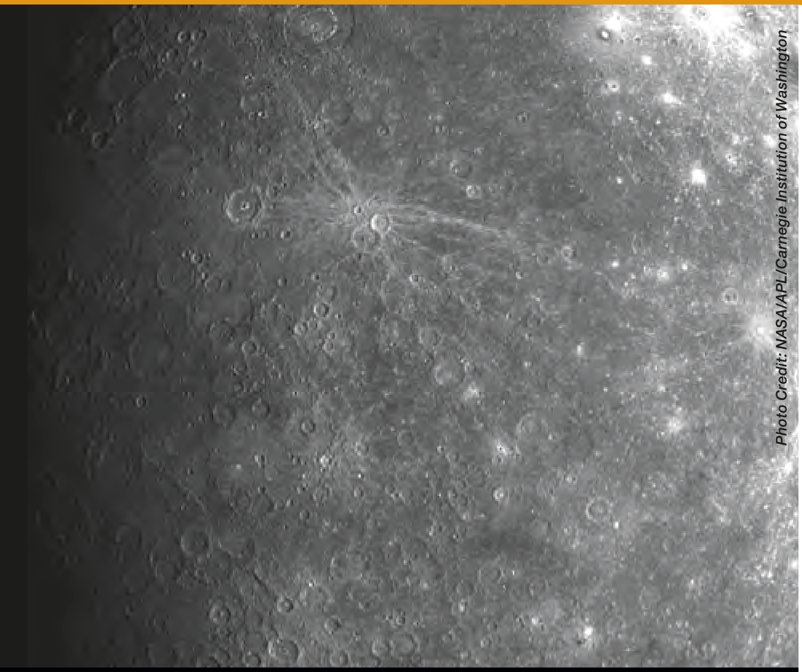


Photo Credit: NASA/APL/Carnegie Institution of Washington

On January 14, 2008, MESSENGER became the first spacecraft to see the side of Mercury shown in this image.

less than 9 percent of the total mass of the spacecraft, compared with 10–20 percent on most other spacecraft.

To save even more mass, the team worked with Aerojet in California to develop a new tank design. Three of these new tanks—the lightest ever to hold this amount of mass—are in the middle of the spacecraft. This also required a lot of hard work, but optimizing the tanks was necessary in order to make the mission work.

The unique mass requirements of MESSENGER presented engineering challenges that required ingenuity to solve—as well as some reworking of ideas. Adapting initial plans to circumvent unforeseen problems is not an unexpected step in NASA's one-of-a-kind projects, and it highlights the need to define requirements and risks early and thoroughly as well as ensure they are documented for reference. Documentation not only helps those who may later join the mission understand the work, but also aids future missions that may look to solve similar problems as NASA ventures further into unexplored space. ●

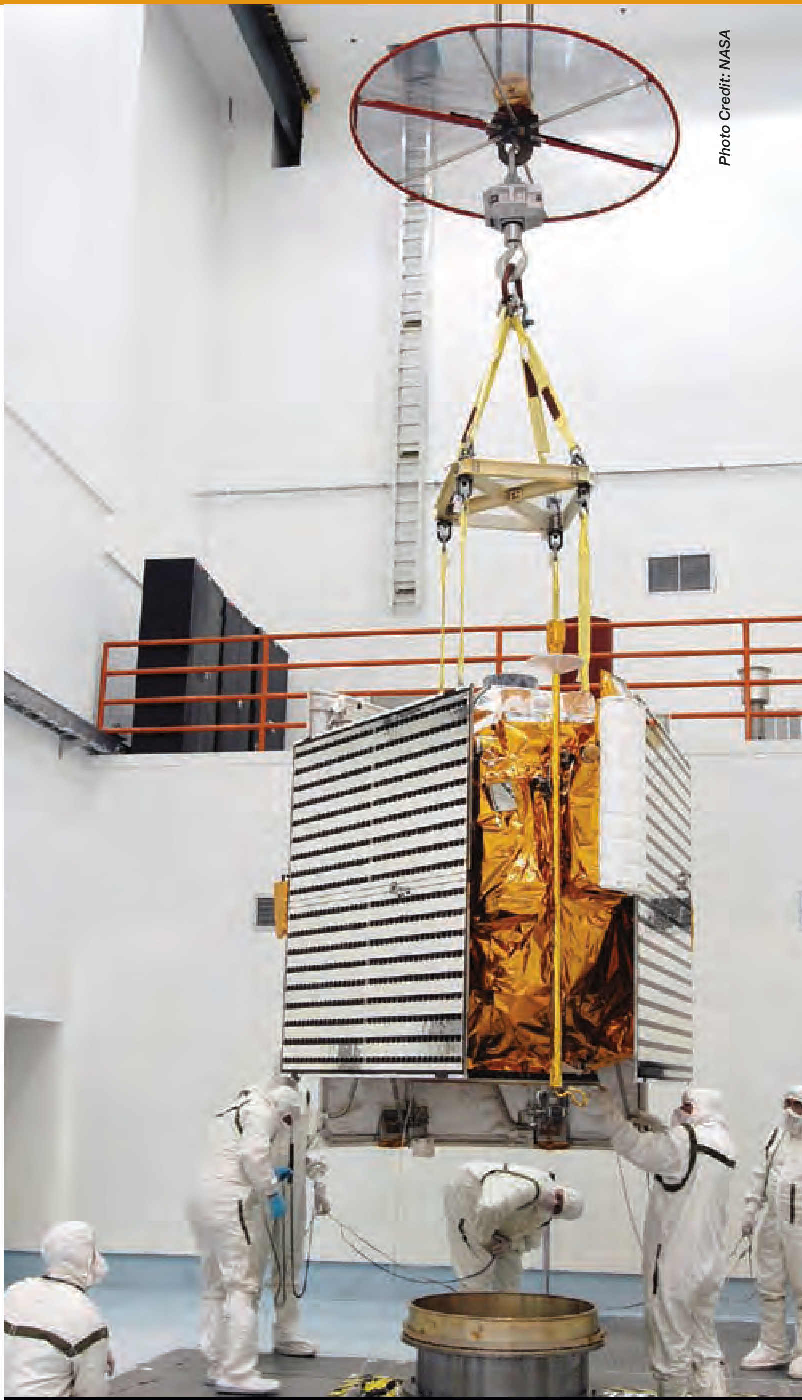


Photo Credit: NASA

Technicians at Astrotech Space Operations in Titusville, Fla., check the progress of the MESSENGER spacecraft as it is lowered onto a spin table for testing.

Nothing Weak About It: Thriving in a Weak-Matrix Project Environment

BY KEITH L. WOODMAN

If you asked the typical project manager how much authority he wants, he would likely respond by saying the more, the better. In NASA's increasingly complex project environment, however, project managers often find themselves facing situations where they have less authority than they would expect. This is the nature of what is called a weak-matrix project. But "weak" is poor choice of words because only strong leaders will succeed in this challenging project environment.

The Weak-Matrix Project Environment

As our Agency's projects increase in size, complexity, and distribution, a secondary project manager is often needed. This secondary project manager represents both a project's interests at a geographically distributed support organization and the organization's interests within the project. This position can go by many names, including weak-matrix project manager, distributed project manager, or, in the case of the Constellation program, center focal.

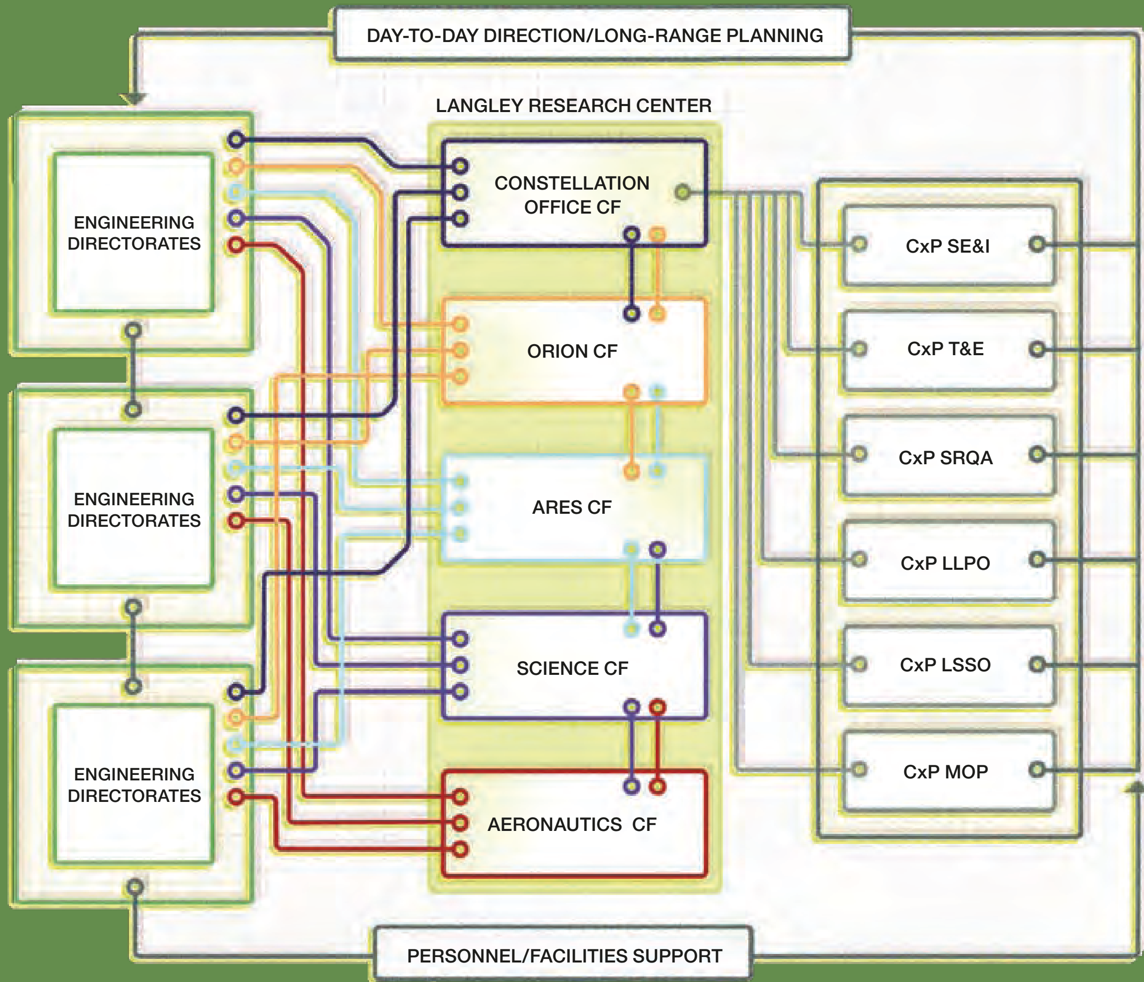
In the weak-matrix environment, the center focal communicates the project's requirements to his or her center's functional engineering units, which may contain design, development, testing, and fabrication capabilities. After needs and capabilities are identified, the center focal leads negotiations between the center and the project leaders to develop resource and task agreements. Once those are in place, the center focal is responsible for managing the budget allocated by the project and for ensuring the timely delivery, completion, and quality of the products developed at the center.

The center focal's role is different from the traditional project manager's. Unless requested to do so by the project manager, the center focal does not plan or direct the day-to-day or long-range tasks for the personnel who support the project. The project manager or her technical subordinates do that; the center focal's responsibility becomes coordination, integration, and oversight of these tasks. In this respect, the center focal has much less authority than the traditional project manager.

The Langley Research Center Constellation Projects Office exists in a weak-matrix environment with some complicating factors not accounted for in the generic model. The first complicating factor is that the office represents six Constellation program (CxP) projects: three Level II offices, the Lunar Lander and Lunar Surface Systems Project Offices, and the Mission Operations Project Office. Each of these projects has its own requirements and ways of conducting business. For example, some projects require formal internal task agreements with Langley while other projects will insist that there is no need for formal agreements. It is up to the center focal to adapt to these varying cultures and make the situation work.

Another challenge involves workforce availability and established commitments. Several other projects draw on Langley's resources. For Constellation at Langley, there are separate Orion and Ares project offices, as well as project offices representing the Agency's science and aeronautics programs. Attempting to balance priorities across the exploration, science, and aeronautics programs requires constant and complex negotiations between the center focals, the projects they represent, and Langley's engineering directorates. It also requires continually balancing the civil servant and contractor workforce. Successful negotiations require the center focal to meet constantly with the center's line management and other project focals to communicate issues and needs and to establish priorities.

While the weak-matrix project might sound like a situational nightmare to some, it can be a very rewarding activity to lead and offers the center focal some unique opportunities that other project management positions do not. Successfully leading a weak-matrix project calls for situational awareness, negotiation skills, technical assignments, and influence.



CF = Center Focal(s)
CxP = Constellation Program
SE&I = Systems Engineering and Integration (Level II)
T&E = Test and Evaluation (Level II)
SRQA = Safety, Reliability, and Quality Assurance (Level II)
LLPO = Lunar Lander Project Office (Level III)
LSSO = Lunar Surface Systems Office (Level III)
MOP = Mission Operations Project (Level III)

Situational Awareness

Langley, like other centers, offers a wide range of engineering disciplines and facilities. Because it is so large and diversified, few people can claim to have complete knowledge of the center's capabilities, but center focals need to know a lot about them to do their jobs well. One effective way to develop organizational knowledge is setting up and conducting tours. Conducting tours for visiting project leaders not only acts as a reinforcement of the center focal's knowledge, it may also reveal new or unknown center capabilities.

To develop an intimate understanding of a project's requirements, culture, and way of conducting business, the center focal should take advantage of opportunities to meet the project manager face to face. When travel is not possible, center focals should "virtually" attend as many project meetings as possible. As situational awareness of the project and the organization grow, the center focal becomes an information conduit, keeping his or her organization informed of the project's needs and ensuring the project understands the organization's abilities and commitments.

Often, center focals compete against other projects for their organization's resources. Understanding the nature of these other commitments and the priority level assigned to them will aid the center focal's negotiation skills.

Negotiation Skills

Negotiating in the weak-matrix project environment is like walking a multidimensional tightrope. The center focal must continuously balance the project's changing needs with the center's capabilities while maintaining an awareness of the priority level of all activities. In this complex, multiparty environment, negotiating "win-win" solutions is rare. Typically, the optimal solution is *satisficing*—satisfying as many of the interested parties as much as practically possible. When dealing with many interests—the project's, the center's, the employees'—the center focal must constantly ask, "What solution will bring a balance between the Agency's values of safety, teamwork, integrity, and mission success?"

The health and welfare of the Agency's workforce must be carefully balanced against the needs of its programs. At Langley's Constellation Project Office, Project Manager Jerry Hill and I have an engineer on our team who was being stretched across multiple projects because his avionics skills were in such high demand. During a regular status meeting with him, he confided to us that he was starting to suffer fatigue and burnout. We immediately and aggressively negotiated with Langley's engineering directorates and the various projects to reduce his workload. Of course, some of the projects he was pulled off were not happy, but we worked with them to fill those tasks with other qualified personnel and agreements were eventually reached that satisfied all parties.

Once a center focal has negotiated the majority of necessary task agreements between the project and his organization and set up a monitoring and reporting system, the project manager may request that he take on a more technical role. Few traditional project managers have this opportunity, and it is an important one for leaders of weak-matrix projects.

Taking on Technical Assignments

There are many benefits for center focals who do as much technical work as they can. First, it keeps them technically sharp by allowing them to use their project management, systems engineering, or other discipline skills. Second, although center focals already perform a very important service, taking on technical assignments reduces their constituents' and the project's tendency to view them as overhead or middlemen. Third, and most important, taking on technical assignments can greatly increase job satisfaction. Adding challenging technical assignments can provide greatly needed balance for communication and negotiation work.

When Constellation began, Jerry and I worked very hard to understand our customers' requirements and to fill their needs with qualified Langley personnel. We then helped our people develop strong working relationships and effective lines of communication with their Constellation project customers by ensuring that requirements were clearly communicated and milestones were met. Once these relationships were established, our need for constant relationship building and oversight decreased. With this freed-up time, Jerry and I began looking for opportunities to assist the program in a more technical capacity.

Based on his experience, Jerry was chosen to act as the CxP Level II representative to the Ares I-X project and to be a member of the Constellation Safety Engineering Review Panel. Based on my experience in technology development and assessment, I took the opportunity to work for CxP Level II on their technology prioritization process, helping the program determine its long-term technology investments. Tackling these technical assignments not only improved our situational awareness and professional satisfaction, it also contributed to increasing our influence within the program.

Building Influence

The project manager controls the budget and task assignments, and the center functional managers maintain a high level of control of their personnel supporting the project. While the center focal has limited control in this environment, his ability to influence can be great. Influence means that you can make things happen, without actually being in control. Understanding this difference and striving to build influence as opposed to taking control will help the center focal excel.

To influence the project, center focals must demonstrate an understanding of project requirements, be able to identify and obtain their center's assets, consistently ensure that tasks are completed on time and within budget constraints, contribute to technical efforts when possible, and be able to communicate this knowledge and use it in negotiation. The center focal must also understand the pressures other commitments put on his center and be able to negotiate with the project for proper and timely funding. Another great way for the center focal to build influence is to regularly request performance feedback on center personnel from their project customers and provide this information back to center line management.

Keeping Weak-Matrix Projects Strong

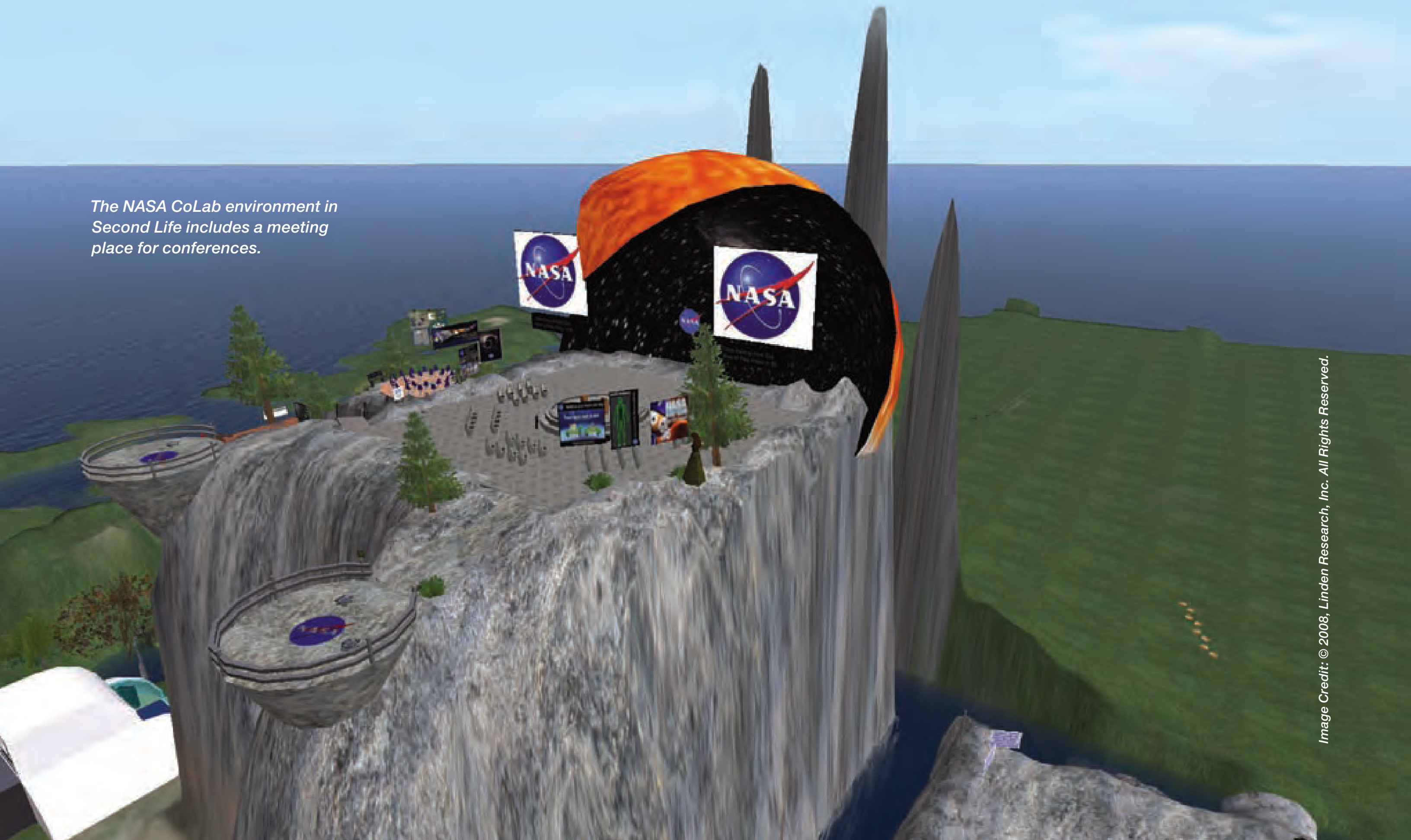
Weak-matrix projects are challenging. Their size and complexity and the roles different centers—with their individual capabilities and ways of working—play in them make the work of center focals important to their success. Center focals' understanding of the project *and* the realities of their own center put them in an ideal position to understand how the center's resources can best be marshaled to get the work done. Their communication and negotiation skills help ensure that competing demands on the center's workforce are fairly and effectively balanced and that their projects get the most possible benefit of the center's special expertise. ●

KEITH L. WOODMAN is deputy manager of the Constellation Project Office at Langley Research Center. He has been with NASA for twenty years in a variety of technical positions, including electronics technician, embedded systems designer, commercialization portfolio manager, and systems engineer and analyst. He is also an engineering management doctoral student at Old Dominion University in Norfolk, Virginia.

NASA CoLab: Creating a Space for Participatory Exploration

BY MATTHEW KOHUT

Silicon Valley has long been the epicenter of high technology, but until recently NASA maintained a low profile in the neighborhood. "NASA Ames Research Center is 1,800 acres in the middle of Silicon Valley, with neighbors like Google and Yahoo!, and [yet] you go a mile away and people don't know that we're there," says Robert Schingler, special assistant to NASA Ames Research Center Director Pete Worden. "That was one of the things we wanted to do [under Worden's leadership]—to become more a part of Silicon Valley."



The NASA CoLab environment in Second Life includes a meeting place for conferences.

A skeptic might ask why this is important. Isn't NASA doing fine without an outreach effort to its wealthier neighbors? From Schingler's point of view, the Agency stands to gain a lot by opening its doors and letting others look in. "A lot of the problems that we're actually solving are not unique to NASA," he says. "[For instance] our information technology problems were solved five years ago by Google, and our power generation problems are currently being worked on by the clean technology sector. So the more that we can open up and allow transparency to occur within the space program, the more that other tools, technologies, and solutions can come into the space program and vice versa. We [NASA] may be developing something that is the linchpin or the missing ingredient of a new technology in a different sector."

To tackle this challenge, Schingler and a small team did a brief study to figure out what they could do to help NASA become more ingrained in Silicon Valley. "We came up with a very simple thesis, and that is participatory exploration," he says. "Quite generally, that means allowing people who don't work for NASA to participate in a meaningful way in the space program."

In an era of open source code, shareware, and freeware, there is no shortage of ways to collaborate using information technology. "The culture here in Silicon Valley is one of collaboration; the Web 2.0 technology tools are all about collaboration. What we tried to do is come up with a platform," Schingler says.

The platform that Schingler and his colleagues came up with, NASA CoLab, is a series of projects and frameworks designed to foster collaboration "between the nation's space program and talented, creative, tech-savvy communities," as the NASA CoLab homepage explains. The project attempts to create the environment for this collaboration to occur by using online tools, experimenting with physical co-working environments, and hosting a collaboration community based in Second Life, the online 3-D virtual world created by its "residents."

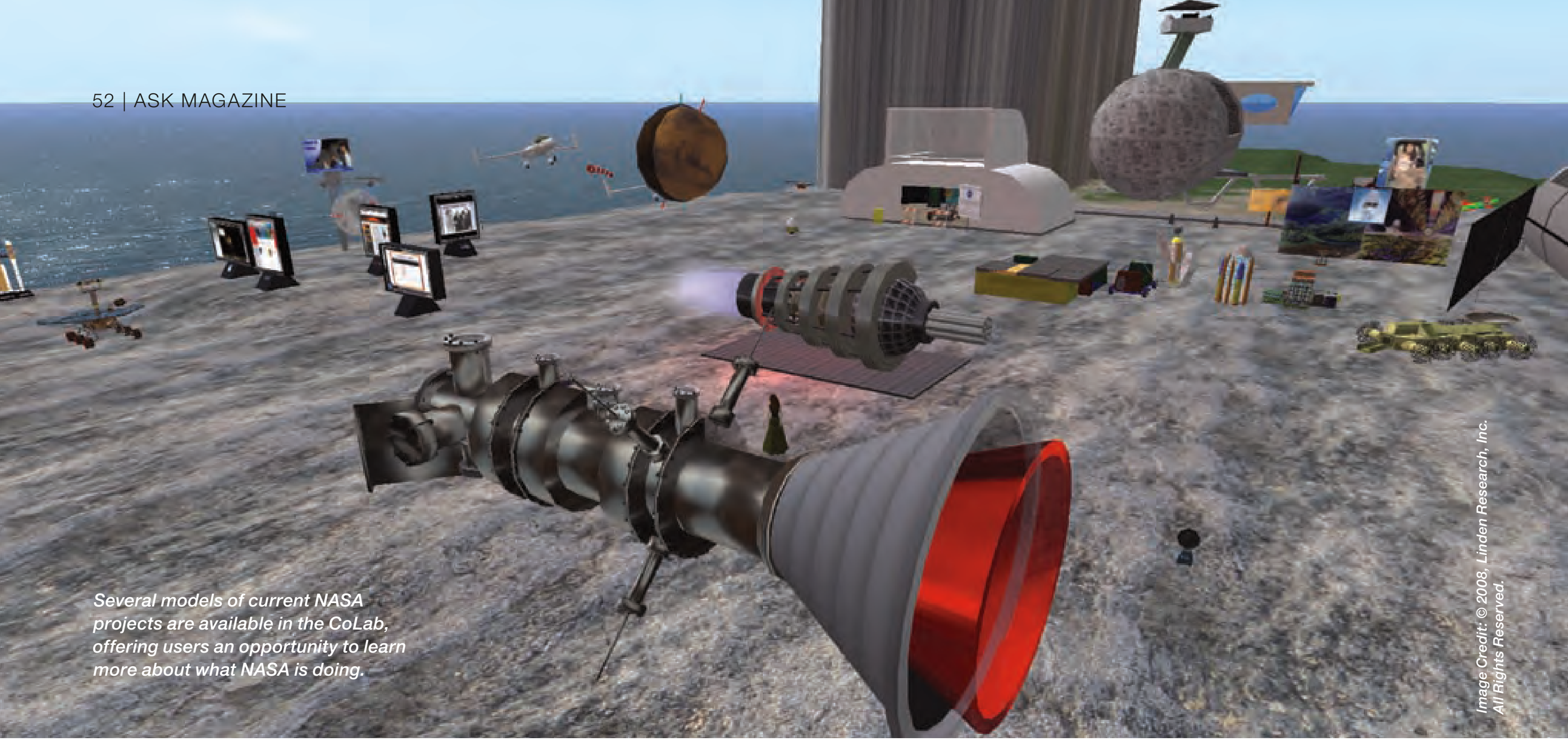
True to its Silicon Valley roots, NASA CoLab is a labor of love run by a skeleton crew. "It feels like a start-up, which is a pretty rare experience within a large government organization," says Delia Santiago, the project's only full-time employee. "It's a small team, and we all do a lot and learn a lot."

NASA CoLab's Second Life community attracted a great deal of media attention when it was first announced. Second Life is considered a "massively multiplayer online game" that can support thousands of users simultaneously. When Schingler and his colleagues went looking for a space to host a virtual collaboration community, Second Life offered a ready-made answer. "We didn't want to create a bunch of technology, we wanted to use what's out there," he says. "The easiest thing we could do was to get an island—a virtual island in Second Life. So that was what we did. We got an island … and put a flag down and said, 'All right, we're NASA, and we're open for collaboration. What do you guys want to do?' And slowly people started coming."

A year later, the island seems to have caught on. "We have regular people from all ten NASA Centers," Schingler says. Others have followed NASA CoLab's lead: the Jet Propulsion Laboratory set up its own island in Second Life. The NASA CoLab island includes a sandbox where people can "play" with and build space-related objects, but the majority of the island is actually meeting space, Schingler says: "A number of space organizations use it for their weekly meetings."

The NASA CoLab team is quick to point out that the collaborative tools they use are not meant just for younger, tech-savvy users. "One of my favorite things is working with someone who isn't familiar with Second Life or Twitter and is maybe somewhat afraid of the technology, and helping them see that these are just tools, and they're not hard to use," says Santiago. "You don't have to be an über tech geek to get something out of Second Life."

Schingler sees big possibilities for the long-term future of virtual collaborative environments in space exploration. "As Pete Worden says, the next time a human lands on the



Several models of current NASA projects are available in the CoLab, offering users an opportunity to learn more about what NASA is doing.

moon, we all get to go. Rather than watch it on a black-and-white television like we did in the past, we want avatars to be there, and we want it to feel like you're experiencing what it's like to be there."

BY HOSTING THE SALONS IN SAN FRANCISCO, WE ARE BRINGING NASA TO THE AUDIENCES WE WANT TO REACH AND MAKING IT EASY FOR THEM TO LEARN, EXPERIENCE, AND HOPEFULLY PARTICIPATE WITH NASA'S INNOVATORS.

NASA CoLab's online tool set includes a space for collaborative conferences. The team has been deeply involved in two conferences with the Next Generation Exploration Conferences (NGEC). After a highly successful initial conference in 2006 sponsored by the Exploration Systems Mission Directorate, a second conference took place in February 2008. Billing itself as a gathering of emerging global space leaders to design the future of space exploration through direct input at NASA's highest levels, NGEC-2 focused on "Entrepreneurial Opportunities in Lunar Development." The proceedings from this second conference will be published online in the near future.

NASA CoLab's in-person collaborative community includes a series of salon gatherings in San Francisco, called Luna Philosophie, and experiments with co-working environments. The Luna Philosophie series features NASA guest speakers followed by group discussions, as well as plenty of time for socializing. "By hosting the salons in San Francisco, we are bringing NASA to the audiences we want to reach and making it easy for them to learn, experience, and hopefully participate with NASA's innovators," says Schingler.

NASA CoLab also aims to have a co-working space in San Francisco. Co-working spaces are collaborative workspaces where people can drop by to meet and work alongside new people. "We just started a co-working space at Ames, bringing the culture of collaborative workspaces closer to home, but we hope to have a presence in San Francisco as well so as to infuse the vibrant, innovative social and cultural capital of the city into NASA's work," says Santiago.

During the next year the NASA CoLab team plans to play more of an enabling and facilitation role for participatory exploration projects across NASA. "We intend to document some of our successes and make it easier for other NASA Centers to create environments to support their innovators and facilitate participatory exploration elements of their missions," says Schingler. ●

Find out more about CoLab at http://colab.arc.nasa.gov. Read the proceedings from the 2006 Next Generation Exploration Conference at http://ngec.arc.nasa.gov/2006proceedings.

ASK Bookshelf

Here are descriptions of two books that we believe will interest ASK *readers.*

The Rational Project Manager: A Thinking Team's Guide to Getting Work Done, by Andrew Longman and Jim Mullins (Hoboken, NJ: John Wiley & Sons, 2005)

Sometimes the hardest part of managing a project is finding time to think about the planning and issues involved. *The Rational Project Manager* stresses that thinking before taking action is a critical factor in successful project management. It offers several brainstorming questions and suggestions to help project managers use critical thinking throughout their projects.

Andrew Longman and Jim Mullins, senior consultants at consultancy Kepner-Tregoe, define the steps involved in a project's life cycle and what project managers should stop to think about before ever touching a GANTT or PERT chart. While the authors encourage the use of tools that are prevalent in many project managers' toolkits, they stress that getting the right information into those tools by asking yourself and other people the right questions is more important.

The authors are big proponents of making lists, which help divide and conquer what can sometimes seem like an unmanageable mountain of problems. They simplify project management as definition, planning, and implementation, with chapters devoted to each of these steps in the book. They break these down into smaller actions, the last of which is always a reminder to talk to the people on the project. Often these conversations lead to new information that affects planning. Longman and Mullins devote a substantial section of their book to communication and managing people.

Probably most valuable for NASA employees are the chapters on deciphering contracts and working with large, diverse teams. The tips on how to handle big changes late in a project to ensure they don't affect the project's critical path are also vital for NASA project managers. But most useful are the lists of prodding questions project managers can use to elicit the information they need to make decisions.

Charts and graphs alone never complete projects. People need to be involved. The authors understand this point and would do well to emphasize it more in future revisions to this work, which was first published in 1959, shortly after NASA's foundation. It shows that project management as a practice hasn't changed much, but our approaches to it can be continually refined.

The Shock of the Old: Technology and Global History Since 1900, by David Edgerton (Oxford: Oxford University Press, 2006)

Most books and articles about technology focus on the latest innovations. Given the public's avidity for novelty, the pressure on journalists and historians to laud the new and neglect the virtues of the tried and true is strong. This book looks at familiar, successful technologies that the author calls "technology in use." It is very different from those histories of one "wow" thing after another. For example, Edgerton considers the refrigerated cargo ship, an invention that changed the course of history in Latin America, the United Kingdom, and the United States, allowing fresh fruit and meat to be transported anywhere. And he lauds the modern bicycle. Bicycles are more numerous than cars and more often used (and may be even more important in the oil-constrained future).

It is hard to dislike a book whose first chapter begins, "Is the condom more significant than the airplane?" This bottoms-up history is a fine counterweight to all the gee-whiz writings about inventions that have relatively little effect in the long run. ●

The Knowledge Notebook

Managing Your OWN Knowledge

BY LAURENCE PRUSAK

Knowledge management as a discipline and practice has now been with us for about twenty years and shows no sign of disappearing into that distant land where old fads and fashions go. It may change its name and some of its practices, but it continues to thrive because organizations need to develop and use knowledge effectively to deal with increasing uncertainty in their environments. But what of individuals? Don't they too live in very uncertain times, with tectonic shifts in the global economy and in the relations between employers and employees? Don't they need to manage their knowledge?

The answer everyone gives (at least everyone I poll) is, "Of course, I manage my own knowledge. I wouldn't get anywhere if I didn't!" Yet when I ask them *how* they do it—what specific activities they undertake—I usually get a blank stare and a response that goes somewhat like, "Well, I try to read on the plane," or, "Every year I go to a conference, or every year when I have the budget." Pretty slim pickings for what is perceived to be an essential activity.

So what can one do to manage one's knowledge? What can an individual learn from what organizations have been doing for the past few decades? Here are some practices to ponder based on my own observations and consulting as to what works in this field.

Scanning and adopting: Joseph Stiglitz, a Nobel laureate in economics, observed that one of the most important things for any organization to do is "scan globally and adapt locally." This lesson is also pertinent for individuals. One needs to continuously search for new ideas, products, even new dreams and visions, to keep abreast of the vibrant and growing global marketplace of ideas, a market that has been made both more competitive and more efficient by the Internet. If you don't, you can be sure someone else will, and you will lose a step in keeping your own knowledge up to date.

Vetting and filtering: Even if you spend much of your limited time scanning and searching for new ideas, you still need to learn how to evaluate what you are taking in. This vital skill is seldom taught in school. How do you judge how true or how useful what you are reading is? Can you "take it to the bank"? Do you have the tools to discern the valuable parts of the fire hose of stuff coming from the Web? With so many firms, journalists, publicists, and consultants pushing products, how can you judge what really matters? It's possible to distinguish good from bad, but it takes time and effort.

Networking: Many of us get our new ideas from colleagues, friends, co-workers, and others in the varied networks we belong to. This is fine. Face-to-face (or terminal-to-terminal) communication with those we know and trust has always been a potent source of ideas and always will be. Here too, though, think through how you go about it. Are you yourself trustworthy? That is, do you provide valuable knowledge when someone in your network asks for help? Do you make real contributions to your network or just take what you need? One of the least-mentioned subjects in the many books on networking is the need to invest in your network, putting in time and resources to strengthen the network's density, content, and reach.

Getting out of your office: This might sound a bit banal and obvious but it is important to say nonetheless. What you know depends on where you are. Stay in your office all the time and what you know will be the walls and windows surrounding you. Yes, you have your trusty computer and access to all the world's information, but information isn't knowledge. Think of the difference between reading about a country (information) and spending time there (knowledge). And new ideas are more than words on a screen. They include passion and other emotions that can only be communicated by being there. There is no substitute for getting out and going someplace to really "get it"—to deeply and usefully understand a new idea, problem, situation, or opportunity.

As you can see by now, a key concept in this piece is *investment*. Knowledge is expensive to obtain. If you are going to manage your own knowledge assets, you will have to spend some of your scarce resources—especially of time and perhaps money. There just isn't any shortcut to knowledge or technical marvel that makes learning fast and easy. Genuinely *knowing* a technology, a market, a country, a firm, a set of propositions, or a concept takes investments in attention, travel, and care. Obtaining new knowledge is expensive, but a lot of old knowledge loses value over time. My advice is to keep investing. ●

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ASK interactive

NASA in the News

NASA and the U.S. Department of Agriculture's Forest Service have partnered to obtain imagery of wildfires in response to requests from the California Department of Forestry and Fire Protection, the California Governor's Office of Emergency Services, and the National Interagency Fire Center. A remotely piloted aircraft carrying a NASA sensor flew over much of California in early July, gathering information that will be used to help fight more than 300 wildfires burning within the state. The flights by NASA's unmanned Ikhana aircraft are using a sophisticated Autonomous Modular Scanner developed at Ames Research Center. Read press releases and view the images returned by Ikhana at http://www.nasa.gov/fires.

Learning and Exploration

Expand your scientific knowledge of the cosmos and the world around us with Neil deGrasse Tyson and PBS's *NOVA ScienceNOW*. View video clips on a variety of topics, including physics, space science, health, bioscience, and technology. Learn more about the scientists, catch up on science news, and download podcasts for more video excerpts and outtakes. You can also preview the new episodes of *NOVA ScienceNOW* airing this summer online at http://www.pbs.org/wgbh/nova/sciencenow.

Web of Knowledge

Ever wish you could get a peek inside the walls at NASA and glimpse the projects being worked on? Or have a direct conversation with some of the leading minds inside the Agency? With the NASA blogs, you can. Read up on thoughts from NASA Deputy Administrator Shana Dale and Wayne Hale, deputy associate administrator for strategic partnerships and previously the Space Shuttle program manager, or catch up on missions like GLAST. You can also get a glimpse of new lunar rover and spacesuit concepts. Find it all at http://blogs.nasa.gov/cm/newui/blog/blogs.jsp.

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National Aeronautics and Space Administration

NASA Headquarters
300 E Street SW
Washington, DC 20546

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