National Aeronautics and Space Administration

Academy Sharing Knowledge

ask

The NASA Source for Project Management and Engineering Excellence | APPEL

SUMMER | 2007

Inside

ON THE COVER

A thermal vacuum test is conducted on Deep Impact instruments in the instrument assembly area in the Fisher Assembly building clean room at Ball Aerospace in Boulder, Colo. The high-resolution instrument (at right) is one of the largest space-based instruments built specifically for planetary science. It is the main science camera for Deep Impact, providing the highest-resolution images via a combined visible camera, an infrared spectrometer, and a special imaging module.

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

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

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

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In This Issue

The articles in this issue of *ASK* touch on themes already familiar to regular readers of the magazine. Learning from hands-on experience is one. David Rogers' "Sustaining NASA's Safety Culture Shift," Bob Seamans' reflections on NASA in the sixties, Edward Ingraham's "Living with the Contractor," and Kerry Ellis' report on systems engineering education at Glenn Research Center all attest to the unique educational value of experience.

Another theme is the power of stories—the subject of Ed Hoffman's "From the APPEL Director." Good stories give us the feel and flavor of other people's experience; they are the next best thing to being there. And, as Ed writes, the stories we tell and hear help shape experience, tilting our efforts toward success or failure.

The overarching theme of the articles (and, of course, the whole purpose of *ASK*) is communication. Continual, effective communication is the essential foundation of cooperative work on complex projects. John McCreight's "Creating the Future" puts communication at the center of successful organizational change. In "CompanyCommand," Nancy Dixon details the thoughtfulness and attention needed to support effective online communication. Rick Grammier's "Making a Deep Impact on Science" tells a story of careful, extensive communication overcoming the culture clash between two project groups.

Communication means listening as well as talking, which brings me to another important theme: openness to learning and change. As David Rogers suggests, experience provides *opportunities* for learning, but you can't learn unless you reflect on experience with an open mind and a willingness to change. Lee Graham's description of working with the Naval Research Lab shows that kind of flexibility in the process of understanding and accommodating an organization that works in a different way. The capabilities of the air traffic modeling and prediction tool described in this issue's featured invention were developed because the inventors listened to the controllers, dispatchers, and pilots and modified their original concept to address the needs of those potential users. Listening underlies the value of the knowledge democratization tools Thomas Davenport describes (if people in power don't listen, what's the point of talking?); it contributes to the trust that Larry Prusak talks about in "The Knowledge Notebook" and encourages the innovations and connections discussed in "Crossing Boundaries."

Learning depends on a willingness to confront your own weaknesses. That willingness is an essential part of the open-minded listening and reflection that lead to better ways of working. Without what one writer calls "higher modesty"—the belief that you might be wrong, no matter how smart you are—improvement is impossible.

Don Cohen
Managing Editor

From the APPEL Director

The Power of Stories

BY ED HOFFMAN

What is your story?

That question can be taken in many directions. It can express powerful interest or doubt. In Brooklyn, where I grew up, people said, “So, what’s your story?” to make someone reflect on and change foolish behavior. But the same question can be a request for insight and inspiration from a life’s journey.

Telling the right story is an essential requirement for any person, project, or organization that hopes to succeed in a complex world. Individuals and projects thrive or fail because of stories, and the stories we ignore are just as powerful as the ones we tell. We proceed at our peril if we leave the stories of our mission to chance.

Stories change people and projects. Several years ago, teaching a course on leadership, I required students to share two stories that reflected leadership challenges they successfully encountered. I wanted to force honest learning based on real-life experiences. One student seemed particularly distant and cold toward the class. I developed my own internal story of him as a skeptic and resistant to this type of learning.

When the first stories were submitted, that student’s vignette of the impact of racism stirred me to my core. Believing the military was a place where he would not encounter discrimination, he started his army career filled with anticipation. He was emotionally broken when an officer’s racist label went unchallenged. In the twenty-five years since then, he had never described the incident, but he told the class that he felt compelled to tell it now. He was a different person after telling the story: engaged, alive, smiling. At the end of the class, he said he never realized the weight he carried until telling the story helped him let it go.

Every project or organization has a story that can promote or retard the effort. When the Apollo 13 movie came out, the International Space Station and the Supercollider were in a life-and-death struggle to survive political scrutiny. The Supercollider was canceled while the International Space Station survived by one vote. A commonly held view at the time was that NASA benefited from the film that powerfully conveyed a story of struggle, passion, and purpose.

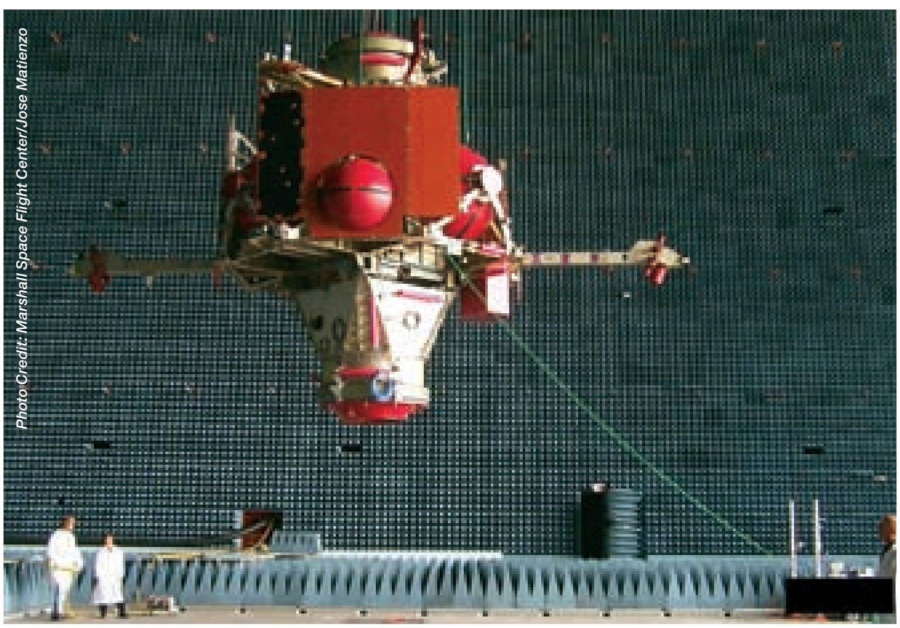
Projects are modern-day quests that can tell tales of challenge, complexity, and meaning. They are purposeful journeys that involve personal commitment to overcome challenges that are sure to arise. Successful project leaders skillfully shape stories that communicate the value of the goal and the importance of collaborative effort. The stories can include challenges represented by milestones and feature everyday heroes who make sacrifices for the good of the mission.

Everyone lives a story and every project has a story, which unfolds whether or not conscious effort is made to shape it. A dysfunctional team tells a story of poor communication, distrust, ineffective leadership, and competition. A successful team benefits from a story of purpose, collaboration, trust, and focus.

Effective leaders communicate stories in ways that connect with people and create energy and support. Crafting and communicating your project story is a vital skill. The story must include a clear sense of purpose and value. It paints an honest picture of challenges and risks and provides action plans showing the path the journey should take. It values the team’s everyday heroes and what they learn from the trials and tribulations of the journey to project success. ●

WORKING WITH NUTS RUNNING LOOSE

BY LEE GRAHAM



The final integrated vehicle is tested in the anechoic chambers at the Naval Air Station–Pauxtent River.

As I walked though the gates at the Naval Research Laboratory (NRL) for the first time, I couldn't help but smile to myself. Six years previously, while doing a tour at the Office of Spaceflight at NASA Headquarters, I had driven by NRL many times and had often thought, "That sounds like an interesting place to work." Little had I realized then that, as a deputy project manager for NASA, I would get a chance to be the senior NASA manager on site.

SPELLING OUT THOSE EXPECTATIONS IN A WRITTEN AGREEMENT WOULD HAVE AVOIDED MANY OF THE REQUIREMENTS, DESIGN, AND INTEGRATION ISSUES WE WERE TO SEE IN THE FOLLOWING TWO YEARS.

With the Russians in the assembly critical path, the International Space Station (ISS) program had decided earlier that it needed to develop an "insurance policy" to protect vehicle development. The program reviewed many options and settled on the solution of slightly modifying an existing NRL flight system. The project became the development and delivery of the vehicle to provide low-cost propulsion for the space station and was to be called the Interim Control Module (ICM). Budget and schedule were predicated on existing NRL processes, minimizing the use of NASA processes and, most important of all, not imposing new and unique system requirements to "human rate" the vehicle. It was to be "used as is." None of this was formally documented; it was mentioned by some senior NASA officials while visiting NRL, with a few other NASA personnel in attendance. This lack of formal definition would cause many of the management and design problems the project was to face. Spelling out those expectations in a written agreement would have avoided many of the requirements, design, and integration issues we were to see in the following two years. Or at least it would have given us ammunition to defend our position and start the discussions. It's a lesson I'll never forget.

I joined the project prior to the preliminary design review, and I had an overall understanding of the requirements the vehicle needed to meet. Armed with this knowledge, I met the NRL program manager, Al Jacoby; his deputy, Bob Towsley; and the entire NRL team within an hour of coming through the gate. As I talked to them about how they were organized and how they operated, a number of points became obvious to me:

- They were a confident and technically competent organization.
- They were a "skunk works"-type organization—very flat with a lot of delegated responsibility.
- Man, this is going to be fun. (Not, how do we integrate this fast-moving, rapid-prototyping, minimum documentation approach with the document- and process-heavy bureaucratic approach of the ISS program?)
- The use-as-is approach, using NRL processes, was probably overly optimistic, but it was a good starting position.
- The program-provided requirements were not very detailed and would require some evolution later.

As the project matured over the following several years, the requirements and the resulting design changed and evolved. And changed, and changed. Our budget and schedule never really stabilized. We eventually completed the vehicle—just in time for the program to mothball it, since the Russians did fulfill their commitments. We also ended up addressing virtually all the points I had seen at the beginning.

Our NRL teammates were also civil servants, so they wanted to be treated as partners, not contractors. I learned that they, and only they, could call themselves the "Nuts Running Loose." In addition, while NRL was very competent, it quickly earned a reputation with us as an overly confident, even at times cocky, workforce. (Sounds similar to us.) The phrase I most often heard from NASA folks was "but we have lives at stake in our missions, they don't." When I got to know the NRL people personally and learned about their integrity and some of their flight history, I discovered that they often had literally tens of thousands of lives depending on their missions. So their confidence began to be understandable. This joint understanding of motivations was the start of mutual respect that began the true team-building we needed. But in getting there, I spent a lot of time soothing troubled waters and getting folks on both sides to understand the other's viewpoint.

One day I received a call about a heated exchange between our NASA civil servant quality assurance representative and one of the outstanding NRL technicians. I called all members of the on-site NASA office together to get the details and to calm everybody down. I reminded our folks that the technicians in this particular area were very close to completing their tasks and, since there was no other immediate work in sight, were probably going to be laid off in the near future. It was therefore understandable that the technician in question would be on edge; we needed to be sensitive to that and act accordingly. The folks involved in the argument apologized to each other later that day, and we got on with the job (and the NRL technician was picked up by another in-house project and kept working).

On another occasion I was called and told we had a "problem" with some of our NASA-provided government-furnished equipment. I found that a small air conditioner had malfunctioned and dumped some condensate water onto our EVA handholds. It turned out not to be a major problem. We were able to fix the air conditioner so it wouldn't happen again, log the incident, dry the hardware, and press on. But as I walked out into our "high bay" area, and with this increased sensitivity to water damage, I noticed our powered-up flight avionics and power decks sitting in the open, right next to our only set of government support equipment that we would have to use in pre-launch and day-of-launch processing. When I pointed out the potential of a water leak destroying this hardware, Al Jacoby reminded me that we were in a large building inside a larger building. It was literally a separate building with about six feet of separation between the roofs. He also mentioned that the odds of any leak finding our hardware in the nearly 100,000 square feet of production space were unbelievably remote.

I still felt uncomfortable and wasn't willing to let it go. So Al got an estimate for protective covering. The cost–benefit trade-off was a no-brainer for me, so we installed it. Some of the NRL engineers good-naturedly joked to me about "Lee's Folly." Fast-forward a couple of months: a hurricane came up the East Coast and hit the Washington, D.C., area with 60 mph winds that tore off a ventilation cover. Rain poured in. The area of the inner roof right on the edge of one of the protective covers turned out to have a hole in it. Sober expressions replaced the laughter. In addition, people started to ask questions about what other protection could be put in place. I saw covers appear around non-NASA flight projects near us. They had never had anything like this happen before, and they probably won't again, but they learned to trust our opinions.

On yet another occasion, during automated acceptance testing of one of our flight star trackers, we had an unexpected reset of the instrument. No analysis of the test data nor examination and additional testing of the flight hardware itself gave us any clues about the cause. We assembled a group of outstanding engineers from Marshall Space Flight Center, along with NRL ICM Chief Engineer George Flach and myself, and set off for the vendor. We spent two difficult days going over all the manufacturing and test records trying to find the cause. We eventually settled on a "most probable" cause that fit all the circumstances, since we couldn't find definitive data. We unanimously agreed to make the unit our spare and only fly it when absolutely necessary. Even more importantly, the in-depth technical discussions increased both groups' respect for the other's technical abilities.

I was shocked at how fast NRL could make changes to the flight hardware and software. We could discuss a change in the morning, make a decision, and have the new drawings and procurements out by that afternoon. Because of this, it became obvious that the NASA folks needed to be tied in tightly with their NRL counterparts to stay aware of what was happening, and why, and to concur with the changes. Constant contact quickly became our standard way of doing business and helped keep the project on track. I, and many others, spent a lot of time on the phone making sure we stayed coordinated across disciplines.

Photo Credit: Marshall Space Flight Center/Jose Matienzo

The ICM is inspected at the Naval Research Lab to ensure the adapter support posts are level with each other.

Getting this fast-moving, bare-bones-approach project integrated into the program was a lot more difficult, however. We ended up creating new documents and products that the program absolutely needed but we hadn't planned on. We also ended up killing some documents that the program team felt were initially needed, but only after a lot of face-to-face meetings and teleconferences. They were often deleted because the program people didn't understand the functionality or interfaces of the ICM to ISS, and the documents they wanted didn't make sense.

Just as important to me was how we worked with our NASA counterparts across the Agency. We were moving so fast that a delay of a few days, while people went off to study minor issues, would be devastating to the project. So I sat down and developed a set of parameters that would allow us to make some changes and corrections without having to ask permission.

For Material Review Board dispositions, I developed a list of delegated authority criteria. The agreed-to approval authority would not require additional off-site NASA approval or review if

- The change didn't affect the required performance of the item.
- No new or re-do of any analyses of any kind were required.
- There was no impact to any ISS interface(s).
- There was no impact to any NASA-provided hardware interface(s).
- There was no effect on the form, fit, or function of the item.

As you would guess, a certain level of trust had to exist between NASA and NRL, and even between the NASA on-site folks and other NASA personnel, to allow this to work. This trust was absolutely critical to avoid stop-work conditions on the shop floor. Just as critical was a desire to make the project a success. We did eventually reach an acceptable level of trust and commitment. On one occasion, we were scheduled to lift some major structural components for final positioning when NRL discovered their lifting equipment needed recertification. Neither they nor I were willing to lift the flight hardware with uncertified hardware, so a quick resolution was needed. I hastily called some friends up the road at Goddard Space Flight Center who agreed to loan us the necessary hardware. I signed the necessary paperwork that morning, loaded it in the back of my pickup, and headed back to NRL. The lift went off without a hitch.

The biggest impact to the project came from the changing requirements, though. The program had originally created the ICM project to ensure the ISS could continue to function should the early Russian modules not show up. With political changes in the wind, and as the technical requirements evolved from the original idea of use-as-is, those of us building the vehicle started to see a fluctuating set of requirements from the program. The vehicle design had to change accordingly. This continued for most of the project life cycle. At the build level, we really had no requirements control because the program was responding to external factors. As a consequence, we developed a lot of hardware that wasn't used in the final configuration. Parts of wiring harnesses, power converters, and other black boxes were designed, built, tested, and certified but never used. It was a great experience but not the optimum project management model.

A number of us NASA human space flight folks gained a wealth of experience working directly with the NRL. We were able to get hands-on experience developing and assembling a complete space flight vehicle, including being test planners and directors on some development and integration tests. We also were able to gain valuable experience developing an Agency-wide distributed team that included outstanding can-do folks from Marshall, Johnson, and Goddard, among others.

I learned a lot. If I had to pick the top five lessons, they would be these:

1. Trust is the key to making any distributed or cross-organizational team work. It may take time to build between people working together for the first time, but it is *always* worth the effort.
2. Requirements stability is critically important. There will always be some level of requirements instability, but we need to be ever vigilant to avoid requirements "churn."
3. Communication, communication, communication. E-mail is okay, but the telephone is better. Face to face is best.
4. Project management folks need to be aware of and sensitive to the mind-sets and experiences of the different organizations supporting their effort. An encouragement approach might work well for one organization yet be an utter disaster for another. That's one reason why project management is as much an art as it is a science.
5. It is possible to integrate a "skunk works"-type project into a "normal" program, but it requires both sides to be flexible. Just as important, it requires someone that understands both organization types and processes to guide the integration process.

Would I do it again? In a heartbeat. ●

LEE GRAHAM joined the Constellation Program office after twenty-two years of working at Johnson Space Center or in support of NASA. His experience includes participation and leadership roles in both large program offices and in small "skunk works" project offices. His expertise includes systems engineering and integration, safety and mission assurance, and real-time operational flight support.

Space Mission Excellence Program: Launching Systems Engineers at Glenn

BY KERRY ELLIS

On January 8, 2007, twenty-three participants in Glenn Research Center's Space Mission Excellence Program met for the mock preliminary design reviews they had been preparing for the past few weeks. When Harvey Schabes, one of the guest review board members, asked after one presentation, "Why did you pick the most expensive options each time? Is there not a risk of running out of money on this?" participant Leah McIntyre responded with a smile in her voice, "Because we want the mission to succeed." The instructor, Joel Sercel, replied quickly, "The right answer is, you tell the board, 'When we engaged with you and the key stakeholders you identified, you all told us cost was not an issue. What you care about most is risk and schedule. These figures reflect that.' At that point, you find out if that was really their criteria. That's the power of this methodology."

Photo Credit: Kerry Ellis

SMEP participant Tom Doehne highlights part of his presentation for the class.

MARTIN FORKOSH, SMEP'S WORKFORCE DEVELOPMENT MANAGER, EXPLAINED THAT THE PROGRAM DIFFERS FROM OTHER TRAINING PROGRAMS BECAUSE IT ASSIGNS PARTICIPANTS TO A VARIETY OF PROJECTS AS SYSTEMS ENGINEERS. "WE TAKE THEM OUT OF THE CLASSROOM AND PROVIDE THEM AN AVENUE FOR REAL, HANDS-ON EXPERIENCE."

For more than sixty years, Glenn has excelled at research in aeronautics; the generation, storing, management, and distribution of power for space systems; electric, nuclear, and chemical propulsion; communications; and microgravity science. Glenn has also played a key role in developing engines and rockets that have launched NASA missions into space, but over time it has lost experience creating aerospace systems that will operate outside Earth's atmosphere. As the Agency turns to the Constellation program and the new Vision for Space Exploration, it is looking especially for the skills required to create new space vehicles. Senior management at Glenn realized they needed new types of experts—systems engineers—to make a significant contribution to Constellation.

In March 2006, Glenn Deputy Director Richard S. Christiansen asked the center's Organization Development and Training Office (ODTO) to help find and prepare candidates for the challenge ahead. The office responded by creating the Space Mission Excellence Program, also known as SMEP, which is currently led by training specialists Kathy Clark and Adam Ross. "We needed to produce highly trained systems engineers in a short amount of time, and we were creating a program from scratch," Clark explained.

Through courses that would offer hands-on experience and in-depth guidance from seasoned systems engineers, SMEP would strive to provide Glenn with systems engineers who possess leadership and communication skills as well as technical expertise. "It is important for systems engineers to be able to work with the project as a whole, including the human interaction involved," said ODTO Chief Cindy Forman. They also wanted to expose program participants to new and different perspectives on systems engineering and help them recognize and define problems and potential solutions.

The program would also provide participants with mentors, but in an unusual way. Martin Forkosh, SMEP's workforce development manager, explained that the program differs from other training programs because it assigns participants to a variety of projects as systems engineers. "We take them out of the classroom and provide them an avenue for real, hands-on experience," Forkosh said, and he played a key role in making this lofty goal a reality. "We wanted a workforce development manager who had contacts across the Agency, was an expert in his field, cared about training, and could find projects for participants to join," said Ross. "Martin had all that and was previously chief of systems engineering, so he understood what we needed from candidates to get them reassigned."

With a bit of trepidation—because they were uncertain how the experienced workforce would respond to taking on "green" members and helping them learn the ins and outs of systems engineering—the training team began asking program and project managers if they would enlist the SMEP recruits for their projects. "The response from project managers was huge; it was really quite fantastic," Forkosh said. Many eagerly took on the SMEP members and placed them on projects to work and gain hands-on experience. All participants work on these projects while they are taking in-classroom training, applying what they learn from both avenues of instruction.

The participants come with a variety of backgrounds and experiences. Charles Farrell spent thirty years in fluid dynamics, software development, management, and software engineering. He joined SMEP because he felt systems engineering best practices were more advanced than those in software engineering, and he wanted to apply his learning back to software engineering. Kathy Shepherd was previously a project manager for the Exercise Countermeasures project, part of a program at Johnson Space Center to study the effects of exercise on astronauts in space. She was looking for a change and wanted to expand her knowledge of NASA, referring to herself as one of the "new kids on the block" because of her six-year tenure with the Agency. James Scott spent twenty-three years researching in aeronautics and acoustics and was at a point where he wanted a transition in his career and could make it. "The mechanism to make such a change had never existed before, so I was excited


Photo Credit: Kerry Ellis

Harvey Schabes leans in to discuss part of a PDR with CalTech instructor Joel Sercel.

about the program," he said. Another participant started down the systems engineering path two years ago; others are still acclimating to a shift made only a few months ago.

Together the participants work on elaborate assignments that expose them to areas of systems engineering they may not have experienced yet in person. In early January 2007, I was invited to observe the outcome of the first of these assignments: a mock preliminary design review (PDR).

Engineer for a Day

The first thing that struck me when I arrived for the PDR was the sense of community in the room. Conversations started up as people began filtering in at 7:30 a.m. and delivered donuts, homemade brownies, and other fresh-baked goods to a small table. Cheery "good mornings" peppered the air as people caught up and reviewed their notes before presenting the findings of their PDR.

As a non-engineer with a limited understanding of what goes into building spacecraft, I was concerned about my ability to follow the class and understand what was being presented. When I shared my apprehension with a couple of students near me, they candidly said they hoped they could answer my questions because they were also new to this and learning so much themselves. Reassured, I asked the most basic—and important—question I needed answered: "What exactly is a preliminary design review?"

The easiest way to define it is as a comprehensive, extremely detailed sales pitch. Participants were divided into two teams as if they were contractors competing for a $170 million project that would span six years. Each team would have about three hours to make its case before a review board about why it should be awarded the contract. For comparison, one participant told me that the actual PDRs for a couple of racks flying on the Space Shuttle took four days to present and probably six to nine months to create.

A PDR includes a massive amount of information. In addition to meeting the client's requirements, a contractor needs to show how it will garner resources to build the spacecraft and operate the mission, predict potential risks and explain how they will be reduced, project the overall budget and timeline, define critical milestones, and much more. Most of content presented in PDRs paints the big picture and provides supporting details about what is needed to build, launch, and relay and analyze data for a long-term mission—important information for a systems engineer to understand, since presenting and defending the project requires a grasp of the entire project and how the parts of it fit together and affect each other. To prepare for their PDRs, participants relied on requirements distributed in their previous class and information in documents or on the Internet from real PDRs of projects similar to the hypothetical one they were assigned.

The review board—there to test participants' understanding of the process, ask pointed questions, and deliver immediate feedback—included CalTech course instructor Joel Sercel, Engineering Development Division Chief Dan Gauntner, and

Center Operations Deputy Director Harvey Schabes. Welcoming the participants the first day was also Ricky Shyne, Deputy Director of the Engineering Directorate. As students from each team presented their sections of the PDR, time was reserved at the end for the review board to ask questions and make observations, detailing what had been done well and what had been missed or could have been done better. Participants were often asked to respond to questions as if they were in a real PDR and respond again as a student to clarify what they were learning and what would happen (or *should* happen) in an actual PDR.

The practice also underscored the importance of predicting, defining, and mitigating risk to ensure teams had plans of action for any contingencies. After James Scott presented his team's risk findings, Sercel clarified some of the confusion about identifying risks: "A risk is an event or condition that has a probability or a consequence. Cost overrun is not an event, but a consequence. Meteor damage to the antenna, however, is a well-defined risk. If a risk can be applied to any project, it is too general and therefore inaccurate." Gauntner elaborated with a quick tip to help participants delineate the difference, "To define a risk, I find it helpful to start with a statement and then ask 'why?' five times to find the root cause. That is your risk."

Stories from personal experience bolstered the generalizations. To help define an acceptable percentage probability for risk, Sercel shared one story about a JPL mission that was developing a composite propellant tank. The engineering team for the tank guesstimated that there was an 80 percent chance the tank would be delivered on time, "which was completely unacceptable," Sercel said. So the team fully funded a back-up titanium tank in parallel.

Interaction among the participants and with the review board members was open and honest, with students challenging some of the board's feedback and even inspiring some friendly debates among the board members about engineering requirements, the best way to accomplish goals, and new approaches to standard PDR requirements. Student-to-student conversations sprang up during the question-and-answer sessions as they discussed details and incorporated the board's feedback into upcoming presentations. Though the exercise had been playfully described as a competition between contractors, it was obvious from the exchanges that there was one community in the room.

Each team learned from the other. They discussed the differences in their approaches and what they had learned from each other over lunch, so they all reached a cohesive understanding together. After the presentations were completed, the review board assigned a few "requests for action" and asked the teams to revise some slides for the next day to ensure they understood the feedback they had received the first day. The next morning, the line between teams was further dissolved as the entire group worked together to revise portions of their presentations. Gauntner observed these interactions as well, saying at the end of the exercise, "Everyone showed remarkable teamwork and camaraderie, which will be a benefit for exploration."

Using their new hands-on experience to bolster the PDR exercise and taking lessons learned from their mock PDRs back to their projects creates a rich and ongoing educational experience for the participants. The students also discovered they were using their previous work experience in ways they had not anticipated. Shepherd said that her previous project management experience helped her see the whole picture that systems engineering required. Scott said he was surprised he was using much of his research background in systems engineering, because systems engineering is a completely different discipline. He also shared with me a realization we'd both come to that day: "You just can't build spacecraft without systems engineering."

Future Generation

SMEP has more experience and mentorship ahead for the participants. By the time the program concludes at the end of 2007, Glenn's office of development and training hopes its program of formal training, hands-on experience, and in-depth exercises will have helped the next generation of systems engineers contribute to the Vision for Space Exploration. ●

CompanyCommand: A Professional Community That Works

BY DR. NANCY M. DIXON

Army Capt. Chanda Mofu, left, prepares to lead a joint American–Iraqi patrol. Since returning from Iraq, where he commanded two infantry companies, Mofu has stepped up to play a leadership role on the CompanyCommand team.

Photo courtesy of CompanyCommand

The term "community" has become ubiquitous—everything from list serves to "MySpace" has been tagged a "community." The kind of community I describe here is one whose members are dedicated to mutual growth and development—so I might label it a professional development community.

CompanyCommand is a professional forum through which soldiers who have been given command of a company (about 150 soldiers) learn from each other in the mess hall, over the hood of a Humvee in Iraq, and online at http://companycommand.army.mil. CompanyCommand has been heralded by the army as its premier professional forum, notwithstanding its grassroots beginnings in 1995 by two young U.S. Army officers. Even after being brought behind the army firewall, CompanyCommand has retained its grassroots spirit and governance, remaining a community of young officers exchanging knowledge based on the daily struggles of frontline professionals like themselves. Company commanders are a rich source of knowledge about how to be effective leaders in the rapidly changing battle environment; they alone have firsthand knowledge of what the role demands.

Conversation about subjects that really matter to this group of soldiers is at the heart of this forum: "How do I deal with the death of a soldier I am responsible for?" "Is it my responsibility to help soldiers be comfortable with the reality of killing or just train them to do it?" "How do I keep soldiers physically fit for the mountainous terrain and overwhelming heat and cold of Afghanistan?" "What have we learned about how to interact with Iraqis?" There are no doctrinal or clear-cut answers to these issues; they are the ambiguous questions of leadership. When answers are not clear, conversation with those facing similar issues is an essential means of deepening one's own thinking about important subjects.

Company commanders challenge each other's thinking by raising difficult issues in the online forum; they meet together to read and discuss books through the Pro-Reading program; they provide emotional support in informal face-to-face gatherings on base; they celebrate each other's lives and successes with pictures, honors, and recognition on the CompanyCommand Web site; they meet together at a yearly rendezvous; and they provide practical firsthand knowledge about the task they are all engaged in through conversations.

These company commanders believe they are making a difference in each other's professional development. They would say they are "giving back" to a profession that has given them much.

The Core Team Is the Heart of the Community

This willingness to give back and to support each other does not occur without a great deal of effort by a volunteer group at the core of the community that actively builds the relationships that glue the community together.

Any community that shares knowledge and supports and develops each other must have a small, socially connected, and committed group of members that takes responsibility for the majority of the activity in the system.[1,3,4] CompanyCommand has some thirty dedicated volunteers, each responsible for a specialized section of the community: for instance, maintenance, war fighting, military police. Each core team member is a company commander, who is a specialist from the field he or she leads—someone who knows the ins and outs of the daily work of that specialty field.

Company commanders typically stay in their command post for only a couple of years before being rotated out to a new assignment. So the core team, like the whole of CompanyCommand, is a dynamic community with a constant influx of new members, while others are phasing out.

CompanyCommand team members (left to right) Chanda Mofu, Dan Dwyer, Nate Self, and Jay Miseli share ideas during the CC team's annual "OnFire! Rendezvous," which brings together the team for a face-to-face weekend of camaraderie, training, and planning. All four have led soldiers in combat. Self was awarded the Silver Star for his valor in Afghanistan.

Once out of command, core team members quickly realize that they are no longer in touch with the needs of soldiers on the ground and begin to look for the person who will follow them in leading their section. But not just any volunteer will do; they look for someone who, like themselves, wants to have an impact on the profession—who has a willingness to give back.

This core group maintains the care and feeding of CompanyCommand, but like any community, they require care and feeding themselves. The core group becomes a subcommunity within the whole, training, encouraging, and supporting each other in their efforts to be more effective core team leaders. As a vital part of that support, the core team holds a yearly rendezvous to celebrate successes and think about the needs of the community. Here a core team member describes one of those meetings:

> The rendezvous was huge because that brought together such a group of like-minded professionals, and staying with that group of people for three or four days, talking with them, generating ideas, was a huge energy boost. It really just kind of got me reenergized and back into the thick of it. It gave me some huge ideas on reorganizing the taxonomy of how *Soldiers and Families* was organized and trying to make it more content friendly and trying to make it more user friendly. And it really just kind of reaffirmed what I thought I was doing with CompanyCommand and why it was valuable to me and why it was valuable to the profession.[1]

What It Takes to Connect the Community

In studying CompanyCommand, Tony Burgess, one of the founders, identified five roles core team members play in their communities.[1] The words of the core team members themselves best describe what they do in these roles and why they choose to serve in this way.

1. Contributor

Those who become core team leaders have themselves been active members of the forum, and as core team leaders they continue to bring all of themselves to the new role—their current work issues and problems as well as their knowledge and experience.

> [CompanyCommand is] a place I could give what I had to share and at the same time still ask; I could still be in a learning environment. It wasn't, you know, a teacher–student type thing. It was truly a group of guys [saying], okay … let's throw this thing out there and see what people think about that.

2. Connector

In this role core team members connect people to other knowledgeable people and to content that is on the site, and they close the loop by finding out what actions the soldier who asked the question took as a result of the conversation, playing that back as well.

> You know that this guy over here has something to give and this guy over here is looking for it, and you're the one who helps make that connection possible …. [I ask myself] what can I do to find the other people who have had this experience and get them involved with those guys who are over there [in combat] now? And you do it in a variety of ways. You use the Web site itself to make a call to arms, "Hey, you know this guy is out here doing this. Is there anybody who can help him out?" And people jump on it. Or you make the private connection [via e-mail or phone].

3. Facilitator

In this role the core team member works to deepen the conversations that occur in his specialty group, serving as a catalyst and sometimes a provocateur.

Right Photo: U.S. Army Captain and CompanyCommand team member Jason Toole, right, with his company first sergeant in Afghanistan.

> We recently debuted a question about whether or not commanders have a responsibility for teaching soldiers how to deal with killing. It's a great question, and one that needs to be dealt with, but … the problem was that it didn't seem to generate a whole lot of conversation because there was an enormous amount of consensus there. So what I decided to do was play a little bit of devil's advocate … to post an opposing view … and that generated some good responses from other people. I felt like *I* could put myself out there and make myself a 50-meter target for other people to take shots at and help generate conversation.

This core team member used his provocative post to help those in the conversation clarify their own thinking about this issue by articulating the reasoning underlying their positions. Core team members often invite diverse views, from another perspective or from another specialty, to enrich a conversation.

4. Social Catalyst

This role is about making connections and building relationships. One way core team members serve as social catalysts is by warmly welcoming new members and establishing a personal connection with them, sometimes through e-mail, sometimes by picking up the phone, and often by taking the time to meet them in person when the core team member is traveling to an area where the new member is located.

Core team members acknowledge contributions in a personal way that builds the sense of community. This is such a vital part of their role that I include two quotes here to illustrate the nature of their responses. There are no all-inclusive, "thanks for your posting" messages that go out.

> Anybody who posts or responds to questions, or provides a really awesome tool—anybody who contributes to the supply forum—I'd usually shoot back an e-mail saying, "Hey, what a great tool." Or "What a great idea." Or "What a great thought. I hope this isn't the last time we see you contributing because you were really on target with your comments." Or "The tool you provided, I see how that can help."

> "[Name], you many not realize it, but you really helped that guy. Did you see the response that he brought up?" Or, "Did you see that this guy that you helped then turned around and added to two other conversations and imported this knowledge object, and now he's a contributor to CompanyCommand and he's working hard? That was because of your intervention; that was because of your answer; that was because of the content that you helped him find; that was because you just wrote to him and said, 'Good work,' you know; that was due to your intervention. Well done!"

In an ever-changing community of 2,000 company commanders, participants in the site cannot hope to build a trust relationship with each person in their specialty area, but they can know and have been touched by the core team members. Through exchanges illustrated by those above, the community takes on a spirit of openness and acceptance. Core team leaders create a tone and attitude that permeates the whole.

5. Steward

Core team members look for gaps in the knowledge of their section and find ways to plug those holes. They shoot videos of company commanders on the ground, interview heroes and generals, send out surveys to capture the collective thinking on issues, and watch the site to see what issues and concerns are rising through the conversations. They serve as a quality control for their section, although always in a way that continues to build relationships.

> … it doesn't mean that I just reach out and delete; it means that I reach out to that individual who put it up

IN AN EVER-CHANGING COMMUNITY OF 2,000 COMPANY COMMANDERS, PARTICIPANTS IN THE SITE CANNOT HOPE TO BUILD A TRUST RELATIONSHIP WITH EACH PERSON IN THEIR SPECIALTY AREA, BUT THEY CAN KNOW AND HAVE BEEN TOUCHED BY THE CORE TEAM MEMBERS.

Army Capt. Jason Toole talks with an Afghanistan National Police chief in 2006. After returning from his second deployment to Afghanistan, Toole became a CompanyCommand topic lead as a way to share what he had learned about that country and counterinsurgency operations.

> there and say, "Can you tell me why you thought this should be on CompanyCommand?" Because frequently what happens is that … they wanted to do the right thing and they were in such a rush to get it up there that they didn't really think about how to phrase it. So by talking to them and refining it and saying, "Give me the context behind this" … you get some really great products.

Ownership and Professional Pride

What I hear in these many quotes, and what I hope you as the reader hear, is the sense of ownership these core team leaders feel about CompanyCommand. It is *their* community, not the U.S. Army's, and though they work hard to serve the army, they do so by helping company commanders meet their own needs for professional development.

There is a final quote from an early study I conducted with leaders in the core team, which for me sums up the need for a professional development community:

> As I become more senior, more professionally mature, I have a greater desire to have an impact on the profession—not only because I care about it and I care about the soldiers, but also because I'm going to continue to work inside this profession. If you believe in something, you want to have an impact on it because it's going to come back to you at some point. So I ask myself, "What direction are we taking our profession?" You could ask that about your company, your battalion, about the Web site, about the army. In the same way that you are an active participant in shaping the government when you vote, you have the opportunity to be actively involved in shaping this profession.[2]

Professional development occurs when professionals face difficult issues that they care about and are able to reflect on that experience with colleagues who do similar work and in an atmosphere of trust and acceptance. ●

DR. NANCY M. DIXON is an author and consultant working with clients to create effective ways to hold knowledge conversations. She is the author of eight books, including *Common Knowledge* and *The Organizational Learning Cycle*, as well as more than fifty articles that focus on how organizations learn.

1. The quotes in this article are from Tony Burgess, *Understanding the Core Group in a Distributed Community of Practice* (Dissertation, The George Washington University, 2006).
2. Nancy M. Dixon, Nate Allen, Tony Burgess, Pete Kilner, and Steve Schweitzer, *CompanyCommand: Unleashing the Power of the Army Profession* (New York: The Center for the Advancement of Leader Development and Organizational Learning, West Point, 2005).
3. Etienne Wenger, Richard McDermott, and William Snyder, *Cultivating Communities of Practice: A Guide to Managing Knowledge* (Boston: Harvard Business School Press, 2002).
4. Nancy M. Dixon, *Common Knowledge: How Companies Thrive by Sharing What They Know* (Boston: Harvard Business School Press, 2000).

Living with THE CONTRACTOR

BY EDWARD INGRAHAM

I began working with Stanford University, the Gravity Probe B (GP-B) prime contractor, in 1993 and worked full time at the contractor's facilities from 1997 to 2005. When I first visited Stanford, the GP-B team was working in a classic laboratory research environment. The team was brilliant to watch as they came up with solutions to the many technical issues they faced. They were not afraid to challenge each other on even minor technical issues. In one of my first meetings, I watched co-investigators argue about whether the atomic number of niobium was 92.90638 or 92.90637. I didn't know the fifth decimal point of the atomic number of niobium off the top of my head! How was I to add value to this incredibly smart bunch of scientists and engineers? It turns out there were some useful things that I did know. To successfully launch GP-B, I knew that one day this team of academic researchers needed to create an aerospace infrastructure to perform the tasks that awaited them. We started pulling in the reins to convert GP-B from a research project to a flight program—not all at once but by introducing continuous, systematic improvements at a pace that allowed the majority of the workforce to adapt. Changing how a team works isn't easy, especially if you need to maintain their trust and cooperation while doing it. Here are some important approaches.

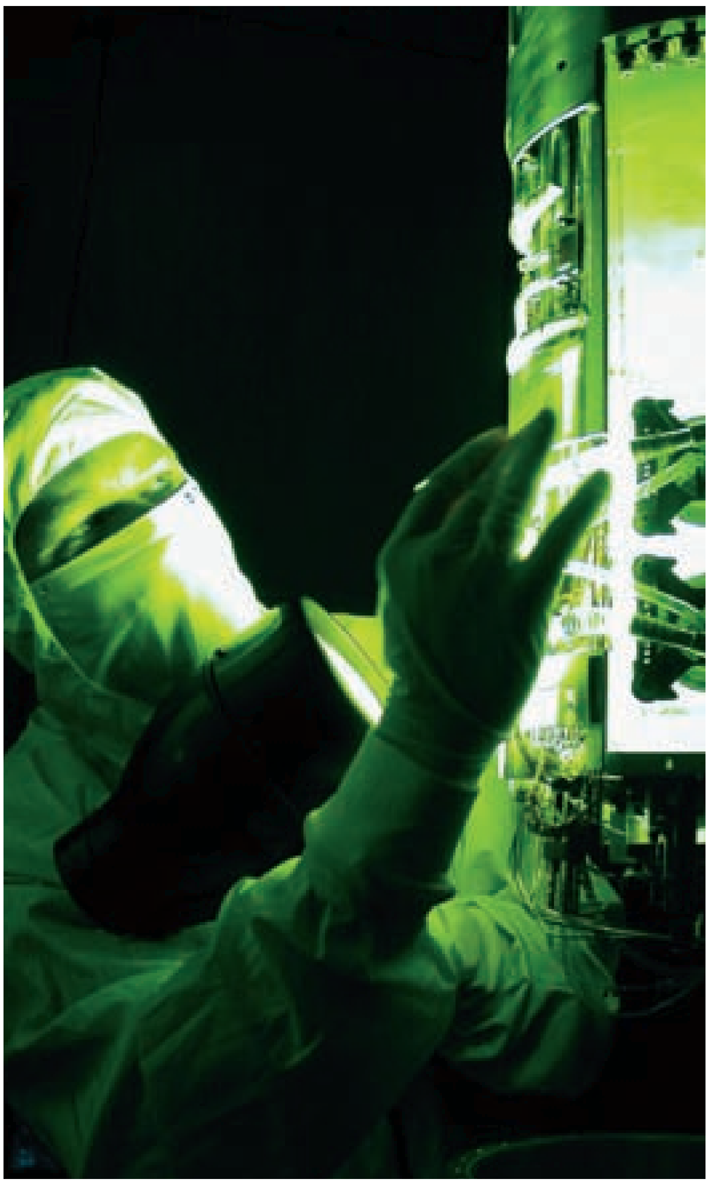


Photo Credit: Stanford University/Russ Leese

Stanford engineer Ken Bower inspects the Gravity Probe B fused-quartz block, which houses the four fused-quartz gyroscopes.

Learn and Teach

Initially I worked to become part of the team. I got beyond the review meetings to where the real work was going on. It was important to spend some energy becoming part of the team and proving my value. All new leaders or team members must do this to be effective. I think we all need to earn the right to be part of a team regardless of what our official roles and responsibilities are. Humans are social creatures and team dynamics play an important role in one's effectiveness. Initially engaging others in what they do, listening more than talking, and helping others accomplish their tasks are all great ways to earn the right to influence the process. For the customer at a contractor's facility, this is also a great way to gain in-depth knowledge of existing processes. It's difficult to really understand what is broken without rolling up your shirtsleeves and doing some of the work yourself. You learn where the processes are breaking down.

When Stanford said it didn't have the resources or expertise to train its people, I worked with the team to devise a process to build flight hardware on campus and brought in other NASA personnel to help train and certify key members of its workforce. The training included the nuts and bolts of building and testing flight hardware for NASA, and it was designed specifically for Stanford's applications. The engineers, technicians, scientists, and managers began to appreciate how everything from purchasing parts, writing test procedures, dispositioning discrepancies, and approving readiness reviews came together logically to demonstrate that their subsystems, systems, and eventually their spacecraft were ready to fly. The training gave team members a common understanding of how they needed to operate and demonstrated that NASA and the contractor were on the same team.

Manage Change Thoughtfully

To be an effective project manager, you must see your role as the one in charge of understanding and monitoring all interfaces, whether subsystem to subsystem or team member to team

INITIALLY ENGAGING OTHERS IN WHAT THEY DO, LISTENING MORE THAN TALKING, AND HELPING OTHERS ACCOMPLISH THEIR TASKS ARE ALL GREAT WAYS TO EARN THE RIGHT TO INFLUENCE THE PROCESS.

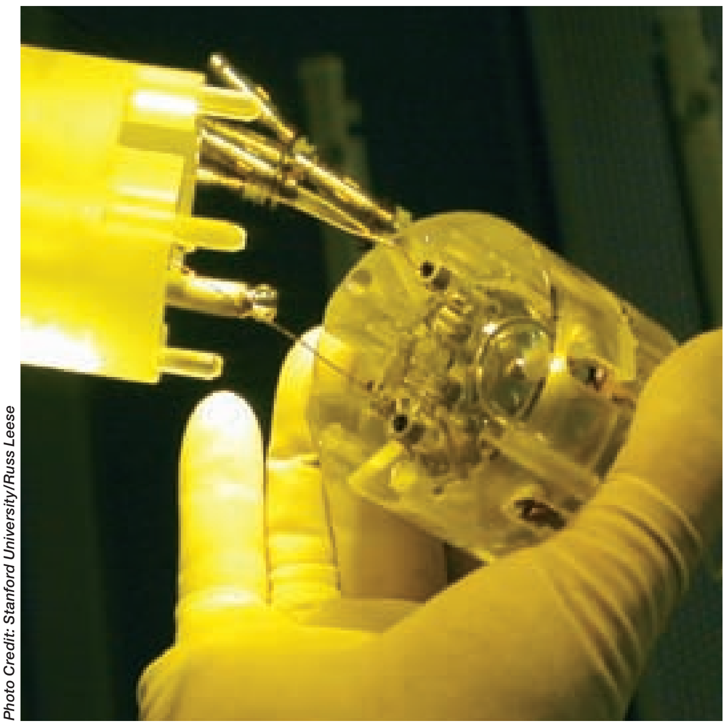


Photo Credit: Stanford University/Russ Leese

Stanford engineer Chris Gray inspects the number-four gyro under monochromatic light after it was removed from the Science Instrument assembly.

member. Interfaces require effective communication, whether between electronic boxes or humans. Be on the lookout for key interfaces that span organizational lines and could create a barrier within your team. For example, when I first started, the program had a weak system for process changes. A new, unified Program Change Board (PCB) system was organized at Lockheed Martin, Stanford, and Marshall Space Flight Center to handle all programmatic and technical changes for the program. I worked hard to get that system started and working efficiently. That meant modifying the contract to include

NASA representation at the contractor's level, which was key to coordinating all levels of the decision process. It gave everyone involved clear insight into what was going on. In the end, more than 675 changes were effectively processed.

Find Common Ground

When I came into the program in the early nineties, the challenge was not just to integrate flight subsystems but also to integrate NASA, Stanford University, and Lockheed Martin—organizations with three very different mind-sets. To see the other teams as collaborators instead of competitors, team members needed to understand each other's challenges and adjust their ways of thinking.

When a large number of NASA engineers joined GP-B a couple of years before launch, the contractor team—which already felt overworked—resented spending what seemed like more time replying to NASA engineers' questions than working on the project. NASA engineers, for their part, were not used to having only limited access to the contractor. Both sides were frustrated. We worked on getting them to see each other's points of view and looked for solutions to the conflict. The contractor hired additional personnel. NASA changed its priority and emphasis to a risk-based management system. This served to substantially reduce questions about some subsystems that posed little or no risk to mission success and allowed concentration on mitigating issues that could threaten mission success. In the end, this compromise produced a solution that served the team and the project well.

Seek Out the "Doers" on Your Team

Sift through the "knowers" and find the "doers" for your project. There is a loose and imperfect relationship between knowing what to do and the ability to act on that knowledge. Many times, people confuse talking about what a group ought to do with actually getting it done. A "doer" is someone you can rely on, for instance, to get a particular system manufactured and tested. We had several "go to" team members who could jump into a difficult situation and succeed. A manager who is a "doer" creates positive change in the team to make it more effective and more able to create a product that fulfills its mission. Concentrating on words rather than turning words into action is the easiest way for managers to fail. One of the biggest mistakes I've seen a manager make is believing that just because he or she said something or documented it, it would be done. Do not confuse talking a lot, sounding smart, or using complex rhetoric with "doing."

Understand Weaknesses As Well As Strengths

It is important to understand weaknesses in addition to strengths. The brilliance of the GP-B team members was actually both a strength and a weakness. For example, the Gas Management Assembly (GMA) used to hold and pump helium gas into

Lessons Learned

- First, work to become part of the team. Earn the right to be part of the team through hard work and by demonstrating value as a team member.
- Listen more than you talk. Before making process changes, analyze how and why the team uses its current processes.
- Cover your flank. Ensure that NASA speaks with one voice. Make sure your senior managers are aware of what you're doing and will back you up.
- Accept ownership of problems. Move past unproductive blaming of others and begin to focus on figuring out what to do about problems.
- Understand and manage the technical and programmatic interfaces.
- Know your contractors' weaknesses. Help them by finding "doers" in your organization who can come in and help solve problems.
- Look for problems in the dark spots. Problems are usually found in places where others are not looking.

Photo Credit: Don Harley

Image of a coated gyroscope rotor and matching housings.

the gyroscopes to spin them up in the beginning of the flight experiment did not get a lot of management attention. While this subsystem was critical to mission success, it was basically a big plumbing system. The best engineers wanted to work on other, flashier subsystems.

Responsibility for the GMA shifted among a few development engineers until it ended up on Chris Gray's lap. Soon thereafter, Chris proposed a series of tests to try to fully understand the performance of the partially built subsystem. Each time Chris came back with test results, they showed an additional problem. It was like putting your finger in a leaking dam and having another leak pop up. I quickly concluded that we'd need a major hardware change for the GMA and Gravity Probe B to succeed. The contractor had a hard time coming to terms with a major change at a late stage in the program.

By this time, the team trusted me enough to accept my offer to fly in a NASA valve expert to help. Within a day, I had the best valve person from Marshall Space Flight Center at the contractor's facility, and the NASA Program Office was preparing upper management for the schedule and cost impact of the major hardware change that might be necessary. By the time the decision was made to restart the development of the GMA system from scratch, NASA management and the contractor's team were on board. NASA, Stanford, and the new subcontractor team designed, manufactured, tested, and integrated the new GMA system from scratch in thirteen months, and it worked flawlessly during the mission.

The Importance of Being There

Having NASA engineers and managers reside at contractors' facilities, if done properly, reduces the risk of hidden problems and adds to the openness, trust, and unity of the entire team. And working day to day with flight hardware at a contractor facility provides training that no course or textbook can match. The time I spent at the contractor facility for the GP-B mission was an incredible journey and an invaluable experience that taught me how NASA should work with a contractor. ●

For more information on the Gravity Probe B mission, visit http://einstein.stanford.edu.

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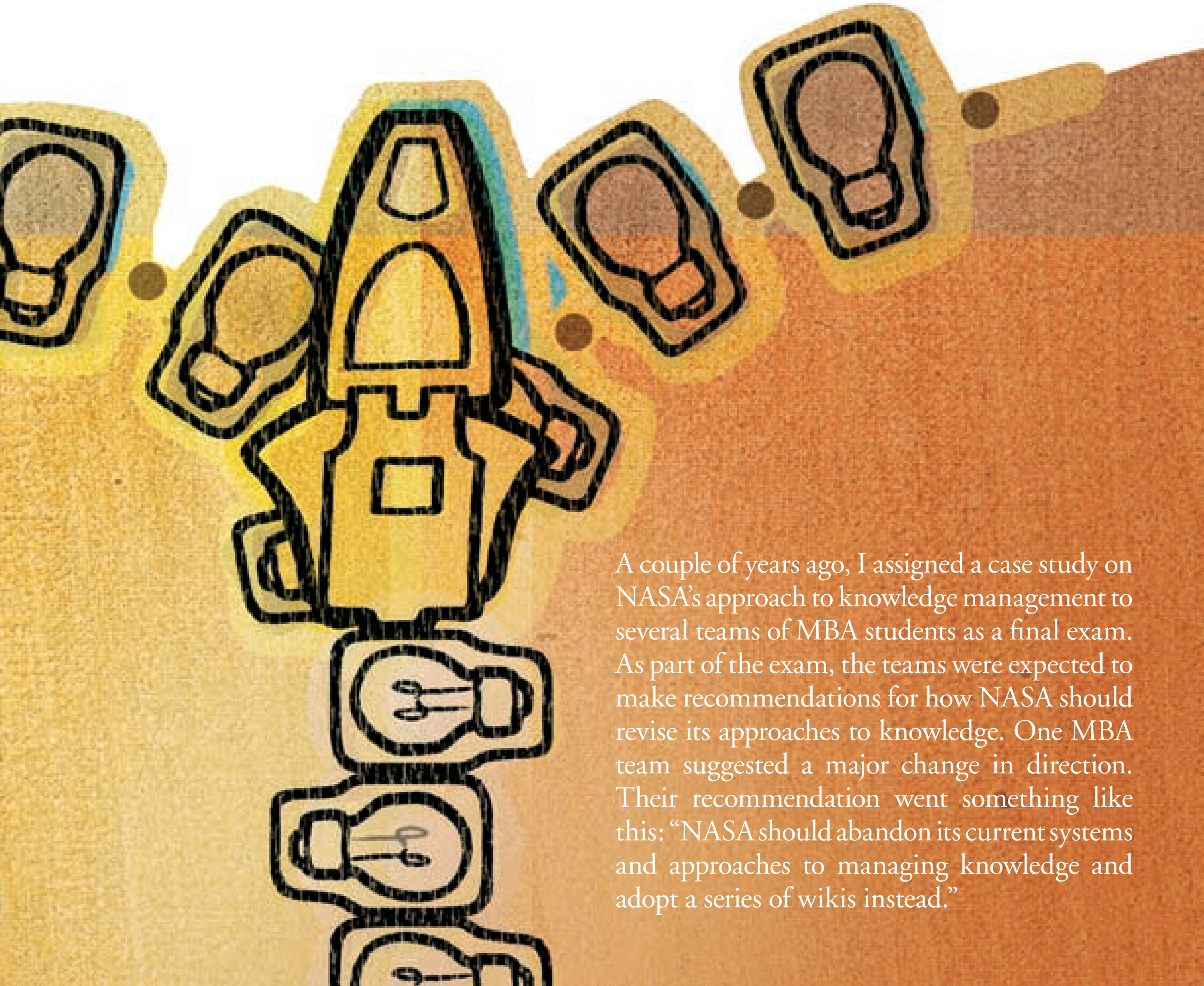
Democratizing Knowledge at NASA and Elsewhere

BY THOMAS H. DAVENPORT



A couple of years ago, I assigned a case study on NASA's approach to knowledge management to several teams of MBA students as a final exam. As part of the exam, the teams were expected to make recommendations for how NASA should revise its approaches to knowledge. One MBA team suggested a major change in direction. Their recommendation went something like this: "NASA should abandon its current systems and approaches to managing knowledge and adopt a series of wikis instead."

KNOWLEDGE IS ALMOST ALWAYS A SOCIAL CONSTRUCT AND SELDOM THE SOLE POSSESSION OF A SINGLE BRILLIANT INDIVIDUAL. WHY NOT ENGAGE THE INTELLIGENCE AND EXPERTISE OF AS MANY PEOPLE AS POSSIBLE?

A wiki is a system by which multiple individuals can edit a document over the Internet. It was a relatively new feature at the time, but it is much better known today because of the success of Wikipedia, a publicly edited encyclopedia. I didn't give these students a high grade. I commented on their paper that, "I'd hate to fly on a Space Shuttle mission with expertise contributed by committee."

Since then, however, the "democratization of knowledge" has become an influential idea, and wikis, blogs, and social networking software have risen dramatically in popularity. A recent *New York Times* article described the embrace of these democratic tools by several groups within the U.S. intelligence community. MIT has formed a research center dealing with what it calls "collective intelligence."

Were my students, then, only a bit ahead of their time? Was I an old fogy and an elitist in resisting this democratic movement? In this article, I'll consider the tools and management issues driving the democratization of knowledge and speculate a bit on their potential relevance to NASA.

What's So Good About Knowledge Democracy?

The general idea of making knowledge more democratic has strong appeal for many. It recognizes that knowledge is almost always a social construct and seldom the sole possession of a single brilliant individual. Why not engage the intelligence and expertise of as many people as possible? All of us together are clearly smarter than any one of us.

It's also an appealing notion that knowledge democracies would eliminate political or hierarchical barriers to knowledge exchange. In a fully democratic organization, everyone's ideas would be heard and considered. The democratization idea suggests that knowledge will flow more readily around an organization, and the best ideas will float to the top. NASA, of course, has encountered situations in which the broader dissemination of knowledge might have prevented failed missions.

Substantial technology that could yield a more democratic form of knowledge management is now available. Wikis are being considered, for example, for applications such as comments on patent applications. There are more than 80 million Web logs, or blogs, in which individuals express their opinions or personal knowledge in an informal fashion. Social networking software is primarily for social interchange now, but new versions of it are being introduced that allow sharing of business relationships and contacts. "Prediction markets," such as the Iowa Electronic Markets, are being touted as yielding better predictions of difficult-to-forecast phenomena (most notably, in the case of the Iowa market, the U.S. presidential elections). These technologies could bring an approach to capturing and managing knowledge that is much more democratic and participative than those typically used to manage organizational knowledge.

Alas, however, this utopian vision can hardly be achieved through new technology alone. The absence of democratic knowledge technologies in the past is not the only reason that knowledge is hierarchical in nature. Software and the Internet won't make organizational hierarchy and politics go away. They won't make the ideas of the frontline worker in corporations as influential as those of the CEO. Most of the barriers that prevent knowledge from flowing freely in organizations—power differentials, lack of trust, missing incentives, unsupportive cultures, and the general busyness of employees today—would not be addressed by technology alone. For a set of technologies to bring about such changes, it would have to be truly magical, and the tools employed for knowledge democracies fall short of magic.

For NASA, however, a more important issue in moving to a more democratic knowledge environment is the quality of the knowledge itself. NASA is full of experts on various topics, but in any specific knowledge domain some people are more expert than others. It would seem irresponsible to treat all knowledge equally where lives and very large amounts of resources are at stake, as they are on all NASA space missions.

Therefore, I would argue that it is not a good idea for NASA to adopt a fully democratic approach to knowledge, at least under certain circumstances, including situations in which there are clear right answers and where some people are more likely to provide those answers than others. Indeed, on the Internet and in other environments where knowledge creation and distribution have already been democratized (for instance, CB radio and community access television), knowledge quality levels are often degraded.

Some argue that knowledge quality can remain high in a democratic knowledge environment. The most common example given is Wikipedia, the wiki-based encyclopedia. A widely discussed article in *Nature*—itself usually a source of high-quality knowledge—reported that Wikipedia's science-oriented entries were not significantly more error-prone than *Encyclopaedia Britannica's*, which rely heavily on expert writers and editors. There is more to this story, however. Even *Nature* found that Wikipedia had 32 percent more errors than *Britannica*, and in many cases the *Nature* reporters did not use actual entries from the real *Britannica* encyclopedia as the basis for comparison. For example, one entry they used consisted of several excerpts from *Britannica* entries strung together with text written by the *Nature* reporters; another came from a *Britannica* encyclopedia for children. While many democratically minded observers have used this comparison to support a more democratic knowledge management approach, I believe that it supports the opposite conclusion—that experts provide a higher quality of knowledge than the general public.

Finally, there are some who argue that these democratic and socially oriented tools can be used to distribute knowledge by experts. Why not, as some have suggested, get experts to write blogs on NASA's intranet (or even the public Internet)? While this approach is certainly possible, and some companies I have encountered do employ it, I don't believe it's very helpful. There are already many tools for distributing the knowledge of experts—from corporate portals to online expertise directories to printed books. The power of social media is their social nature; it is, I believe, a misuse of those tools to restrict them to experts.

When Are Democratic Approaches Appropriate?

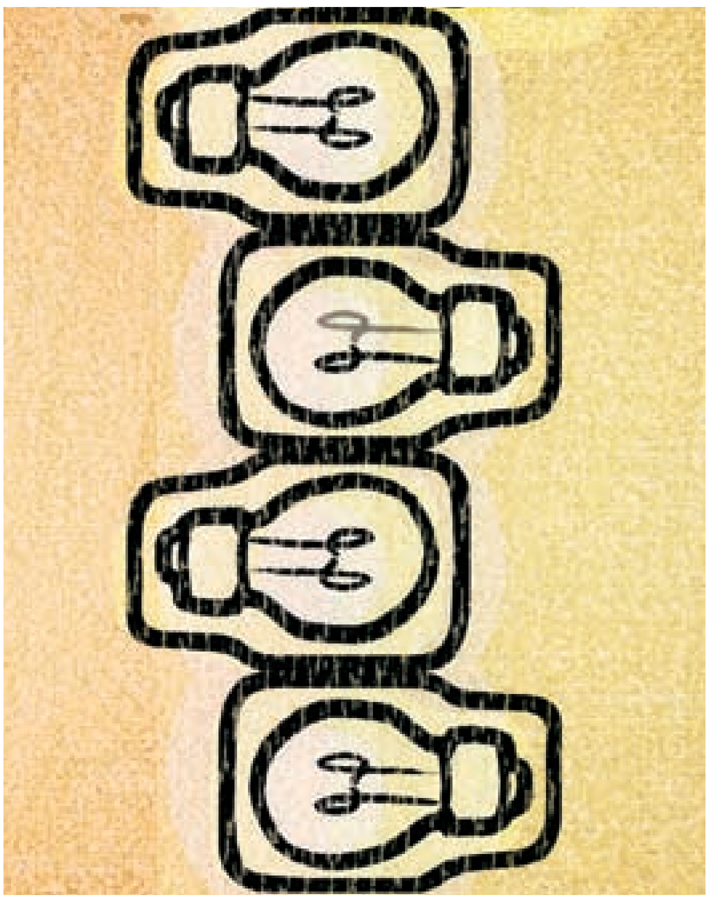
Under what circumstances, then, might it be feasible and even desirable to use these social and democratic tools? One fairly obvious set of conditions would be when there is no right answer but only opinions as to the best alternative. A debate on which U.S. presidential candidate might provide the greatest level of support for manned space travel, for example, would seem to be well-suited to a series of blogs and online discussions.

Democratic approaches may also be useful to debate questions (again, that have no right answer) when broad participation and commitment by affected parties is necessary for success. Organizations that care deeply about employee satisfaction, for example, might use blogs, wikis, or discussion databases to debate changes in human resource management policy. This participative approach would seem especially relevant to organizations like NASA where there are high percentages of well-educated knowledge workers.

Another setting well suited to democratic knowledge is when there is a correct answer, but the knowledge needed to elicit it is equally distributed among a population. In *The Wisdom of Crowds*, James Surowiecki refers to the frequent contests in which many individuals guess how many jellybeans (or other small objects) there are in a large jar. No individual knows the correct answer, but all are equally qualified to guess. In such situations, Surowiecki reports, guesses will vary widely, but the average of all the guesses is likely to come close to the correct number. One hopes that NASA usually has better means for coming up with an answer, however.

This "averaging" approach can also work when experts are the opinion holders. Individual expert predictions are often wrong, but collectively they can be impressively perspicacious. Law professor Cass Sunstein points out in *Infotopia: How Many Minds Produce Knowledge* that while an individual economist may not accurately predict economic growth every year, the average of a number of economists' growth predictions is usually quite accurate.

MOST OF THE BARRIERS THAT PREVENT KNOWLEDGE FROM FLOWING FREELY IN ORGANIZATIONS—POWER DIFFERENTIALS, LACK OF TRUST, MISSING INCENTIVES, UNSUPPORTIVE CULTURES, AND THE GENERAL BUSYNESS OF EMPLOYEES TODAY—WOULD NOT BE ADDRESSED BY TECHNOLOGY ALONE.



Another (possibly more useful) approach for democratic knowledge at NASA is in situations where a non-accountable opinion may be more honest or accurate than those who are accountable for an outcome. Some corporations (Hewlett-Packard, for example) have experimented with "opinion markets" to predict sales performance based on multiple opinions; accountable salespeople may be likely to overestimate the likelihood of a particular sale. Pharmaceutical firms use the same tool to predict the likelihood that a drug compound will receive FDA approval. NASA might employ opinion markets to anticipate the likelihood of a mission failure.

Finally, democratic approaches to knowledge can work well when the goal is only an approximate, convenient answer. Google, for example, employs a democratic approach to deciding what Web page you are seeking when you do a search. It ranks pages primarily on the basis of the degree to which other pages have linked to a page. The page-ranking algorithm may yield the site you seek, but it is usually just an approximate result. Similarly, while Wikipedia may have a lower definition accuracy level than *Encyclopaedia Britannica*, the wiki-based encyclopedia is free and convenient to use, and it usually provides a generally correct answer.

Choosing the Right Approach

There are, then, a number of settings in which democratic knowledge tools can provide an accurate or useful answer. But these are by no means the only settings in which organizations have a need for knowledge. NASA and other organizations seeking to manage knowledge and improve knowledge work need to analyze and diagnose the setting in which knowledge will be used before deciding on any particular technology to facilitate the process.

There is little doubt that democratic knowledge technologies should be employed to augment the more traditional, accepted approaches to creating, gathering, refining, and distributing knowledge. However, they should not be viewed as a panacea for NASA nor as the only useful tool in the knowledge toolbox. ●

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INTERVIEW WITH

Robert Seamans

BY DON COHEN

Robert C. Seamans was appointed associate administrator of NASA in 1960 and became deputy administrator in 1965. He later became secretary of the U.S. Air Force and then dean of the School of Engineering at MIT. Don Cohen spoke with him at the Robert C. Seamans Learning Laboratory on the MIT campus in Cambridge, Mass.

COHEN: What was NASA like when you became associate administrator in 1960?

SEAMANS: A lot of people thought I was nuts to take the job because Eisenhower's term was about over, and there was a real question as to what might happen next. Was Nixon or Kennedy going to be elected? That was still in the lap of the gods on September first, when I was sworn in. My first job was to try to see what was already going on. I'd served on NACA [National Advisory Committee for Aeronautics] committees, and I'd even been on an interim committee to see what NASA might do in certain areas, but it's one thing to have a general idea and another to know what each of the centers is doing. Keith Glennan, who was the administrator, was very thoughtful and said, "Why don't you take the first month and get around to every one of the centers?" I started off at Langley. The first thing that Tommy Thompson, the director, had set up was for me to get to know something about Mercury. I climbed into the simulator; John Glenn put the hatch down and went through a very modest simulation. Next I met with John Houbolt and one or two others. Oftentimes when you go for briefings you have a lot of people in the room and

> “WE FELT VERY **strongly** THAT WE COULD NOT **manage** APOLLO UNLESS WE HAD **technical competence** WITHIN NASA TO COVER **any aspect** OF **any problem** THAT MIGHT ARISE.”

slides like you wouldn’t believe. All John had was three or four sheets pinned up to the blackboard explaining what’s involved if you go direct ascent to the moon, and what you might gain if you rendezvous in Earth orbit—basically you don’t have to build such a big launch vehicle. But if you go lunar orbit rendezvous, you don’t have to decelerate 4,000 feet to land on the moon and then accelerate to get back home. It’s a hell of a savings of energy.

COHEN: So you were presented with the lunar rendezvous idea as soon as you joined NASA.

SEAMANS: It was either my second or my third day.

COHEN: That’s a powerful argument for being on the spot and meeting people.

SEAMANS: I’m a great believer in not sitting at your desk all day long. You have to do your homework at some point. My wife will attest to the fact that I usually brought home one briefcase and sometimes two on weekends.

COHEN: At that point there was no government commitment to go to the moon.

SEAMANS: I was in one of Eisenhower’s final cabinet meetings with Keith Glennan to discuss the budget for NASA for the following year, which was something like $1.029 billion. I’d been with Keith to Morey Stans to see if we could extract more funds. Morey said, “You’ve got to be kidding, Keith.” Keith asked, “What do you want, Morey?” He said, “I want a bargain basement figure.”

At the cabinet meeting, Kistiakowsky, Eisenhower's chief scientist, gave a short presentation on what it would take to go to the moon: something like $20 to $35 billion. Somebody said, "If we let those scientists go to the moon, the next thing you know they're going to want to go to Mars." Eisenhower said, "I wish someone would tell me what is the best possible program in space that costs no more than a billion dollars."

COHEN: Did that attitude change as soon as Kennedy came in?

SEAMANS: When Jim Webb and I went to Dave Bell, who became director of budget, we started discussing some of the things we thought should be added, or at least discussed. Bell said, "The president is very busy. He knows space is important, but he doesn't feel any great rush about it. He wants to get his mind around it next year for the following year's budget." It's one's prerogative at that point to say, "That's unacceptable," so we had a meeting with President Kennedy. The president said, "OK, Jim, what are we here for?" I was amazed when Jim said, "We're here to hear Bob Seamans tell us what more we ought to be doing."

COHEN: You weren't prepared for that?

SEAMANS: He hadn't told me, but I knew how much we'd put in to the Eisenhower people for the second stage of the Saturn 1, for a larger rocket, for studying possibilities beyond the Mercury project. I was able to run through the figures: for instance, if we get $45 million more, we can have the Saturn 1 ready for a manned flight in '65 rather than '67, and so on. Kennedy immediately said, "I want that in writing tomorrow morning." George Low had already run one study on what it would take to go to the moon—a short, general study, nothing very quantitative. The idea was that it seemed technically feasible; there didn't seem to be anything major that couldn't be handled. I also knew from that study the time that could be saved with additional money. We had Bill Fleming pull together a group to really think through all the different things that would have to be done and in effect make a gigantic PERT [Program Evaluation and Review Technique] chart of what it would take to go to the moon. We did it on the basis of direct descent. I wanted to base it on lunar orbit rendezvous but there was great hesitation on everybody's part to do that. They said, "We don't know enough about it." We came up with an estimate of $12 billion and presented it to Hugh Dryden and Jim. Jim said, "I think we ought to put an administrative discount on it."

COHEN: He didn't think you could get that much?

SEAMANS: Not a discount of money. He meant discounting our ability to think of all the things that needed to be done.

COHEN: A discount in reverse.

SEAMANS: He said, "Let's make it twenty." That's the number we used forever after.

COHEN: Presumably Cold War competition created support for that kind of investment.

SEAMANS: Hugh Dryden used to work with his counterpart from the Academy of Science in the Soviet Union. At one time Hugh said, "Couldn't we accomplish more if we worked together on some of these things?" The Russians said, "Good God, don't do that. Then we won't be able to get money for anything." We didn't even know who we were dealing with in those days. It turned out to be Korolev, a very imaginative guy. He got Khrushchev to go along with a few shots against the wishes of the army of the Soviet Union, which didn't want to see anybody else get funds for rocketry. Korolev did amazingly well with first the Sputnik, then a dog, then a flight around the moon that took pictures. Then Gagarin went up. Khrushchev could see the benefit of this effort on a worldwide basis. We here, including Kennedy, could see how we were losing on a worldwide basis. After Gagarin flew, Congress was mad as hell that the Russians had done something else ahead of us.

COHEN: Which led them to fund Apollo. Do you see any equivalent pressure now?

SEAMANS: The Japanese have geared up to do some things and the Chinese have, but there's no real driver in the country today. I happened to be at NASA a couple of days before President Bush spoke and recommended that we have a program to go first to the moon and then to Mars. In all honesty, I was surprised. I don't know whether he could see the glory in it or felt that would be a way to inspire the younger generation to go into science.

COHEN: Has NASA drawn on your experience of the earlier moon flights in planning the return?

SEAMANS: I was asked by Mike [Griffin] to sit in on a multiday review of the internal planning at NASA. I was impressed with the fact that an awful lot of thought and detail work had taken place. I was concerned that the cost estimates, which were questionable, were done by comparison with Apollo. The idea was that we were smarter now than we were then, so we ought to be able to build a capsule and launch vehicles for 25 percent less. I felt that the dollars were low and at some point there wouldn't be enough money available, and Congress would be yelling about overruns. We were very fortunate on Apollo that we had about the right number to work with.

COHEN: Do you think the past experience on Apollo won't save money?

SEAMANS: NASA not only has to go off into the future, they've still got a major program, namely the space station, and Mike has reintroduced going back to the Hubble. There's a tremendous amount invested in the station—by ourselves, the Japanese, the Europeans, and the Canadians. We have a responsibility to finish it off in reasonable style. Once we get the launch vehicles for the lunar work, we will presumably also have vehicles that can sustain and operate the space station. In the near term, the four years before the shuttle fleet is supposed to be retired, you've got a heck of a lot you have to do to come close to completing the space station while at the same time going into the most expensive part of the lunar program and maybe the Mars program. It's in those initial development years that you really have to spend a lot of money. To have one program phase out and mesh with the new program building up is really a difficult problem.

COHEN: Aside from the financial concerns, what lessons does Apollo offer for the new mission?

SEAMANS: There wasn't any question that most of the Apollo work had to be done on contract: it ended up being 90 or 95 percent. We felt very strongly that we could not manage Apollo unless we had technical competence within NASA to cover any aspect of any problem that might arise. Again and again, that proved critical. We had a lot of trouble with the second stage of the Saturn 2. One day when we were doing static testing at a cryogenic temperature, it just unzipped all the way down because there had been one small crack. Between Langley and Huntsville, we had as many competent people in fracture mechanics as there were in the country. I worry that we don't have as much competence within NASA today as we did then.

COHEN: How can NASA develop and maintain that level of technical competence?

SEAMANS: You cannot have good technical people on standby doing nothing and suddenly put them on the job when you have a problem. You have to have competent people doing exciting work that is not central to the program so they can be thrown in to fix the problem even if it takes six months. We had a line item that was called SRT, Supporting Research and Technology, which meant funds in every one of our major projects for scientific and technical people to look at alternatives—a different material, a different gyroscope, or whatever. We had to keep fighting for that capability with the budget people.

COHEN: Coordinating all the Apollo work must have been a tremendous challenge.

[THE APOLLO 1 FIRE] WAS A HORRIBLE WAY to get educated, BUT IT WAS A very real EDUCATIONAL experience.

SEAMANS: You needed to have not only the competence throughout NASA, you also needed to pull it all together. Somebody had to take a look at the totality of what was going on at NASA. As general manager, I was responsible not just for Apollo but for all the other projects we had. I had to balance the funding and the disposition of manpower. I also had to decide whether we were going to need new facilities. There was a problem down at the Cape because every single NASA center had its own senior person managing his or her project with no single person to bring it all together.

COHEN: It must have been a challenge even to know what was going on.

SEAMANS: I myself am a great believer in monthly project assessments. My view was the minority view. Most people felt they were a waste of time. It's the way I worked when I was at RCA. From the time I got there, we had reviews of all major projects on a monthly basis. When I got to the air force, I said that was what I planned to do. They said, "Let us show you how we've been doing it." I went into a room, a colonel clicked his heels, and some guy stood up and started running through a lot of slides. I asked how many levels in the air force had reviewed them. "Fifteen," they told me. I said, "There's no point in my being in the room," and I got up and left.

COHEN: Did you think it wasn't worthwhile to hear something that had gone through fifteen levels of review because it was removed from the people who had done the hands-on work?

SEAMANS: If it goes through fifteen levels, God knows what you get out at the other end.

COHEN: Were your monthly reviews a way of uncovering problems, or opportunities to share expertise?

SEAMANS: More the second than the first, but you've got to have people who understand that they can't hold back information. Sometimes there's something you don't want to tell anybody because you're not doing well on some part of the project. You figure you can get it resolved in another month.

COHEN: Engineers want to solve their own problems. Were there major surprises during the Apollo program?

SEAMANS: Of course the major event that had not been anticipated was the Apollo 1 fire. Just as I arrived home that day, my wife said George Low was on the phone. I picked up the phone and George said, "They're dead." I said, "George, slow down. Who's dead?" He had great difficulty talking about it. I went tearing over to my office and first called Jim Webb to be sure he knew and talked to George Mueller. We started thinking about what kind of group to put together to study the accident and make recommendations. That was far and away the worst experience.

COHEN: Did that tragedy damage morale?

SEAMANS: I don't think so. It had a terrible impact on people immediately involved. Some people who had to fly into Washington for a hearing were in tears all the way in. It was a very sad time. [Apollo Spacecraft Program Office Manager] Joe Shea felt directly responsible, thinking if he'd only done something different it never would have happened. A lot of us felt that way. It was a horrible way to get educated, but it was a very real educational experience. I can't say that we wouldn't have succeeded if the fire hadn't happened, but we made important changes because of it. We never should have had 100 percent oxygen in the capsule, but we'd gotten away with it with Mercury and Gemini.

COHEN: You think there would have been an accident further down the line?

SEAMANS: Yes, and one that would have been more difficult to recover from.

COHEN: Did the fire lead to management changes as well as technical changes?

SEAMANS: The biggest one was to bring in Boeing as the integration contractor. We didn't have a good internal system. When we had an interconnect between, say, a capsule and something at Huntsville, both parties would sign an agreement. We had a very large number of interface documents. It was better in the final analysis to bring in a company that was familiar with integration from their airplane experience.

COHEN: Landing on the moon eight years after Kennedy announced that goal was an amazing accomplishment.

SEAMANS: When George Mueller came in, the first thing he did was try to see whether we had a chance of going to the moon within the decade. He concluded that we couldn't make it the way we were going. We launched four Saturn 1s with dead upper stages. The first launch was successful. We had three more. Basically, we were shooting I don't know how many tons of sand into the Atlantic Ocean; we were not learning anything more. George recommended that we go to all-up systems tests. On the very first Saturn V launch, we piled everything on. If the first stage worked, we were going to get information on the second stage, and so on.

COHEN: Am I right in thinking that Wernher von Braun was against all-up testing?

SEAMANS: Yes. Wernher practically wept with relief the day we launched the Saturn V for the first time and everything worked. Also, the Apollo itself worked. We just didn't have the LEM aboard because it wasn't available. It was incredible. Without that approach, we never would have gone to the moon within the decade. ●

MAKING A DEEP IMPACT ON SCIENCE

BY RICK GRAMMIER

How do you hit an object zipping through space at 23,000 mph, 268 million miles from Earth, and capture what happens after the impact with a camera 300 miles away? In 1999, a team of more than 250 scientists, engineers, managers, and educators set out to meet that challenge and discover what exists inside a comet.

The Tempel 1 comet appears against a background of stars (with two especially bright ones) as it passes in front of the Virgo constellation before impact.

Photo Credit: Canada-France-Hawaii Telescope, 2005

WE … ESTABLISHED AN ALTERNATING, WEEKLY TRAVEL SCHEDULE THAT HAD ONE OF US ON SITE AT THE SYSTEM CONTRACTOR FACILITY EVERY WEEK IN ORDER TO ENHANCE COMMUNICATION, QUICKLY IDENTIFY AND RESOLVE PROBLEMS, REESTABLISH AN INTEGRATED TEAM, AND PROVIDE FOR EFFICIENT KNOWLEDGE TRANSFER.

The idea originated in 1978, when Alan Delamere, an engineer at Ball Aerospace & Technologies, and Mike Belton, then at the National Optical Observatory in Tucson, analyzed data from Comet Halley and found the comet was far blacker than they had anticipated. "So we asked ourselves: how could this happen?" Delamere said. The search for an answer evolved into a proposal by Dr. Michael A'Hearn (University of Maryland) to NASA's Discovery Program to hit an active comet and gather data on its inner material and crust. When the idea was approved in 1998, it became eighth in the Discovery Program's series of low-cost, highly focused space science investigations. It would be the first space mission to look beneath the surface of a comet.

A first-of-its-kind mission and tight budget weren't the only challenges awaiting me when I joined the team as project manager in January 2004. The launch had already been delayed one year. If Tempel 1, the target for Deep Impact, sped beyond a reachable orbit from Earth, we would have to wait another five and a half years before the comet would circle around again. With the project already at risk of being canceled by NASA Headquarters due to significant financial overruns, a five-year delay was not an option. With one year remaining until Deep Impact's last chance for launch, I faced a project with a fractured team and split responsibilities, incomplete development of flight avionics hardware and software, and a system-level verification and validation program that had not yet begun.


Photo Credit: NASA/JPL-Caltech/UMD

This spectacular image of comet Tempel 1 was taken 67 seconds after it obliterated Deep Impact's impactor spacecraft. Scattered light from the collision saturated the camera's detector, creating the bright splash seen here.

Contributing Factors

Though the largest visible contributor to the launch delay was the development and delivery of the flight avionics, many other causes contributed to Deep Impact's problems. Cultural differences between the Jet Propulsion Laboratory (JPL) and the system contractor, knowledge and experience gaps within the combined team, and an eviscerated independent check-and-balance process led to miscommunication and misunderstanding. The cultural differences were primarily rooted in the distinction between Earth orbiter missions—using spacecraft architectures similar to those flown previously, which the system contractor was very experienced in—and a one-of-a-kind, complex planetary mission like Deep Impact. A good example of the difference between these types of missions is in the complexity of fault protection software required for each. An Earth orbiter may simply enter safe mode due to a fault occurrence; a planetary spacecraft will try to autonomously diagnose the fault and recover from it, entering safe mode only as a last resort. The cultural differences resulted in a great deal of misinterpretation and mismatched expectations that had to be continually recognized and managed.

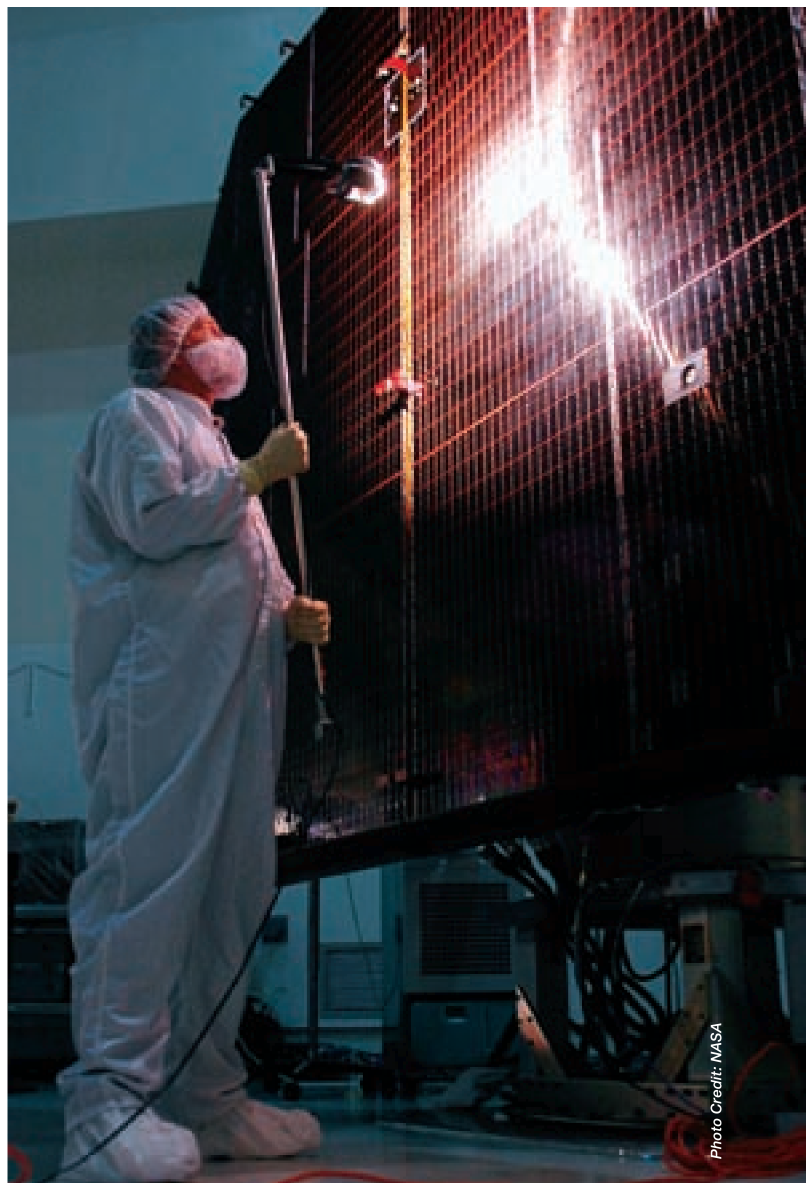
The contractor's lack of deep space mission experience also had a significant impact on defining and planning for the flight system validation and verification (V&V) program. The contractor understood the need to validate that requirements were met for each component but not the importance of verifying that the flight system could operate as intended when all the components were assembled. This "test as you fly, fly as you test" approach had not yet been implemented on Deep Impact; combined with late system maturation, this presented a significant challenge to completing the V&V program in time for launch.

Yet another source of problems was ineffective teaming arrangements between JPL and the system contractor. It was not always clear which organization had product delivery responsibility at each level and life-cycle phase. In some instances, the organization with delivery responsibility didn't have the necessary skills or experience to deliver the product. This was further complicated by a lack of effective management and leadership at multiple levels within the project.

Finally, the project had an inadequate flight operations concept and plan. The original mission was designed to have an eighteen-month cruise period prior to encountering Tempel 1. The one-year launch delay reduced the cruise period to six months, yet the amount of work that had to be done stayed the same; the management team never truly appreciated or analyzed the implications of this schedule compression. The operations schedule and staffing plan were also inadequate to accommodate such a workload, and the system contractor originally given the responsibility for conducting mission operations had no prior experience in conducting operations of this magnitude and no familiarity with the various ground systems and processes that were required. Last but not least, earlier budgetary problems meant that insufficient staffing and funding were available to appropriately plan for the operations and conduct the necessary operations team training.

Change in Course

Acknowledging the challenges I had in getting the project on track and meeting the launch date, the first thing I did was hire an outstanding deputy project manager, Keyur Patel, to help share the tremendous workload and grueling travel schedule.



A technician at Astrotech in Titusville, Fla., conducts an illumination test on the Deep Impact spacecraft as a final check of performance.

Together, we focused on opening all communication channels and ensuring our expectations were known and understood by all involved. We then established an alternating, weekly travel schedule that had one of us on site at the system contractor facility every week in order to enhance communication, quickly identify and resolve problems, reestablish an integrated team, and provide for efficient knowledge transfer. Next, we held several working meetings to go over JPL's flight project practices and design principles to communicate expectations regarding project implementation and design practices and to bridge cultural differences. These had been previously reviewed in a piecemeal fashion and were not well understood across the entire team in the context of Deep Impact. The real value we gained from these meetings was in discussing together what each requirement meant and understanding whether each one was met or not. Not meeting a particular requirement wasn't necessarily a bad thing, as long as we all understood the risk of each exception and whether or not that risk was acceptable. Engineers from each subsystem, as well as senior and mid-level management, participated in these meetings.

I LEARNED THAT … THE BEST THING TO DO WAS TO SAY, "I THINK WE DECIDED THIS, AND YOU'RE GOING TO DO X, Y, AND Z. WHAT DO YOU THINK?"

One lesson I learned early in this process was to check that actions the team had agreed to were actually done as intended. I would converse with the contractor's management or engineers and think we had an agreement; then I would come back to check on it, and find that the way they had worked on it was different than I expected. This was another manifestation of our cultural differences. I learned that at the end of these conversations the best thing to do was to say, "I think we decided this, and you're going to do x, y, and z. What do you think?"

We also reestablished the mission assurance (MA) rigor that had been eviscerated somewhere along the way. A few months before I came on board, an MA audit team had been formed to determine the state of affairs and provide recommendations. Nothing had been done with the recommendations, so we formed a Tiger Team of experts to implement them and correct the deficiencies. This was a painful and costly process, but you have to do the right thing right. It paid big dividends in the end.

We also changed how often the management review process occurred. Less than a year from launch we had a huge list of issues and risks and a lack of communication; I couldn't wait for a monthly meeting to hear about the issues, so we moved to a weekly process. Because there were so many issues to review, we didn't try to solve every issue in each meeting. We frequently defined action items and moved on, then revisited the actions the following week. I also invited the NASA Headquarters program executive and program office to call in to the meetings so they were aware of the issues and able to witness the progress being made. This helped keep the team focused on priorities from week to week while ensuring the management team was aware of the "big picture."

Once the team found a better way to communicate, Keyur and I focused on helping them work better together as well. I organized the product teams—by component, subsystem, or some other deliverable—to take advantage of flight project experience and specific product knowledge, combining JPL and contractor members within teams. We also provided continuous management and engineering presence at the contractor site, which helped improve communication through continuous

Photo Credit: NASA

At Ball Aerospace in Boulder, Colo., the infrared (IR) spectrometer for the Deep Impact flyby spacecraft is inspected in the instrument assembly area in the Fisher Assembly building clean room.

interaction. This enabled the teams to more quickly share knowledge and identify and resolve problems together. Over time, this directly contributed to re-integrating a fractured team, building esprit de corps, and establishing an appreciation for team members' expertise and dedication to getting the job done. Make no mistake about this: the teams on both sides of the Rockies were very smart, very dedicated individuals. The challenge here was to provide the team with the resources, tools, experience, and leadership to get the job done.

Mitigating the Impact

These changes allowed Deep Impact to launch on schedule on January 12, 2005, but the problems were far from over once the mission was headed for comet Tempel 1. At launch, Deep Impact still had not passed a test encounter with the comet. Contingency plans for the encounter had also not yet been identified, developed, or tested. The operations team had been certified and trained but were still green in terms of hands-on experience. In short, too much work remained for the current size of the operations team.

To address this shortage, we retained a majority of the development team and continued to use the processes that had so successfully gotten us to launch. The daily operations were jam packed from day one, and we increased the staff tremendously in order to get the work done. We also formed an Encounter Working Group (EWG) to complete development and verification of the encounter plans, sequences, and contingency operations. This team was effectively "fire walled" from the day-to-day operations team so it could concentrate on the encounter development and V&V activities. This did cause some issues with bench depth and knowledge transfer to the daily operations team, but it was absolutely necessary in order to complete the tremendous amount of work in such a short time.

Together we generated an elaborate decision tree, identifying every contingency that might prevent success. For example, if the small impactor had a failure prior to release, we had a contingency plan to either delay the release with a different maneuver sequence or target the entire flyby spacecraft (with impactor attached) for collision with the comet. We planned how to address each possible failure in detail so we would be prepared to salvage the science and mission under as many conditions as possible. We also conducted three risk reviews with the EWG and senior management to alert us to other issues or solutions we may have overlooked.

Big Bang

After an intense year of preparation and another six months of around-the-clock operations, the larger flyby spacecraft released its small impactor and maneuvered away from the impending collision to capture pictures of the impact. On July 4, 2005, Deep Impact successfully collided with comet Tempel 1—with no failures or surprises. The images of the approach, the impact, and its aftermath were relayed to Earth and will be analyzed and combined with data from other comet missions, leading to a better understanding of both the solar system's formation and implications of comets colliding with Earth. Creating a culture of open and honest communication and rearranging teams to ensure everyone's strengths were used wisely helped make this groundbreaking mission a comet-shattering success. ●

RICK GRAMMIER is currently the project manager for the Juno mission in the New Frontiers Program. His experience includes previous roles as project manager for Deep Impact, deputy director for Planetary Flight Projects at JPL, manager of JPL's Office of Mission Assurance, and project engineer and deputy project manager for Stardust. He has a BS in engineering from the United States Military Academy and an MS in electrical and computer engineering from California State Polytechnic University.

Sustaining NASA's Safety Culture Shift

BY DAVID G. ROGERS

It's been more than twelve years since I flew planes on and off aircraft carriers. One flight in particular literally changed my life. I was the aircraft commander and was flying with my squadron's executive officer, who was two pay grades above me but had limited experience flying this particular aircraft and landing on ships. To maintain proficiency requirements, he was to get us aboard that day. During the approach, he got low and did not respond to the landing signal officer's call for power. Then he got caught in a downdraft and got *really* low. The landing signal officer screamed for power then called to wave off the approach. When my XO was slow to respond, I was forced to take control of the aircraft, execute the wave-off, and get us aboard.

In Firing Room 1 at Kennedy Space Center, shuttle launch team members put the shuttle system through an End-to-End (ETE) Mission Management Team launch simulation. The ETE transitioned to the Johnson Space Center (JSC) for the flight portion of the simulation, with the STS-114 crew in a simulator at JSC. Such simulations are common before a launch to keep the shuttle launch team sharp and ready for liftoff.

Photo Credit: Kennedy Space Center

EFFECTIVE TEAM SKILLS AND BEHAVIORS GIVE US THE TOOLS NECESSARY FOR AVOIDING MISTAKES, BUT OUR WILLINGNESS AND COMMITMENT TO USE THOSE TOOLS AND CONTINUALLY SHARPEN THEM THROUGH CONSTANT EVALUATION AND REEVALUATION IS WHAT HAS THE LARGEST IMPACT ON MANAGING HUMAN ERROR AND DEVELOPING EXCEPTIONAL TEAMS.

After looking at the landing video, I was shocked to learn that we were dangerously close to crashing into the back of the ship. In the thirty minutes that followed our landing, I demanded a crew debrief that included a brutally honest self-assessment of my performance. I asked myself, "What did I do that led to the 'success' of the mission?" Then I asked what I did that contributed to nearly losing the lives of my fellow crewmembers and myself in the process. What I did right was take control when it was required. What I did wrong was wait as long as I did to take action. Although the XO was more senior and we got along very well, I did not assess his skill level appropriately. I put too much stock in his pay grade and position and forgot to consider that his experience with this aircraft and flying aboard aircraft carriers was very limited. I should have been just as cautious as I was with a pilot fresh out of training. I learned that reflecting on problems and near misses is both an individual and a team responsibility, which can help build excellence in both. NASA has begun incorporating this best practice in some areas, but it could do more.

Understanding the Real Problem

Let's suppose that an airline pilot fails to acquire an updated weather forecast at his destination. He is behind schedule, and his passengers will miss their connecting flights if he delays much longer, which will mean a financial penalty for the company. Approaching his destination, he notices that some other, smaller aircraft are diverting to fields with better weather. He sees the approaching storm ahead at the end of the runway but still elects to land. On his approach he encounters some dangerous wind conditions but manages to get the plane on the ground and taxis to the gate. The fact that the outcome was favorable, however, does not mean that the pilot made the correct decision.

Suppose that pilot continues to operate in this manner for years and manages to land successfully each time. While the pilot's experience level is high, we can see that his expertise level is very low. He has gained a lot of experience doing the wrong thing. His behavior illustrates the term "an accident waiting to happen." Experience does not automatically translate to expertise. Experience provides us with a learning opportunity, but expertise is only acquired after we take time to evaluate our performance and apply corrections to improve and reinforce the skills that contributed to success.

Like the pilot, our NASA teams need to examine their experience rigorously in order to learn from it. Studies over the past twenty-five years have consistently reported that between 70 and 80 percent of accidents within high-risk and high-reliability organizations can be attributed to human performance errors. *Challenger* and *Columbia* represent the most severe, but certainly not all, of NASA's human performance errors. The primary reason why we repeated the same mistakes is that we corrected some of the symptoms, but we did not effectively address the greatest contributing cause of our errors: our organizational culture.

Since human error cannot be completely eliminated, the trouble lies with a prevailing organizational culture that allows errors to go unchecked. Effective team skills and behaviors give us the tools necessary for avoiding mistakes, but our willingness and commitment to use those tools and continually sharpen them through constant evaluation and reevaluation is what has the largest impact on managing human error and developing exceptional teams. Without this, we as individuals, teams, and an organization are likely to slowly drift back to the same behaviors that created the culture that allowed critical errors to occur in the past. This is where we missed our opportunity after *Challenger*. We "fixed" many weaknesses and processes but never put in place a long-term cultural shift solution that continually improves how well we communicate and make decisions as a collective team.

A Case Where We're Getting It Right

The Space Shuttle Program (SSP) Mission Management Team (MMT) is a recent example of a team that has embraced an attitude that has brought about a definite cultural change within the NASA team at large. As a result of the Columbia Accident Investigation Board's recommendations, the MMT began an intensive training program that included initial and yearly certification requirements for all MMT members. For the most part, people were aware of the skills and behaviors required of them; what they lacked were ways to develop and sharpen them. After two and a half years of senior program management leadership, team training, self-study, and numerous MMT-specific simulations, the MMT that served during STS-114 represented a team far superior to what had been in place for more than nineteen years.

WE ARE ALL STAKEHOLDERS IN EFFECTIVELY MANAGING HUMAN ERROR. TO GAIN TEAM EXPERTISE, IT IS ESSENTIAL—WHETHER AFTER A MISSION OR A PROGRAM MILESTONE—TO GATHER EVERYONE TOGETHER AND EVALUATE THE TEAM'S PERFORMANCE AND HAVE EACH MEMBER ARTICULATE HIS OR HER SELF-ASSESSMENT.

After STS-114, the SSP deputy manager began to look at ways to build upon the team's marked improvement. He recognized that the team training the MMT was receiving could be enhanced if it used their own real-world examples to illustrate the training concepts. By tapping into NASA's own internal resources and talents, key Johnson Space Center Safety and Mission Assurance (JSC S&MA) personnel were asked to refine the training to better meet the specific needs of the MMT membership. The MMT team training is now taught by JSC S&MA and uses shuttle MMT examples taken from MMT training simulations and past shuttle flights. This training restructuring also provided the opportunity to include more effective team debriefing and individual team member self-assessment skills.

A turning point occurred when the chair of the MMT established his expectations during an MMT debriefing. This wasn't done by memo alone, but through mentorship and superior leadership—by modeling the behaviors he expected his team members to emulate. As a result of this action, MMT debriefs are consistently characterized as being brutally honest and open, with all egos put aside both from a team perspective and in each team member's assessment of his or her own performance.

The impact of these measures has been profound. The shuttle MMT membership has shown a steadfast commitment to implementing continual improvement. They have adopted a learning organization mentality where every decision and team interaction, whether it occurs during a simulation or actual mission, represents opportunities to learn and improve both as a team and as individuals. They are especially sensitive to identifying areas where recent successes could lead to complacency. Dissenting opinions—viewed as alternative solutions among the team—are encouraged and actively sought.

Recently, the shuttle MMT has taken a fresh approach to lessons learned. Lessons learned databases capture the "historical record" of errors, but they rarely raise the level of awareness sufficiently to prevent the same problems from reoccurring. Team debriefs and self-assessments work better because they are continually reviewed and give team members a chance to take accountability and actively implement specific actions for

Photo Credit: NASA

Space Shuttle Mission Management Team members take notes during an eight-day simulation at Johnson Space Center in March 2005, preparing for Return-to-Flight mission STS-114.

improvement. In order to keep lessons from being forgotten, the MMT conducts a pre-brief prior to its next event to remind the team of previous lessons learned and develop improvement strategies in order to keep from "running over the same land mines." This concept is not new to us. It is the very essence of a continual improvement process. What makes this different is that the MMT is making this model a living, breathing process for continual improvement.

Continually Learn from Past Effort

We are all stakeholders in effectively managing human error. To gain team expertise, it is essential—whether after a mission or a program milestone—to gather everyone together and evaluate the team's performance and have each member articulate his or her self-assessment. This critical and often overlooked step is, in my opinion, what separates the team of experts from the expert team. Whether at the program, project, or functional level, these strategies apply to all team environments.

In order to effect a true cultural change, we must adopt a learning organization mind-set. We must never be satisfied with our current level of performance. We must always be asking ourselves, "How can we improve?" Expert teams recognize that they are only as sharp as their last decision. Achieving and sustaining a positive team culture and, in turn, organizational safety culture is not a discrete event but a journey. We must never let our guard down and allow ourselves to be fooled into believing that we have gotten as good as we can get.

In these past few years, I have been pleased to witness these behaviors spill over to other boards, panels, and meetings across NASA, such as the past three flight readiness reviews for STS-121, 115, and 116; recent Shuttle Program Requirements Control Board meetings; SSP System Integration Control Board meetings; and also at recent Flight Techniques Panel meetings. Many in the NASA family are committed to not only sustaining but continually improving our safety culture in the midst of the current dynamic and challenging environment. It personally gives me a great sense of pride to be part of an outstanding organization that has demonstrated the integrity and moral courage to commit itself to doing all that is humanly possible to truly learn from our past mistakes. ●

DAVID G. ROGERS has served as a naval aviator and a shuttle guidance and control/propulsion instructor for twenty years. Since 2004, he has been a senior safety engineer with Science Applications International Corporation (SAIC) in the Shuttle Safety & Mission Assurance Directorate at Johnson Space Center. In addition to his technical contribution, much of his work centers on organizational culture, team dynamics, and developing methods to optimize team performance. He has recently spearheaded the effort to bring these techniques to NASA's SSP MMT membership. *david.g.rogers@nasa.gov*

Featured Invention: Future Air Traffic Management Concepts Evaluation Tool

BY JOHANNA SCHULTZ

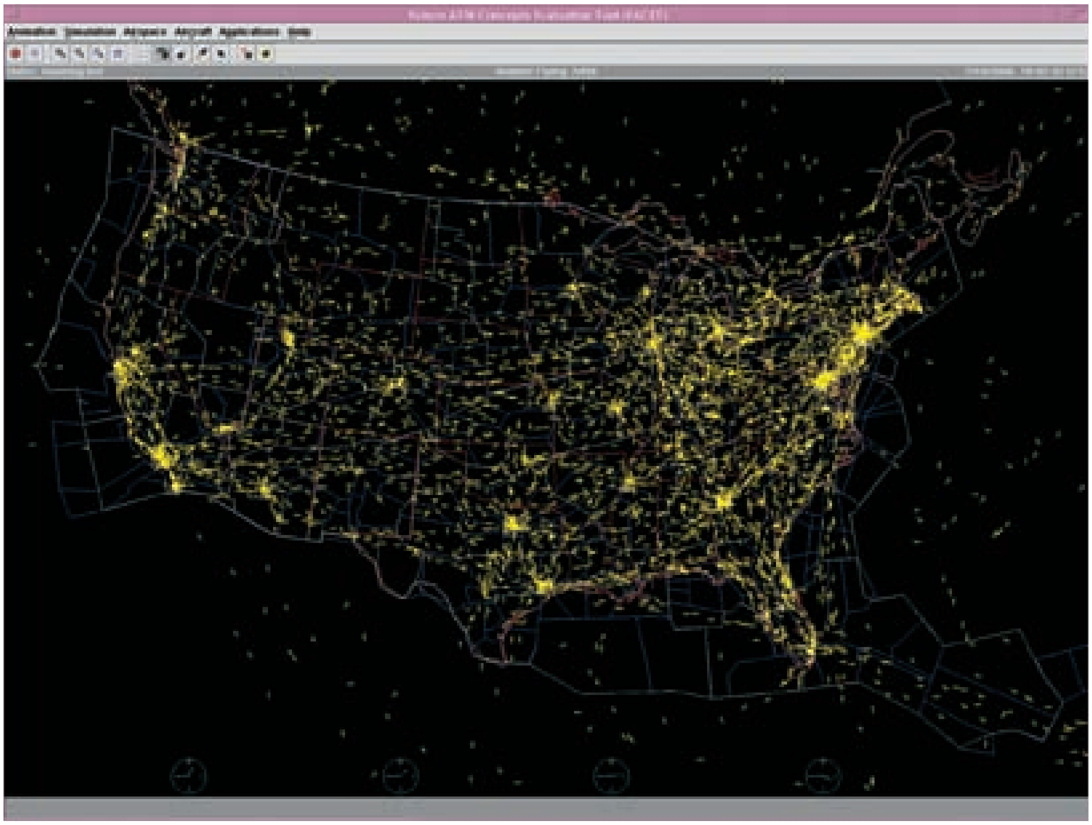


Image Credit: Ames Research Center

A FACET snapshot of air traffic over the United States on July 10, 2006, at 2:45 p.m. EST.

The Future Air Traffic Management Concepts Evaluation Tool (FACET), a unique software program used to model and predict air traffic trajectories both for research and real-time use, received NASA's Software of the Year award for 2006. It is currently in use at more than fifty universities and licensed to more than 4,000 users in the FAA, at major U.S. airlines, and at air traffic control centers across the nation. FACET's unique capabilities as a research and development tool will help guide development of the next-generation air transportation system.

Human interaction was the sine qua non of the creation of FACET by researchers at Ames Research Center. "It's fairly straightforward to develop tools and functionalities; the difficulty is in making these tools useful to the people who actually do the job," says Dr. Banavar Sridhar, automation concepts researcher and project manager for FACET. Sridhar and his team discovered that the end user's input was the key to devising FACET's valuable innovative features.

"One of the biggest surprises to me working on this project was how difficult it was to translate ideas from a research institution into actual usage. Often, what happens is that you make assumptions [based on theoretical calculations] that are hard to translate into the field," Sridhar said. "You can figure out the algorithm, but it just isn't going to work if you design it without the help of those who actually use it."

While the concept may seem basic, this "listen to the consumer" approach took Sridhar and his team's research to a new level. In fact, through extensive discussions with end users—air traffic controllers, dispatchers, and airline pilots—FACET went from a fairly straightforward research modeling tool to a real-time air traffic control tool that currently helps monitor air traffic in skies across the country.

Sridhar, together with University of California–Santa Cruz scientist Dr. Kapil Sheth and a team at Ames, was looking at the issue of air traffic control and experimenting with ways to measure a controller's workload, or the number of aircraft that one controller at a federal air traffic control center can monitor at any one time. Initially, the team focused on an air traffic control center in Ft. Worth, Tex.—near NASA's Houston center—but Sridhar quickly realized that the tool would have to be more comprehensive than he'd initially conceived. "In order to know how busy an air traffic controller in Ft. Worth would be an hour from now, we had to know where the aircraft were coming from," Sridhar recalls. "Although we were interested at first in one small location, our research problem depended on everything around it, so we decided to build a tool that could see and understand air traffic control all over the United States."

"Initially, we wanted to explore different futuristic concepts of air traffic management, but we found that in order to explore these concepts, a certain amount of realism was necessary to ensure that whatever we were doing was coming out of an environment connected to reality," explains Sheth. "What we discovered was that people actually valued that a lot more."

The team began approaching air traffic controllers and those involved in airline logistics, proposing functionalities and asking for input on additional features. "We had to become more customer-oriented as we moved from the research lab into an operational environment," says Ames software developer Shon Grabbe. With every conversation, the team realized that additional functionalities and modifications were necessary.

In early discussions with users, the team realized that speed and portability were key capabilities missing from contemporary air traffic control tools. "Our goal was to think outside the box and come up with a safer system to accommodate more traffic than it does today," explains Ames researcher Dr. Karl Bilimoria. "We thought, rather than have air traffic controllers separate the traffic, which is very workload intensive and results in a lot of bottlenecks, let's explore a future concept in which pilots do it themselves." Pilots currently work with their airlines' dispatchers before take-off to generate efficient flight plans consistent with airline policy, FAA regulations, weather, and traffic conditions and to determine the appropriate fuel load.

"We wanted to answer some basic research questions on the feasibility of going from centralized control authority (current operations) to distributed control authority (possible operations in the future, say twenty years from now)," explains Bilimoria. "We are not suggesting that FACET be put in the cockpit as an operational tool to assist pilots in separating themselves from other traffic. However, it is certainly possible to use FACET as a research test-bed for developing procedures and algorithms that would make

UNLIKE EARLIER SYSTEMS, FACET CAN PROJECT AIR TRAFFIC AN HOUR OR MORE AHEAD. “WHEN A CONTROLLER SEPARATES TRAFFIC IN A SECTOR, HE IS LOOKING AT SOMETHING THAT MAY HAPPEN WITHIN THE NEXT FIVE TO FIFTEEN MINUTES,” SRIDHAR EXPLAINS. “FACET IS USED TO EXAMINE WHAT HAPPENS TO THE SYSTEM IN THE NEXT ONE HOUR TO SEVERAL HOURS.”

their way to a future air traffic management system featuring airborne self-separation.”

The team’s flexibility and commitment to users translated into an entirely new air traffic control system that has been commercially available through the company Flight Explorer since February 2006. FACET models the National Airspace System and enables planning of traffic flows at the national level through four separate modes of operation: playback mode, to depict and analyze historical data; simulation mode, for predicting the evolution of traffic data; hybrid mode, using historical data for playing out various “what if” scenarios; and live mode, for real-time display and analysis of actual traffic data. FACET is unique in that it is both a research and an operational tool; researchers at more than sixty universities across the country are currently using several of FACET’s capabilities, and pilots, airline dispatchers, and air traffic managers at the FAA and several major airline carriers in both the United States and Australia use FACET to make minute-by-minute decisions on air traffic flows and routing.

Unlike earlier systems, FACET can project air traffic an hour or more ahead. “When a controller separates traffic in a sector, he is looking at something that may happen within the next five to fifteen minutes,” Sridhar explains. “FACET is used to examine what happens to the system in the next one hour to several hours.”

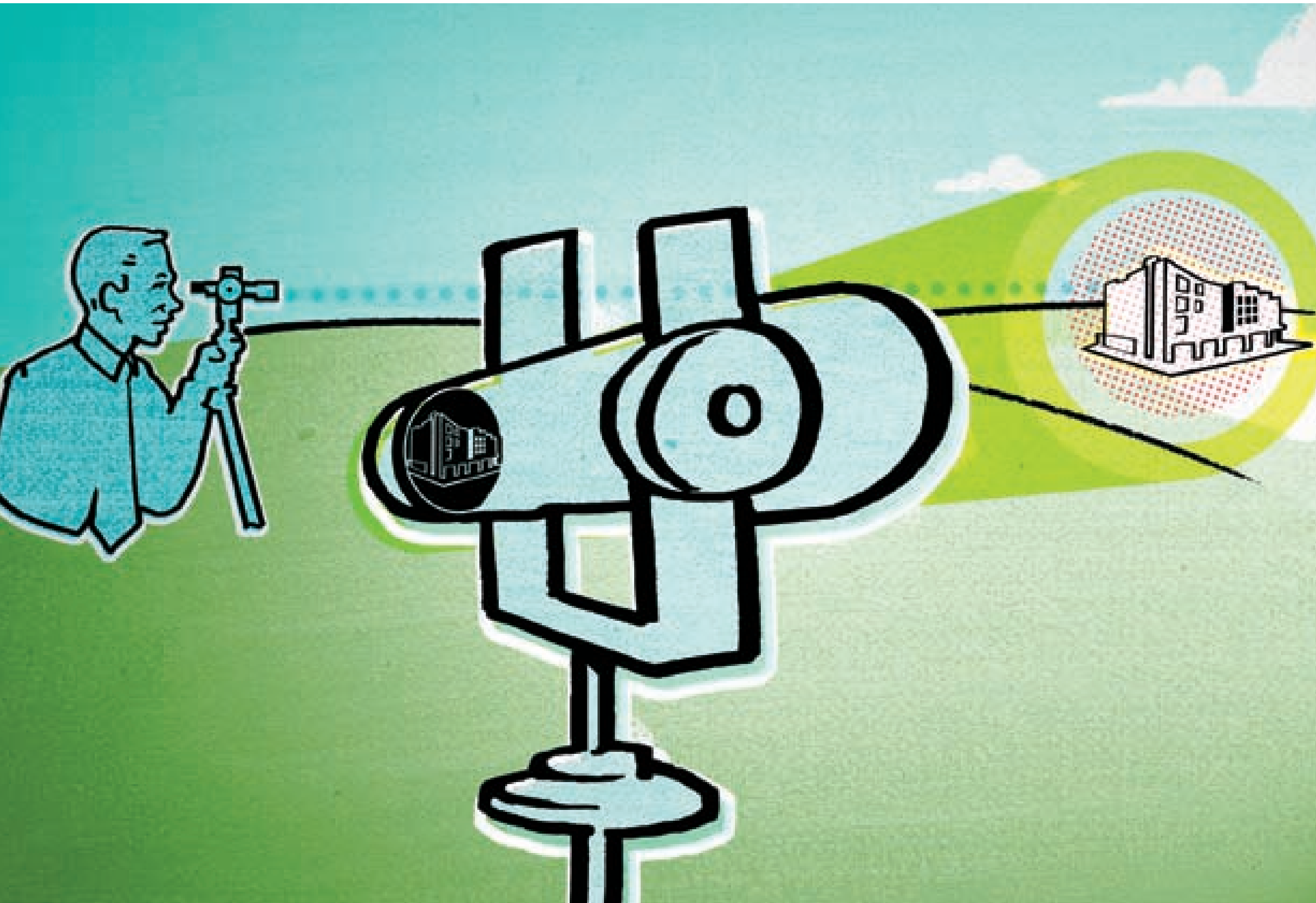
One airline dispatcher explains the software’s unique benefits. “FACET lets me test a reroute, put that into the equation, and predict what would happen. It also helps me identify a list of flights that are going to be impacted by some constraint and suggests an optimized solution that affects the minimum number of flights, or affects a larger set of flights the minimum amount. [FACET] auto-suggests not just one reroute, but several different reroute options to shortcut the dispatcher to a good solution. It is still my place, though, to decide [whether] to move them.”

Bilimoria says, “While our primary goal was always to contribute to NASA’s research, we found and seized those opportunities to go beyond, to get some practical implications outside NASA. Software is a very useful tool, but it’s humans that are ultimately there operating it and making the decisions. It’s the software’s job to help people make better, more informed decisions. We always kept the user in mind, and in the end that really paid off.” ●

Creating the Future

BY JOHN McCREIGHT

Major organizational change—not incremental improvements, but dramatic, sea-change shifts to pursue ambitious new goals and meet major challenges—is hard. Our consulting firm has helped government agencies, corporations, and other organizations evaluate and carry out plans for large-scale strategic change and learned some important lessons in the process.



AN EFFECTIVE PLAN FOR CHANGE IS NOT JUST A BLUEPRINT; IT IS A STORY THAT MUST CONVINCE AND INSPIRE THE PEOPLE WHO HEAR IT.

- Organizations only achieve strategic goals if their members understand them, and why they are the goals that matter.
- Members of the organization need to understand their particular roles and responsibilities during the journey to the desired future state.
- Understanding and commitment are not the same; change leaders must foster both.
- The change strategy must be a compelling story, not just a plan.
- To get where you're going, you have to understand where you are now, the change timeline, and what end-game success will look like.

Most of this seems obvious. *Of course* people need to understand the goal and the plan for reaching it. Leaders of change efforts point to speeches by the CEO and piles of documents to show that they have informed their organizations about the plans. They will note that their senior management teams have signed on to the plan—sometimes literally, by appending their signatures to the change document, like signers of the Declaration of Independence, committing themselves to its principles.

But making speeches and publishing documents do not mean that the content has been understood and embraced—nor that the often dramatic implications of proposed change are understood. Communication is more than documents and pronouncements; it is a dynamic process that includes as much listening as talking. Understanding comes from dialogue—question, response, and comment—that brings what you mean and what your audience thinks you mean in line with one another. In addition, you need to enrich what you think with what your audience knows. This dialogue builds the trust and respect that can lead from understanding to committed action.

The 3 x 5 Card Test

Soon after an acquaintance of ours became the head of a well-regarded educational institution, we paid him a visit to congratulate him and to tell him that we would be happy to apply our competence designing and managing strategic change to his new organization, if he thought that would be useful.

"I respect your abilities," he said, "but I don't think I'll need your services. We already have a strategy."

He showed us a handsomely printed binder of materials that laid out the plan, complete with mission statement and a detailed list of objectives. It was signed by all the organization's department heads.

A few months later, he called. It would be an exaggeration to say we were waiting for the call, but it didn't exactly come as a surprise.

"We're making no progress on our strategy," he said. "I don't understand why nothing is happening. Would you come and take a look?"

The first thing we did was analyze the strategy materials and develop hypotheses on change challenges. We then interviewed the heads of departments, asking them to help us see the organization through their eyes. We asked them to tell us what they thought it could and should be doing differently in the future, and when and how.

We learned the most from what they didn't say. No one mentioned the strategic plan. It was simply not a part of their thinking about their current work or what they hoped to do in the future. When, finally, we asked them directly about the strategic plan, they admitted that they were aware of the existence of what several referred to as "the leader's strategy." Clearly, it was not *theirs*.

We brought the leader and the department heads together for a meeting and passed out 3 x 5 inch cards to everyone. We asked each department head to describe the organization's strategy on one side of the card, and their individual and department's role in carrying it out on the other. Descriptions of the strategy were all over the map; explanations of individual and department roles in carrying it out were similar only in their vagueness.

Part of the point of this exercise was to dramatize the extent to which the strategy, painstakingly described in a document signed by all present, had not been communicated—not absorbed by the people who were expected to carry it out—and to show that those leaders had not "signed on" to the plan, though their signatures were on it.

Communication and Commitment

That 3 x 5 inch card meeting was the beginning of real communication. It began the dialogue about what the strategy should be, why it mattered, and what roles the departments and department heads should play in carrying it out. Together, they developed a change timeline and measurable milestones of success. Understanding and commitment grew out of a process that was both intellectual and social. The back-and-forth discussion—the questions, responses, suggestions, arguments—clarified the leader's plans and brought them to life. It also changed them as department heads reviewed the plan in light of their individual experience and the needs and aims of the groups they led. The process of being heard and involved, not dictated to, began the trust building that genuine commitment requires.

Telling a Story About the Future

Engaging the people who will direct the work in the planning and implementation process is essential to understanding and commitment. So, of course, is the quality of the strategic plan. It must be ambitious enough to inspire action but practical enough to be possible—a stretch, but energizing and *really* important. It must be compellingly described. It must tell a *story* about today and the future that people can enter into and re-tell to others, including their families, to inspire action.

A technology client we partnered with had spent hundreds of thousands of dollars developing its plan for the future. A group of nearly sixty executives worked off site for ninety days to write the strategy document. As in the case of the educational institution, the result was physically impressive: a six-inch-thick binder, professionally written, designed, and published, with beautiful color graphics. The change strategy focused on five areas: new talent, improved governance, new technologies, improved technology infrastructure, and new processes for handling the massive quantities of information they expected.

Goals and milestones were laid out in impressive detail. Yet, even the organization's leaders, who had invested so much time and effort in the plan, were uneasy. They asked for our help before they presented it to their organization's funders.

We spent weeks examining the plan and conducting interviews with senior executives to get their view of the strategy. Not surprisingly, the plan was less well understood than the executives who hired us hoped, and support for it—in terms of passion, and funding and talent commitments—was even weaker.

A chief problem, we quickly saw, was that the plan told no compelling story about what the proposed changes would achieve. It was full of painstaking detail about what would happen in different departments and units, about structural changes and new technologies to be purchased. Missing, though, was any vivid sense of customer needs and what competitive threats and important opportunities the plan was meant to address. The plan was all about *what* would change; it largely ignored *why* change was necessary and why it would be worth the effort. It was full of dry details and abstract generalities about the future, but it never painted a vivid picture of what working in the future organization would look and feel like. Importantly, the plans were less than honest about the pain such change would cause.

There were problems with details of the plan—critical phases without sufficient funding, lack of clarity about how some phases supported others, lack of measurable milestones—but these weaknesses were less important than the lack of a compelling answer to the question, "Why does this matter?" An effective plan for change is not just a blueprint; it is a story that must convince and inspire the people who hear it. Like most good stories, it must have a hero. The crisis, challenge, or opportunity the organization is facing has to be vividly described, along with the intelligence, creativity, tenacity, and other resources required to overcome the threat and triumph in the end.

Triangulating on Truth

To lead organizations to a desired future, everyone critical to success needs to understand current truth—the resources you can count on and the weaknesses holding you back. We call the process of developing that understanding "triangulating on truth," because you must look at the organization from a variety of perspectives to learn the truth about it. No one person or group has the whole picture.

We interview dozens, and sometimes hundreds, of people to develop a full picture of an organization. Interviews include employees at all levels, plus investors, customers, partners, suppliers, and, often, competitors. We insist on the confidentiality of all those conversations to encourage people to say what they believe, not what they think their bosses, customers, or others want to hear.

Even without the fear of retribution, many people want to put a positive face on things, to emphasize the good and downplay the bad, and not talk about unrealized opportunities. But ignoring hard truths only prevents or delays dealing with them.

Years ago, when we consulted for the police department of a major metropolitan area that suffered from a high crime rate, we rode along in squad cars on eight-hour shifts to understand what police officers really did and why. Riding with vice officers during one evening shift, we realized that everything we were seeing—the drug busts, the roundup of prostitutes—had been carefully choreographed to make the point that more officers were needed. Though well-intentioned, this "show" threatened to undermine our consulting analysis: If we didn't see the real problems, we wouldn't be able to offer advice on solving them. To get to the reality, we sometimes stayed on for the next eight-hour shift, which had not been planned in advance. Sometimes we switched from the officer we were officially shadowing to another officer, who happened to stop at the same coffee shop for a break at the same time.

Triangulating on truth also means getting the perspective of people outside the organization. During that same engagement, we interviewed a local newspaper reporter who was disparaging the mayor's efforts to improve the department's performance. Her criticism included important hard truths the city needed to hear. We also interviewed a 22-year-old burglar in his jail cell to understand why crime was his career choice. In a city with limited employment opportunities for young men without a high school diploma, the fact that a burglar had a one-in-ten chance of being arrested, and approximately a one-in-a-hundred chance of being convicted, made burglary a rational career-choice gamble. We learned from him that discouraging crime depends on changing those odds, which led to recommendations that needed to get to high-crime areas more quickly and improve case building to increase conviction rates.

The human tendency to tell mainly the good news is matched by an equally powerful tendency to focus on the evidence that supports our beliefs. Successfully triangulating on truth means not only noticing contrary, uncomfortable, or minority views but paying special attention to them and giving them particular respect. Like a good scientist, change leaders should look for disconfirmation of their hypotheses more energetically than for support. We have seen change efforts fail because leaders clung to the good news and ignored the warning signs. The first and biggest step in solving problems is to recognize them.

Major change is hard. To achieve it, change leaders need determination, patience, trust, tenacity, and good listening skills. They need a compelling goal and the understanding and engagement of the people who will make it happen. The commitment to seek and see the whole truth about an organization is essential for success in large-scale, *sustainable* change. ●

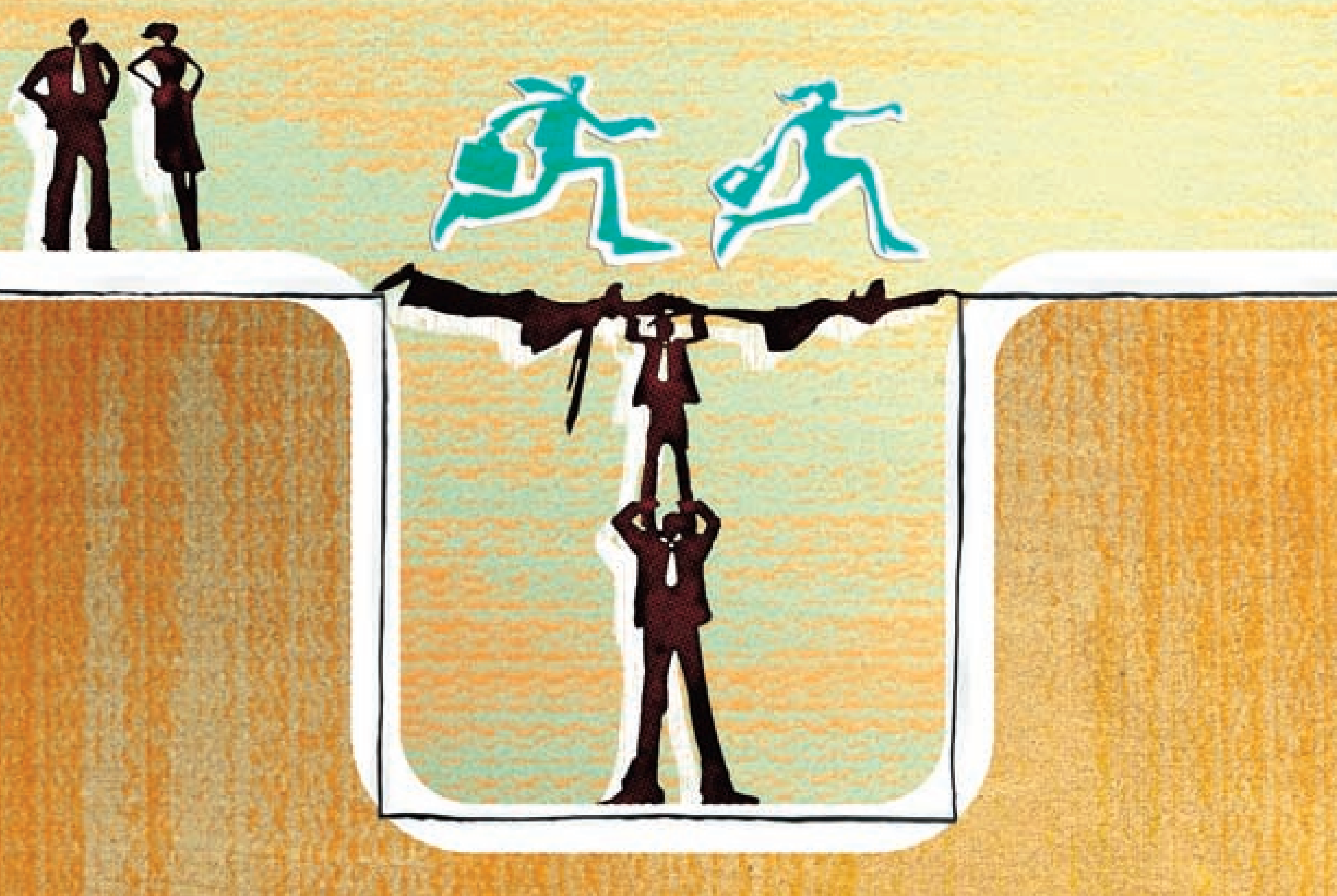
JOHN McCREIGHT has been a management consultant since 1968, following six years as a management systems program manager with Apollo and Minuteman contractors. His consulting focuses on large-scale strategic change. *jmc@implementstrategy.com*

CROSSING BOUNDARIES

TO BUILD CHANGE

BY ADRIAN WOLFBERG AND JOHN T. O'CONNOR

On May 18, 2006, a small crowd in a Bolling Air Force Base auditorium in Washington, D.C., helped launch a new era at the Defense Intelligence Agency (DIA). Lieutenant General Michael D. Maples, the director of the DIA, walked up to the microphone and said, "I am here to hear your ideas." Since that day, nearly a hundred volunteers from across the DIA have stepped forward first to share their ideas for how to improve the agency then to take the risks needed to act on those ideas.



In an organizational culture that has long rewarded quiet adherence to a rigid command-and-control style, coming forward in an open forum to tell the director that problems need to be fixed is a major development. This program, called "Crossing Boundaries," takes on the challenge of adopting the changes necessary to make the intelligence community more collaborative, imaginative, and open to new ideas. DIA's experience offers lessons for innovation and organizational change that others may appreciate and use.

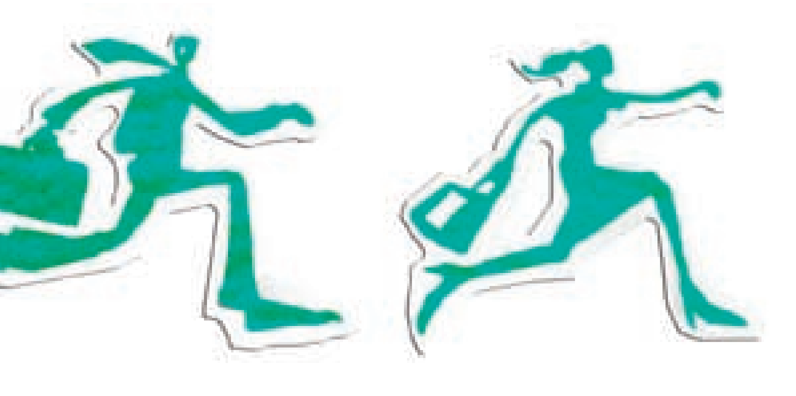
The success of the initiative has at least three critical sources:

- Consistent, visible support from senior leaders
- Focusing efforts on the "seams" between organizations, the potential points of connection and collaboration
- Encouraging the formation of networks of like-minded people to bring about change

The Government Culture

With more than 8,000 employees located at major sites in Washington, Maryland, Alabama, and other sites around the world, the DIA supports U.S. armed forces operations by providing critical intelligence collection and analysis for customers in the U.S. Department of Defense. DIA includes both active military and civilian personnel.

Readers familiar with government agencies will recognize the DIA culture. Separate directorates—each managed by a deputy director who reports to the agency head—oversee human intelligence collection (Directorate for Human Intelligence, or DH), intelligence analysis (Directorate for Analysis, or DI), the complex discipline of measurement and signatures intelligence (Directorate for MASINT and Technical Collection, or DT), and other activities. The directorates formerly functioned as separate entities. Intelligence analysts in the DI knew little about how MASINT capabilities of DT might help them in their mission. Interactions were traditionally controlled by top-down decision making that protected and controlled information and stifled creativity and new approaches suggested by working-level DIA employees. There was little movement of employees, knowledge, or best practices among directorates.



Changing the Culture

LTG Maples inherited an agency that was already changing, becoming a learning organization, and seeking knowledge through collaboration. One of the operating principles behind the DIA's change strategy is to create a network of volunteers who are committed to improving mission performance by helping people collaborate and share knowledge more effectively. The DIA created the DIA Knowledge Lab to support these networks and drive adoption of new practices that would improve mission performance by enabling employees to collaborate, share, think, and imagine with more freedom than before.

Crossing Boundaries

At the first Crossing Boundaries meeting on May 18, 2006, DIA employees volunteered ideas that included new methods of analyzing human networks, developing increased sensitivity to cultural differences, and helping people break down complex problems into smaller, solvable pieces. Maples and a small panel discussed each idea candidly, and he offered support and resources to help the volunteers move forward to explore their ideas further and potentially put them into practice. At the conclusion of the hour, Maples thanked the audience for being a part of Crossing Boundaries. Then the real work began.

A relatively new employee in the Directorate for Information Management proposed the idea of breaking down problems into smaller pieces. Working with the Knowledge Lab staff, she crafted her idea into a concept that could be tested in a pilot project. (Knowledge Lab pilots are limited-duration tests of ideas designed to determine whether they can provide value to the agency). Over a period of months, she refined her idea and worked with her home office, Enterprise Solution Management (ESM), and the Knowledge Lab to fashion a cooperative pilot (now called "Small Victories"). She negotiated with her management, recruited interested employees, and negotiated agreement among all parties. She began her Small Victories pilot

ANYONE WITH AN IDEA CAN PROPOSE IT IN AN OPEN FORUM. FEEDBACK FROM SENIOR LEADERS IS IMMEDIATE AND PUBLIC, AND OFFERS TO HELP OFTEN COME ON THE SPOT.

in November 2006, engaging a team of ESM project managers to develop, coordinate, and deploy guidelines for ESM project management. The pilot participants will use a collaborative leadership model drawn from the health care profession as an organizing principle. The Knowledge Lab will evaluate the process, behavioral changes, and outcomes accomplished by the pilot team.

Ideas and Changes

Since May 2006, DIA employees have volunteered eighty-eight new ideas to Crossing Boundaries. They have shared them with Maples and other attendees in open meetings that include a number of other senior DIA leaders who regularly contribute to these discussions. A number of Crossing Boundaries ideas have led directly to new actions by the agency, including the following:

- Creating a new award program to recognize employees who demonstrate significant collaborative behavior
- Reinstating random security checks at building entrances to raise the level of employee vigilance about protecting sensitive information
- Holding a "Leadership Day" to provide training and educational opportunities to help employees at all levels improve their leadership skills
- Bringing in adjunct faculty to improve training opportunities at the agency's Joint Military Intelligence Training Center
- Investigating ways to improve the agency's antiquated, paper-intensive time-and-attendance reporting system
- Reviewing the process for allocating office spaces in the agency to develop a more efficient and effective space management system

Proposals continue to come into Crossing Boundaries via e-mail, the internal Web site, and LTG Maples' forum.

A Learning Organization

Crossing Boundaries increases trust in the agency's leaders, demonstrates that the agency values knowledge wherever it resides, and encourages employees to take risks and practice analyzing and solving complicated problems.

Increase Trust

In November 2006, the Knowledge Lab convened the first quarterly Crossing Boundaries Roundtable meeting for employees who had volunteered their ideas to the effort. Roundtable participants described the director's involvement as providing a "license for creativity" for employees to step forward and pursue their ideas. One participant described her conversion from the cynicism that some of her peers still express. "I've seen it work," she tells them, and she encourages them to attend a Crossing Boundaries session to see for themselves.

Seek Knowledge

By demonstrating the value of seeking knowledge without regard for organizational boundaries, Crossing Boundaries exemplifies the new culture envisioned by senior national and intelligence community leaders. Anyone with an idea can propose it in an open forum. Feedback from senior leaders is immediate and public, and offers to help often come on the spot. Crossing Boundaries is not a panacea. Employees who propose ideas must still fight battles, and not every idea comes to fruition. But the premise of Crossing Boundaries—that all employees have something of value to add to the mission—is demonstrated every day.

Solve Problems

DIA employees address complex and substantive intelligence issues daily. In Crossing Boundaries, they usually take on complex problems that are outside their areas of expertise and responsibility. For instance, many of the proposals for organizational change have come from analysts in the Directorate for Intelligence Analysis. The proposals for changing the time and attendance system came from analysts, support professionals, and technologists. These people take risks by making a public statement on behalf of change. We are all in their debt.

What's the Secret?

People who are successful in Crossing Boundaries *act*. They build networks of supporters and advisors that cross organizational boundaries inside and outside DIA. For instance, the employee who started the time and attendance project networked with others in the Directorate for Human Capital and the Directorate for Administration, learning about the reporting process and identifying potential improvements. She then led a group that engaged another defense intelligence agency that provides the payroll service to DIA. Together, they identified potential changes that could significantly streamline the process. As a logical next step, the DIA's lean Six Sigma process improvement group began a detailed study of the time and attendance process to identify the set of process changes appropriate to the agency's needs. That study is under way now.

Another employee identified a potential change in how DIA collaborates with another intelligence agency. The change, if implemented, could improve mission performance in a sensitive area. He got immediate attention and support from Maples and senior leaders at a meeting in October 2006. He developed a paper that identified options for improvement, engaged other offices in DIA that had undertaken similar actions, and led a working group to explore details of implementation further. He engaged representatives of the other agency in a detailed evaluation of potential options. Today they are moving toward improving the depth of that agency's support for DIA.

At the Crossing Boundaries meeting on July 14, 2006, another DIA employee proposed an idea for better sharing of useful databases and tools among analysts. He envisioned a regular communication of "News You Can Use" to the broad agency via an internal Web page that would publicize new analytical tools available to analysts. He has gathered a number of volunteers to serve on an editorial board and assess which tools "News You Can Use" would feature, and he has collected a list of numerous tools that already exist. His group is planning to begin "News You Can Use" operations in early 2007. The positive impact on the work of individual analysts could be significant. The group plans to use already available tools, including Intellipedia (the intelligence community's version of Wikipedia), to provide this service. They do not need special permission or support from anyone. They are going ahead.

Building Networks

Crossing Boundaries participants form their own unique and changing networks of supporters. These networks contribute to problem solving in a number of ways. Through interaction with supporters and advisors, proposals become stronger and better. For instance, an employee who proposed saving funds provided to new employees to cover moving expenses found that his proposal may not conform to legal requirements of the hiring process for Department of Defense organizations. Rather than dropping the idea, he has worked with his network to develop a different approach that has the potential to provide the same savings within the bounds of current regulations.

An Innovation Network

As the Knowledge Lab has worked with these and other participants, it has found itself at the center of a virtual innovation center. The Crossing Boundaries network has the ability to apply its members' experience to complex problems facing the agency that no one has solved before. It is a complex, ever-changing set of individuals who are pooling their energy, passion, and resources to address the issues that have seemed too difficult to fix.

The Crossing Boundaries approach represents a real departure from usual change efforts in government. It works in the seams between organizations, draws support from all levels of DIA, and addresses issues that employees feel are critical to the agency's mission. By calling on volunteers to take risks and pursue their ideas for change outside normal channels and chains of command, Maples has demonstrated trust in the judgment and capabilities of the DIA workforce. He has gained (and continues to gain) the trust of those employees who have taken up his cause. They are becoming his advocates, and they prove that change is real. Through them, the DIA is growing a new culture of breaking down barriers, seeking knowledge, and learning new ways to scope and solve problems. Crossing Boundaries represents a visionary, driven-from-the-working-level approach to remaking the culture of an intelligence agency. ●

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Viewpoint: Lunar Opportunities

BY PAUL D. SPUDIS

When NASA's Lunar Architecture Team began to review ideas submitted by the broader space community about what we should do on the moon, they had to reconcile many disparate thoughts and concepts and weld them into a coherent rationale. This process began with a workshop in April 2006 that drew together a wide spectrum of attendees, all bringing their own backgrounds and agendas to the table. Their varied ideas converged to a surprising extent, with human settlement and preparation for Mars emerging as the primary goals of lunar return.

Refinement and expansion of these two themes and four others (science, economic expansion, international cooperation, and public engagement) took the remainder of 2006, with the results being presented at the Second Space Exploration Conference held in December in Houston. In conjunction with unveiling the six themes, NASA released a list (memorably called the "spreadsheet of death" by a colleague of mine) of 181 specific lunar activities, classified and rated by discipline and theme. It was never intended that all these activities necessarily be attempted by NASA; they were meant to demonstrate the scope and breadth of *possible* activities for humans and robots on the moon. It was necessary to examine all possible tasks and events in order to assess how well the emerging architectural details fit the potential list.

The sheer scope of the listed tasks and their collection into six themes led some to the conclusion that we really have no purpose for going back to the moon and that this effort is an attempt by NASA to retrofit a rationale on a goal that in fact has none.

Nothing could be further from the truth. The report is simply the result of the Agency attempting to satisfy as many of its constituencies as possible within the overall framework provided by the Vision for Space Exploration. So what was intended as the reason for lunar return by the architects of the vision? What, if any, are the objective reasons for a return to the moon?

For answers, read the vision policy documents, including both President Bush's original speech and a strangely neglected (but highly significant) elaboration on it by Presidential Science Advisor John Marburger. The presidential speech announcing the vision three years ago is remarkably clear about our purpose in returning to the moon. President Bush said the following:


Image Credit: NASA

In this artist's concept of the future, an astronaut gathers samples on the surface of Mars while a robotic explorer stands by to help. The Vision for Space Exploration calls for aggressive human and robotic missions that will return to the moon and eventually explore Mars and beyond.

> Beginning no later than 2008, we will send a series of robotic missions to the lunar surface to research and prepare for future human exploration. Using the crew exploration vehicle, we will undertake extended human missions to the moon as early as 2015, with the goal of living and working there for increasingly extended periods.

Also:

> Returning to the moon is an important step for our space program. Establishing an extended human presence on the moon could vastly reduce the costs of further space exploration, making possible ever more ambitious missions. … The moon is home to abundant resources. Its soil contains raw materials that might be harvested and processed into rocket fuel or breathable air. We can use our time on the moon to develop and test new approaches and technologies and systems that will allow us to function in other, more challenging environments. The moon is a logical step toward further progress and achievement.

These statements make clear that the purpose of going to the moon is *development:* developing new techniques, procedures, and technologies, all with the aim of making space flight easier, more routine, and more capable.

If this wasn't clear enough, John Marburger's speech (http://www.spaceref.com/news/viewsr.html?pid=19999) two years later clarified our ultimate objectives:

> President Bush's vision also declares the will to lead in space, but it renders the ultimate goal more explicit. And that goal is even grander. The ultimate goal is not to impress others, or merely to explore our planetary system, but to *use* accessible space for the benefit of humankind. It is a goal that is not confined to a decade or a century. Nor is it confined to a single nearby destination, or to a fleeting dash to plant a flag. The idea is to begin preparing now for a future in which the material trapped in the sun's vicinity is available for incorporation into our way of life.

And:

> We have known for a long time that a huge gap separates the objects trapped by the gravity of our star, the sun, and everything else. … Phenomena on our side of the interstellar gap, in what we call the solar system, are potentially amenable to direct investigation and manipulation through physical contact and can reasonably be described as falling within humanity's economic sphere of influence. As I see it, questions about the vision boil down to whether we want to incorporate the solar system in our economic sphere, or not.

The administration clearly stated that we are going to the moon to learn how to use what we find in space to create new space-faring capability. The goal isn't simply to return to the moon or even merely to send humans to Mars, but rather to extend human reach beyond low-Earth orbit and ultimately to all possible destinations beyond.

The Vision for Space Exploration is different from any previous space policy. By design it is incremental and cumulative. We make "steady progress" no matter how slowly we may be forced to proceed at any given time by fiscal constraints. Small steps that build upon each other create new capability over time. Our activities will teach us not merely how to survive, but how to thrive off-planet. Such a task includes inhabiting planetary surfaces, doing useful work while we are there, and extracting what we need from the material and energy resources we find. We will use these new skills and techniques to build a space transportation infrastructure that permits routine access to the moon and all cislunar space.

… WE ARE GOING TO THE MOON FOR ONE CLEAR AND UNDERSTANDABLE REASON: TO BE ABLE TO DO EVERYTHING ELSE THAT WE WANT TO DO IN SPACE. THE MOON IS OUR SCHOOL, LABORATORY, AND FOUNDRY.

The significance of this last point should not be underestimated; access to cislunar space will revolutionize space flight. Currently, we build disposable commercial space systems that have a specific design lifetime, after which they are simply abandoned. Combined with the high cost of getting to low-Earth orbit, this makes space flight difficult and costly. Hence, space largely has been left as the province of government, except for certain highly capitalized businesses such as global communications.

With the vision realized, satellites can be serviced, maintained, extended, and networked—space systems will be designed for an indefinite lifetime. Given existing launch costs, we cannot do this now. Even lowering such costs by an order of magnitude would still make even robotic servicing of platforms at geosynchronous orbit marginal at best. However, if we build a system that can refuel on the moon using locally produced materials, we create the capability to routinely go anywhere in cislunar space. Exporting fuel extracted from lunar resources will permit us to go anywhere, anytime, with whatever capabilities we need. This is the beginning of true space-faring capability. Such an environment would unleash imaginations, realize potential, and expand technology, science, exploration, and commerce.

In short, we are going to the moon for one clear and understandable reason: to be able to do everything else that we want to do in space. The moon is our school, laboratory, and foundry. The vision begins by building a highway through the heart of cislunar space, creating a transportation infrastructure for diverse users—scientists, miners, sellers, buyers, and, ultimately, settlers.

What is the role of NASA and the federal government in all this? It is not to industrialize space but to determine if the industrialization of space is possible. To accomplish such an expansive space vision requires us to understand exactly how difficult these tasks really are. Possible in theory is one thing; practical to implement is something else entirely. NASA must push the technical envelope to address and answer questions and develop new processes too expensive or too difficult for the private sector to tackle. Learning how to live on another world and extract what you need from it is a challenging task, one suitable for a federal research and development effort.

After understanding the technical difficulties and opening up possibilities, government should step back and let market forces work while still retaining a presence to enforce the law and ensure that compelling national strategic interests are served. Thus, while government will never become a resource producer, it is needed to ensure that corporations respect property rights and compete fairly in an open market, subject to the same antitrust and securities regulation as any other modern American business.

So why are some still asking, "Why are we going to the moon?" Some space constituencies are clearly uncomfortable with the strategic direction outlined above. For many, the idea of a government-funded program, controlled by and operated for the benefit of the academic science community, is the "right" way to run a space program. Such a science-driven agenda has been ascendant for the past fifteen years. During the Apollo era, the marshalling of national resources by the government to carry out space goals on a wartime footing was the dominant mode of operation.

Using what we find in space to enable exploration and to create new capability has never been attempted. The vision's goal is to extend human commerce beyond low-Earth orbit. America's desire to explore and create new wealth has allowed our society to thrive and to prosper. The Vision for Space Exploration extends that opportunity for all humanity into the solar system and beyond. ●

The views and opinions expressed in this article are the author's and are not necessarily those of the institution for which he works or ASK Magazine. *Read more at http://www.thespacereview.com/article/791/1.*

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SEARCHING FOR LIFE ON MARS;

MANAGING A DIFFICULT PROJECT ON EARTH

BY MATTHEW KOHUT

The primary objective of the Viking science mission was the stuff of dreams: to look for evidence of life of Mars. One of the instruments at the core of the mission was the gas chromatograph-mass spectrometer (GCMS). The GCMS was actually two instruments in one: a gas chromatograph and a mass spectrometer. Conducting gas chromatography and mass spectrometry in a laboratory was hard enough. Building even a lab model required experts who could keep up with the latest developments in the field, since the science was changing rapidly. The GCMS that Dr. Klaus Biemann, the leader of Viking's molecular organic analysis team, had at MIT was the size of a room; its human operator could literally walk through it. Shrinking the instrument to a mass of less than 15 kg and to fit in a 1′ x 1′ x 1′ box on a spacecraft, operate robotically, and survive the rigors of the journey to Mars and the Martian atmosphere presented myriad challenges.

The technical challenges were compounded by managerial ones, including inadequate supervision and lack of communication among the contractors responsible for elements of the instrument. These concerns put the GCMS on Viking project manager Jim Martin's "Top Ten Problems" list. Experienced, attentive management and a focus on performance over politics and standard operating procedures led to the instrument's eventual success.

A Neglected Stepchild

In August 1968, the Jet Propulsion Laboratory (JPL) was given responsibility for developing, fabricating, and testing a lightweight portable "breadboard" (experimental model) of the GCMS before selecting a contractor to build the flight hardware. JPL also had responsibility for designing and building the Viking orbiters, managing tracking and data acquisition through the Deep Space Network, and managing the Viking mission control and computing center.

In September 1970, Cal Broome, who headed the working group in charge of overseeing Viking's scientific payloads, told Martin that the GCMS was a "stepchild" not getting proper supervision because of the decentralized management structure at JPL. Two weeks later, word came back that JPL had taken steps to strengthen its control of the project, but the changes did not yield the results that Martin wanted. In January 1971, a five-day GCMS engineering model review was a disaster, resulting in between 200 and 300 "request for action" forms. The instrument's mass and cost both far exceeded earlier estimates. At the March Science Steering Group meeting, Martin noted that funding increases, technical problems, and schedule slips were causing considerable concern about the future of the GCMS.

The picture was not entirely bleak. That same month, the GCMS breadboard operated for the first time as a completely automated soil-organic-analysis instrument. Several technical problems were encountered, but Martin and the Viking Project Office considered it a step forward. There was no question about the JPL team's technical talent; Martin's concern was its ability to deliver a working instrument in time for launch.

JPL's oversight of the instrument's contractors was a major source of concern. Beckman Instruments (gas chromatograph), Perkin-Elmer (mass spectrometer), and Litton Industries (data system) were building the components of an instrument that required the highest degree of integration, yet the three wouldn't even talk directly to one another, despite the fact that their facilities were within a fifty-mile radius in California. None had been designated as prime contractor.

In October 1971, Martin considered finding another organization to handle the GCMS contract. The project office awarded Bendix Aerospace a contract to study the feasibility of using an organic analysis mass spectrometer (OAMS) in place of the GCMS. On October 26, he added the GCMS to the Viking Top Ten Problems list.

Martin began the Top Ten Problems list in the spring of 1970 to give problems that could affect the launch date needed visibility and oversight. To make the list, a problem had to have a serious impact on "the successful attainment of established scientific and/or technical requirements, and/or the meeting of critical project milestones, and/or the compliance with project fiscal constraints." Anyone associated with the Viking project could identify a potential priority problem by defining the exact nature of the difficulty and forming a plan and schedule for solving it. When Martin made an addition to his list, a person in the organization was charged with solving the problem, and someone in the project office monitored the progress.

Time for Action

At the February 1972 Science Steering Group meeting, a top scientist reported on the GCMS and OAMS, noting that both had advantages and disadvantages that could not be directly compared. That settled it for Martin. He decided in favor


Photo Credit: NASA Headquarters

Technicians inspect Viking Lander 2 in Kennedy Space Center's Spacecraft Assembly and Encapsulation Facility #1.


Photo Credit: NASA Headquarters

The flight GCMS is tested and prepared for its long journey through space to investigate Mars.

of continuing the development of a simplified version of the GCMS. He removed the GCMS from the Top Ten Problems list for the time being, knowing that in March he would take concrete steps to get the instrument on track. Martin decided to shift management of the GCMS from JPL to his Viking project office at Langley. According to cost projections, it would be cheaper by about $7.5 million to keep the GCMS project (rather than shifting to an OAMS) while transferring management of it to Langley.

This decision to take the GCMS project from JPL was not made lightly. Though technically not a government institution, JPL was an integral part of the NASA family and the Viking mission. Martin knew his decision would cause rumblings, but the potential political fallout was preferable to launching the Viking spacecraft without a GCMS—an instrument critical in the search for signs of life on Mars. Although its development and fabrication were still far from ensured, he was confident that the project office at Langley could bring needed discipline. He sent Angelo "Gus" Guastaferro, Deputy Project Manager for Management, to California to rewrite the GCMS contract with JPL, and he appointed Joseph C. Moorman to manage the instrument.

MARTIN DID NOT CARE ABOUT GUASTAFERRO'S TITLE; HE NEEDED A SENIOR PERSON WHO COULD TAKE EFFECTIVE CONTROL OF THE PROJECT AND THE CONTRACTORS.

Back in the Top Ten

Moorman, who had been managing a biology instrument prior to taking over the GCMS, did not have experience corralling contractors or shifting a project from one center of operations to another. The Viking project was the first in his NASA career, and the difficulties presented by the GCMS would have been an extraordinary challenge for even a seasoned project manager.

Six months later, Martin concluded that Moorman had not brought the GCMS up to speed. This was not a routine science instrument; it required strong systems engineering and experienced project management. He put the GCMS back on the Top Ten Problems list, where it remained for more than two years until shortly before launch.

Beyond the Org Chart

By the end of 1972, Martin took action again. He reassigned Moorman and put Guastaferro, his deputy for management, in charge of overseeing the instrument's development on a day-to-day basis. Martin did not care about Guastaferro's title; he needed a senior person who could take effective control of the project and the contractors.

Guastaferro's first task was to establish a more productive and cooperative relationship among the contractors; his strategy was to shift from "inattention" to "over-attention." He left Langley and relocated to California for the next two years so he could shuttle among their facilities to monitor progress. He also assigned Litton Industries responsibility as the instrument's prime contractor, since its data system would ultimately integrate the information from the gas chromatograph and the mass spectrometer and send data back to Earth.

Reaching Out for Answers

Guastaferro relied on Al Diaz, the GCMS chief engineer, to provide the technical expertise that the project required, since there were still significant problems to resolve. Guastaferro and Diaz sought help wherever they could find it, often reaching out to experts in private industry and academia for answers. On more than one occasion, they discovered that others had overcome similar technical issues, but the solutions were proprietary or classified.

One example involved a problem with electrical high-voltage arcing, which would ruin the instrument. The key to fixing this was developing an epoxy-like compound to insulate the circuitry from the conditions that made the instrument susceptible to arcing. The JPL team had not been able to devise the right formula. Guastaferro and Diaz discovered that a private industry contractor working for the Department of Defense had encountered this same issue with its own technology. While the contractor could not divulge the process to NASA, its representative told Guastaferro and Diaz to send him the component, and he would ensure that the problem disappeared. This "blind" handover had its risks, but Guastaferro and Diaz were more concerned with getting a working instrument to the launch pad on time than with ownership of the technical solution.

The Launch

One by one, dozens of technical issues were resolved. The GCMS critical design review in mid-July 1973 found only three major outstanding concerns, a vast improvement considering the previous difficulties with the instrument.

In May 1975, science payload manager Cal Broome advised Jim Martin that he could remove the GCMS from the Top Ten Problems list. Three months later, on August 20, 1975, Viking I was launched, followed by Viking II on September 9, 1975. In the summer of 1976, the Viking landers began sending GCMS analyses of Martian soil and atmosphere back to scientists on Earth. ●

The Viking Gas Chromatograph-Mass Spectrometer

The gas chromatograph used a thin capillary fiber known as a column to separate different types of molecules, based on their chemical properties. Each type of molecule passed through the column at a different rate, emerging from the column in a defined sequence. The temperature of the column determined the rate of separation.

Once processed by the gas chromatograph, molecules would then enter the mass spectrometer, which would evaluate and identify them by breaking each one into ionized fragments and detecting these fragments using their charge-to-mass ratio. This produced a unique profile of each compound that could be converted into a digital signal and transmitted to Earth.

Used together, these two components offered a much finer degree of substance identification than either unit used separately. Scientists considered the GCMS a gold standard for forensic substance identification because it performed a specific test. (A specific test positively identifies the actual presence of a particular substance in a given sample.) A working GCMS was absolutely critical to the organic analysis of the soil on Mars.

Knowledge in Brief

Here are two true stories about organizational effectiveness. We leave it to you to think about their relevance to NASA and knowledge.

Three Heads Are Better Than One

When Megan was 14, she began to have trouble swallowing and could not seem to keep food down. Her parents brought her to the family general practitioner. He examined her and ordered some tests. Finding nothing obviously wrong, he assured Megan and her parents that the problem would take care of itself.

But Megan's digestive problem got worse and she began to lose weight. She went to one specialist who prescribed an antibiotic that had no effect on her condition. Other doctors who examined Megan were baffled. She continued to have trouble eating and continued to lose weight.

Her parents took her to the Hospital for Sick Children in Toronto. Soon after she was admitted, three specialists entered Megan's room together: an internist, an allergist, and a gastroenterologist. They had all studied her records. They asked a few questions and examined her. Then, in the room with Megan and her parents, they shared their ideas.

The allergist said he was fairly sure the problem was not a food allergy.

"Yes, I think it's an infection," the gastroenterologist said.

The internist agreed and thought he knew why the earlier course of antibiotic treatment had not worked.

Megan had been ill for weeks. Now, within five minutes, the three physicians agreed on a diagnosis and a treatment—a particular antibiotic effective against the somewhat unusual infection she had contracted. Her rapid recovery proved them right.

Decision Making at W. L. Gore

The W. L. Gore companies have built their business on one chemical compound—polytetrafluoroethylene—and on a particular idea of management. They have turned the polymer into electrical insulation, artificial veins, Gore-tex, and Glide dental floss. Gore prides itself on the independence and creativity of its employees. At Gore, anyone can make any decision relevant to his or her work that is not "below the waterline"—that is, that would not sink a division or the company if it proved to be a bad one.

Research scientist Robert Henn's experience shows the decision-making philosophy in action. Some years ago, Henn began to think about a $500,000 piece of testing equipment that he believed could aid his research. He discussed the idea with his colleagues. He was enthusiastic about the equipment, but half a million dollars was a lot of money.

One day, CEO Bill Gore came into his office and said, "I hear you're thinking about spending $500,000 on a new piece of equipment."

Henn admitted that he was.

"Tell me, Bob," Gore went on, "if this device does everything you imagine it can do, will it give us results that can help us improve our products or develop new ones?"

Henn had obviously thought about that question and found it easy to answer: yes, he believed the device would have practical and profitable applications.

"If it fails," Gore asked, "if it turns out to be a $500,000 paperweight, will your division survive?"

Henn hadn't asked himself exactly that question. Gore waited while he mulled it over. Eventually he said, "If it turns out to be useless, that would be personally embarrassing to me, but, yes, the division would survive."

"Then why haven't you ordered it?" Gore asked. So he did. ●

ASK Bookshelf

Here is a description of a book that we believe will interest ASK *readers.*

Infotopia: How Many Minds Produce Knowledge, by Cass R. Sunstein (New York: Oxford University Press, 2006)

Infotopia is about the democratization of knowledge, a subject Thomas Davenport considers in this issue of *ASK*. The book's insights into how people share knowledge and make decisions can contribute to the discussion of these important subjects at NASA. In *Infotopia*, Sunstein analyzes recent developments that he thinks have the potential to aggregate people's knowledge in valuable ways: the prediction markets that James Surowiecki also discusses in *The Wisdom of Crowds;* wikis, those collectively written and edited documents and encyclopedias; and the blogs (or Web logs) that comment on everything from politics to business to the often boring, occasionally fascinating details of the bloggers' personal lives.

Like Surowiecki, Sunstein offers examples of the amazing accuracy of prediction markets and similar mechanisms for averaging the judgments or guesses large numbers of people make about questions ranging from the number of jelly beans in a jar to the outcome of an election or the release date of a product under development. Companies including Google and Hewlett-Packard have successfully used prediction markets to help guide decisions. Sunstein explains why these markets are so accurate and usefully describes circumstances in which they do and do not work. But there is one flaw in his careful analysis that is worth noting. Sunstein talks about prediction markets aggregating *knowledge* when in fact they aggregate *judgments*. Those collective judgments may be informed by knowledge, but the knowledge itself is not collected and cannot be extracted from the markets' conclusions.

Wikis *do* aggregate knowledge and information. Sunstein argues convincingly that the best of them—Wikipedia is the best-known example—can be extraordinarily current, comprehensive, and accurate. Although some wikis have been ruined by maliciousness and ignorance, Wikipedia thrives on the good will and good sense of most contributors and an editorial process supported by "Wikiquette" that establishes rules for disputing content. Businesses including Disney, Yahoo, and Oxford University Press are beginning to use wikis internally. They have great and so far largely unrealized potential as a tool for collecting and organizing what people in organizations know.

Sunstein is appropriately skeptical about the ability of blogs and the multitude of Web sites on any subject you can think of to improve the quality of our collective knowledge and understanding. He points to two related problems. First, many blogs and sites offer up information that is misleading, biased, and just plain wrong. Second, people tend to seek only information that confirms what they already believe (constructing "informational cocoons" for themselves), so they are unlikely to read broadly enough to judge the reliability of a particular source. In other words, the truth may be out there, but it's hard to distinguish from the lies.

Sunstein is highly critical of deliberation—people talking together to come to a decision or evaluate ideas. He offers an important corrective to uncritical praise of the collective knowledge of teams and communities. He notes that groups are likely to defer to the opinions of high-status members and that members are often afraid to express views that differ from what the majority believes. As a result, he says, "deliberating groups discourage novelty" and, because they reinforce the ideas of the powerful or the majority, they tend to strengthen commitment to decisions good or bad. Sunstein suggests ways of improving deliberation that include explicitly inviting varied views, using devil's advocates, and seeking individuals' opinions both before and after group deliberation. ●

The Knowledge Notebook

On Trust

BY LAURENCE PRUSAK

Sometimes a concept seems to be everywhere at once. It arrives on the scene seemingly from nowhere, and everybody is suddenly talking and writing about it. One such idea is trust.

Although philosophers and poets have focused on trust as far back as the Old Testament and in the writings of several of the Chinese sages, it had very little traction as an idea in and of itself until recently. Few books or articles focused specifically on the subject. Then, starting slowly in the 1980s and picking up steam in the nineties, the subject took off. Economists, sociologists, political scientists, and management theorists began to take a serious look at how trust works in people's lives, in organizations, in nations, and in cultures. This attention to trust helped spur the parallel interest in social capital and is, indeed, a major component of that set of ideas about the value of the connections between people. By now the trust literature is huge. I personally own more than a dozen major books on trust and have a thick file of articles on the subject. That collection, which only reflects my amateur's taste for the subject, is by no means comprehensive.

So, what's going on here? Why is the subject so hot? The short answer is: in a complex, connected world where so much depends on cooperation and understanding, trust is essential to the success of organizations and societies.

Trust between individuals can be defined as anticipated reliable cooperation. I help you with the expectation that you will help me when I need it, and your cooperation will be freely offered, not compelled by enforcement mechanisms. People usually base their trust on direct personal experience. When they don't yet know one another, they proceed with caution, testing the water, observing behaviors that show if this person or that one is trustworthy.

Although in one sense all organizational activity comes down to the actions of individuals, focusing on individual trust isn't always the most fruitful path to understanding how it works in organizations. How trust develops (or fails to develop) depends on the organizational context. We all know of organizations where trust is in short supply, between people and between employees and their management. Sometimes employees trust their colleagues while distrusting their managers with varying degrees of intensity, but often distrust at one level discourages trust at others. An organization's trust "climate" can promote or destroy trust in many ways and many places.

Social scientists talk about "generalized trust" in organizations and in societies. When trust and trustworthiness in institutions, leaderships, and individuals are the norm, people are more likely to trust one another readily—they will assume trustworthiness until individuals or groups show they are not worthy of it rather than demand extensive proof before they are willing to trust anyone.

What is the importance of trust in organizations? For one thing, trust or the lack of it has a real economic impact. All organizations spend a lot of money and time (up to 40 percent of their total expenditures) on transaction costs. Transaction costs are the costs of doing work together—negotiating, bargaining, exchanging, and interpreting information and monitoring activities, among others. These activities are especially extensive and important in large, complex organizations. Generalized trust is a great way to cut transaction costs. When trust is the norm, people in the organization do not have to look constantly over their shoulders or nail down every detail of every agreement or monitor and measure compliance with requirements large and small. The organization and the individuals in it are relieved of an onerous and expensive burden. This can mean not only very significant financial savings, but savings of the enthusiasm, commitment, and energy that distrust erodes.

Trust also encourages—in fact, makes possible—the free exchange of knowledge. People tend to share what they know when they are confident they will be credited for it and the knowledge they offer will be well and responsibly used. We have seen many organizations where trust is the great engine of knowledge sharing and people freely and actively offer their expertise to others who need it. This happens whether or not the organization has elaborate and expensive knowledge-sharing systems. It is much more about attitudes, examples, and experiences than technology.

Trust is asymmetrical. As Rod Kramer, a Stanford researcher on this subject, says, it is "hard won and easily lost." One breach of trust can outweigh years of trustworthy actions. It is incumbent on managers and executives to do what they can to build and maintain trust in their own areas of influence. Research and common sense suggest that some good ways of doing this are to act transparently (that is, be trustworthy); reward and promote people who are trustworthy and get rid of those who aren't; talk up the subject and recognize its importance; and, to quote a bumper sticker, be the change you wish to see. Trust me, it really is worth doing. ●

PEOPLE TEND TO SHARE WHAT THEY KNOW WHEN THEY ARE CONFIDENT THEY WILL BE CREDITED FOR IT AND THE KNOWLEDGE THEY OFFER WILL BE WELL AND RESPONSIBLY USED.

ASK interactive

Courtesy of ASK OCE: http://appel.nasa.gov/askoce

NASA in the News

U.S. News & World Report, in conjunction with the Center for Public Leadership at Harvard's John F. Kennedy School of Government, named Charles Elachi of the Jet Propulsion Laboratory (JPL) as one of "America's Best Leaders" for 2006. Other honorees include Warren Buffet, Sandra Day O'Connor, Wynton Marsalis, and Michael Bloomberg. Elachi was chosen for his bold leadership in turning around NASA's Mars projects after the mission failures of the Mars Climate Orbiter and the Mars Polar Lander in the 1990s. His efforts led to the successful Mars Exploration Rover (MER) program, which included the Spirit and Opportunity rovers. The honorees were selected by a committee of government, community, and private-sector leaders convened by the Center for Public Leadership at Harvard University's Kennedy School of Government. Read the *U.S. News & World Report* article online at http://www.usnews.com/usnews/news/leaders.

Learning and Development

Check out these upcoming opportunities for increasing knowledge. For more information, please e-mail APPELcourses@asrcms.com.

Foundations of Aerospace at NASA Part A, *July 16–27, Ames Research Center*
This course is designed for new hires within their first year of employment at NASA or employees that began work within the past five years. The goal of this course is to immerse new hires in what it means to work at NASA and the principles of technical excellence. It will provide participants with a "big picture" of NASA, its governance model, and Agency operations, as well as communication and team participation skills and basic concepts of aeronautics and astronautics.

Project Management and Systems Engineering Part B, *September 10–14, Wallops Flight Facility*
This course is designed for NASA project practitioners and systems engineers prior to or in the first year of entry into project, systems engineering, or supervisory positions. This course is intended to enhance proficiency in applying PM and SE processes/practices over the project life cycle. It will focus on defining and implementing system projects and providing the tools necessary for managing and leading project and technical teams.

Web of Knowledge

NASA has created a knowledge network to promote learning and sharing among NASA's engineers. Through NASA Lessons Learned, an agency-wide searchable database, an expertise locator, and discipline-specific communities of practice portals, the NASA Engineering Network, or NEN, connects engineers to NASA's vast engineering resources to help them solve problems and design solutions more effectively and efficiently. Find out more about the Network online: http://nen.nasa.gov (NASA only).

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- **Space Mission Excellence Program:** http://www.nasa.gov/centers/glenn/news/AF/2006/nov06_training.html

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NP-2007-06-472-HQ