National Aeronautics and Space Administration

Academy Sharing Knowledge

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The NASA Source for Project Management and Engineering Excellence | APPEL

SUMMER | 2009

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MANAGEMENT BY WANDERING AROUND

COLLABORATION AT CERN

INNOVATING TO FLY IN CLEANER SKIES

Photo Credit: NASA

ON THE COVER

This image of Earthrise was taken during lunar orbit by the Apollo 11 mission crew in July 1969. The first manned lunar landing mission, Apollo 11, launched from Kennedy Space Center on July 16, 1969, with a three-man crew aboard the flight: Neil A. Armstrong, commander; Michael Collins, command module pilot; and Edwin E. Aldrin, Jr., lunar module pilot. The lunar module “Eagle” was the first crewed vehicle to land on the moon.

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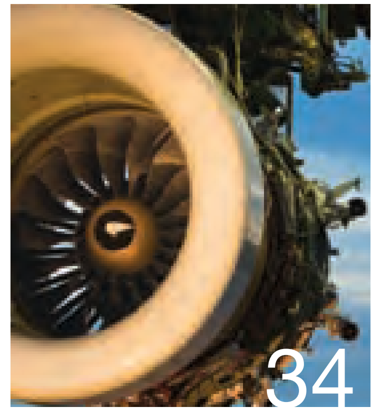

ask

Issue No. 35

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

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

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

For inquiries about APPEL Knowledge Sharing programs and products, please contact Katherine Thomas, ASRC Management Services, 6303 Ivy Lane, Suite 130, Greenbelt, MD 20770; katherine.thomas@asrcms.com; 301-793-9973.

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In This Issue

We usually think of innovation as developing some new product or technology. NASA is in the business of technological innovation, of course, and several articles in this issue of *ASK* deal with new or improved technologies. Brent Cobleigh's "Unmanning the Fire Lines" reports, in part, on the novel capabilities NASA's Ames Research Center and Dryden Flight Research Center brought to Ikhana, an unmanned science aircraft. "Innovating to Fly in Cleaner Skies" describes the new, efficient jet engine being developed by Pratt & Whitney. And building the Large Hadron Collider at CERN ("A Model for Collaboration," by Krisztina Holly) demanded new capabilities in areas including cryogenics, superconductivity, and vacuum systems.

These articles and others also consider innovation in *how* things are done. Process innovation often contributes to the other kind. So, for instance, CERN's radically collaborative way of working helps ensure that the best ideas will be heard and applied to the project's technical challenges. Widening the search for knowledge is a process innovation featured in a number of articles. Ed Campion's "Rising to the Challenge" tells the story of one of NASA's agencywide requests for new ideas. Rocketdyne has developed a variety of ways to make important knowledge available ("Rocketdyne: Committed to Knowledge Sharing," by Carri Karuhn), and the Pratt & Whitney engine innovation story is partly one of knowledge shared back and forth between companies.

More broadly, developing innovative ways of doing work is often necessary to carry out complex, challenging projects with limited budgets. That is why Alexander Laufer, in the interview, says that the most important attribute of a project leader is the ability to challenge the status quo—that is, to insist on a new approach when it becomes clear that the old one won't do the job. In "Bidding Your Way to the Launch Pad," Randii Wessen and David Porter make the case for a (so far) rarely used market-based system to allocate project resources. Noel Hinners ("Management by Wandering Around") describes his experience with a communication practice that is not new but that we can think of as innovative because it is probably not used as much as it should be. Fayssal Safie's "Process Improvement for Space Flight Safety" shows the far-reaching consequences of a new approach to process control, one that lessens risks for missions and astronauts.

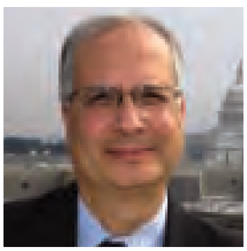
None of these improvements would do much good without the commitment, cooperation, and goodwill that make project work possible. That is why Bryan O'Connor emphasizes shared values and universal accountability in "Some Safety Lessons Learned," why Nancy Mangini's article promotes engagement ("Engaged Workers Boost the Bottom Line at Ames"), and Robert Hurley and Joseph Jimmerson insist on the importance of helping team members deal with the cancellation of their project ("Managing the Trauma of a Terminated Project"). It is also why the words "trust" and "judgment" appear so frequently (for instance, in the Laufer interview, Laurence Prusak's "Knowledge Notebook," and the CERN article). In other words, innovation and the ability of teams to do work well in general rest on a foundation of very old and very basic human values.

Don Cohen
Managing Editor

From the APPEL Director

Technology-Enabled Learning

BY ED HOFFMAN



Information technology develops at such a rapid clip that most of us are scrambling to keep up. This is particularly true for those of us involved in workforce development. If you need compelling evidence of how information technology is affecting the delivery of learning, you need look no further than higher education, where many colleges and universities are experiencing double-digit growth in technology-enabled courses and programs. Government agencies have discovered that technology assists with learning at a significant cost savings. But there's the rub: management loves the idea of saving money, so learning efforts that promise better learning with fewer dollars are immediately embraced, even though they may actually result in less learning.

I possess a healthy skepticism when it comes to using technology to achieve better learning outcomes. This is not an unfounded bias. I have seen millions of dollars spent on technology that promises gains in workforce competence and capability but fails to deliver. One example: learning repositories that store organizational knowledge to make it available for reuse. Some very expensive systems have been constructed on the *Field of Dreams* build-it-and-they-will-come philosophy, but they don't come, and that money and effort are wasted.

But the right technology in the right situation can pay off. Applying good learning practitioner-based learning-design principles to clearly defined and strategically aligned learning objectives comes first. Then technology can often help achieve these clear objectives at a cost savings. I have seen established programs and courses use technologies to improve what they already do very well; for example, by helping them to extend the reach of their products and services or allowing them to update content more rapidly and efficiently. Effective learning in the future will rely on the smart application of technology because of accelerating knowledge expiration, with content becoming outdated and inapplicable much faster than in the past.

The Academy for Program/Project and Engineering Leadership currently uses various technologies for learning. *ASK Magazine* is available on the Web as well as print; case studies are distributed online; and we use decision-making tools to guide discussions in meetings. Blogs and wikis allow us to create updated online essays to distribute knowledge and invite participation through online editing. Social and professional networking sites like Facebook, MySpace, and LinkedIn help us create communities of practice, chat, and share information using videos and sound. Virtual worlds allow us to socialize in simulated environments based on real-world and imagined situations and processes. Twitter and Tumblr create mini-blogs that allow people to report and follow activities minute by minute. YouTube allows the sharing of knowledge in a video format and connects us to other potential resources related to the content.

One new development that excites me is Google Wave, a communication and collaboration platform based on HTML 5 that is open source, browser-based, and will encourage myriad third-party widgets, gadgets, and Web-based tools to enhance learning. Think of it as a combination of any technology tool you can think of in a browser. One Google Wave gadget already allows for automatic translation of more than forty languages in real time as you type. So take it from a skeptic: technology can be wonderful. ●

Some Safety Lessons Learned

BY BRYAN O'CONNOR

The proximate causes of an accident and the changes needed to avoid repetition are usually clearer and more readily dealt with than the associated root causes. As a team of engineers, we usually find a way to modify the design, change the software, or develop an operational workaround that adequately mitigates the proximate and near-proximate causes of our mishaps. But root causes are different kinds of problems.

Lightning strikes near a silhouetted mobile launch tower about 36.5 seconds after the 1969 liftoff of Apollo 12, which was also struck during its ascent. This event led to updated weather criteria for governing launch decisions, but a rationale for the update was not recorded.

Photo Credit: NASA

Root causes tend to be related to the broader, sometimes squishier aspects of what we do: such things as the what-versus-how of our procedures and requirements and the appropriate volume and frequency of organizational communications up and down and left and right. Sometimes they involve organizational and authority relationships, the effectiveness of checks and balances, and other cultural aspects of program and operational management.

The *Columbia* Accident Investigation Board (CAIB) report recommendations and associated internal studies resulted in two very challenging sets of activities: the first technical, the second managerial. Efforts dealing with the proximate (technical) causal factors were tough because the physics and engineering and production processes related to external tank insulation in the ascent environment are very complex. As for the managerial changes, they too were difficult, but probably for very different reasons.

The CAIB report listed a number of organizational/cultural findings and recommendations, but that section did not include the kind of factual basis that characterized the technical parts of the report. Of seven volumes of factual information in the CAIB final report, none pertained to the root causes of the mishap; they were all about the technical failure itself. The relatively limited summary of organizational and cultural material in volume one was all we had, leaving much to the NASA team to determine for itself. By itself, this should not have been a problem for us. After all, any mishap board is advisory, and the ultimate findings often come from Agency follow-up. In this case though, the high visibility of the CAIB investigation, along with the public statements by the board about lack of engineering curiosity and authority imbalances between the institution and the program, made it very difficult for the Agency to modify, let alone disagree with, their specific recommendations.

On top of that, we asked another external group (the Covey Stafford team) to oversee our return-to-flight activities and told them they should evaluate our efforts relative to the "intent" of the CAIB. We asked the Covey Stafford management team to interpret the intent of the CAIB's three management recommendations. Unfortunately, the CAIB members they consulted, the Covey Stafford management team members, and our own NASA leaders could not agree on intent. The result was several false starts, uneven application of the new governance model, and residual issues and misunderstandings that persist to this day.

Having said that, I believe NASA's governance model and safety culture in general are as good today as they have been for a long time. In retrospect, though, I think it was a shame to waste so much time and effort getting to this point.

A Recipe for Safety

So what are the best ways to make the inherently risky activity of human space flight as safe as possible? My recipe for flight safety goes like this:

1 part shared values
1 part organizational structure
1 part requirements
2 parts risk management
A pinch of luck

A CAIB reconstruction team member examines debris with a video microscope. The CAIB report included technical and managerial recommendations, both difficult to put into practice for different reasons.

CAIB Photo by Rick Stiles 2003

The value of luck goes without saying and, although some environments seem to be more conducive to good or bad luck than others, luck generally is not something you can do much about. I'll look briefly at the other ingredients.

Shared Values

An organization whose core values include teamwork, integrity, excellence, and, of course, commitment to safety is likely going to have a good mission success and safety record. Alcoa and DuPont are two well-known organizations whose strong core values are reflected in excellent safety records. Closely related to teamwork and commitment to safety is accountability. Everyone in NASA is responsible for safety, although the degree of individual accountability varies in accordance with this formula:

Accountability =
responsibility x authority x capability

A given individual's level of formal responsibility and authority may vary from project to project. Their capability—the relevant knowledge and experience they have—will also vary from situation to situation. But none of those factors—responsibility, authority, or capability—is ever zero, so no one can entirely lack accountability, regardless of how far they are from the prime decision makers. At the very least, every person is accountable for his or her own safety. Those with programmatic and technical authority and capability find themselves more or less accountable for the safety of the mission.

Organizational Structure

A key aim of NASA's recent governance changes has been to establish an independent technical authority and ensure that technical concerns that arise at any level will be addressed. The check-and-balance model we have chosen means that the programmatic and agency strategic leadership decide on programmatic and performance parameters, and the institution uses years of lessons learned to decide which technical requirements apply. The program needs institutional (independent technical authority) approval for relief from technical requirements but works as necessary within the programmatic chain of command for relief from cost, schedule, and performance requirements. This is the model we believe the CAIB intended.

Requirements

Good requirements are nothing more than lessons learned. To be effective, though, they must come with enough context and background to explain why they exist. Without an understanding of the underlying reasons for a requirement, decision makers are more likely to make the wrong choices. An example of the problem is the 1987 Atlas Centaur 67 lightning strike that destroyed an Atlas 2 and its FleetSatCom payload. A lack of rationale—of context—for the weather criteria governing launch decisions was a factor in a faulty decision and the loss of the mission.

Risk Management

Much of what we do at NASA is not conducive to simple requirements compliance. The nature of our missions means that our performance margins are often very low, and we often find ourselves accepting "residual" safety risks in order to accomplish the mission. If we were to design a human space flight vehicle that fully met all our standards and requirements for human rating, it likely would be too heavy to fly. So some number of waivers for our technical requirements and less than fully controlled hazards are inevitable. Bad experiences from the past (notably *Challenger* and *Columbia*) tell us that we are capable of fooling ourselves when we fail to apply technical rigor and process discipline in our risk management processes.

Learning from Experience

No matter how dedicated we are to safety, accidents happen. When they do, they give us an opportunity—though often a painful one—for learning that can prevent problems in the future. We also need to be careful not to derive the wrong lessons from experience. Specifically, we don't want to "learn" from a string of successes that a particular kind of mission is inherently safe and we no longer need to look so carefully at risks.

There are, broadly speaking, two modes of learning and behavior that help organizations prevent mishaps. One is incident recovery: the intense, focused period of analysis and action that follows an accident and takes steps to avoid a recurrence. The other is complacency avoidance: countering the tendency to assume that recent success promises future safety.

Learning from Incident Recovery

A serious mishap galvanizes an organization. Experts minutely study the evidence to uncover the proximate causes of the accident. This type of work, though reactive, is engineering in every sense of the word. NASA engineers know how to investigate failures and, in the wake of a major mishap, motivating them to do it well is not an issue. If anything, we have to tell our investigators to back off and take a breath once in a while.

Fighting Complacency

After the mishap investigation and the return to flight, the team focuses again on the mission, and the challenge for the leadership team shifts from recovery to fighting complacency. Countering complacency is arguably harder than recovering from a mishap. We have to find creative ways to counteract the common psychological tendency to assume that a string of successes means that we have somehow reached a state of engineering and operational perfection—and, therefore, immunity from failure. One way I have found useful to get our team back to the proper state of humility and respect for risk is to occasionally revisit accident case studies. This does two things. It reminds us that other people who thought they were paying sufficient attention to safety have been surprised by failure; the case study serves as a vivid reminder of the fact that most past accidents almost always happened during a period of complacency. It also gives them a challenging and—we hope—relevant technical problem-solving session. These two things can go a long way toward reviving the critical recovery mind-set. They, along with the safety factors I mentioned above—shared values of teamwork, integrity, and commitment to safety, and requirements that make clear *why* they are important—are crucial weapons in our fight against complacency. ●

BRYAN O'CONNOR is a former Marine Corps test pilot and aeronautical engineer. He served at NASA as a Space Shuttle commander and program director and is currently serving as the Agency's Chief of Safety and Mission Assurance.

Management by Wandering Around:

A POTENT ARROW IN THE MANAGER'S QUIVER

BY NOEL W. HINNERS

One of the great mysteries of life is that very few of those we work for have the least inclination, or possibly the needed skills, to consciously mentor us in the fine art of management. We are left largely to trial and error, with the likelihood that error will occur at just the wrong time and we won't realize it until the infamous stuff hits the fan. This is not necessarily bad as long as a lesson is indeed learned and no serious damage occurs. In many regards, on-the-job training is much more effective than reading myriad books on management; it is not the ideal way to avoid a management catastrophe, however.

Many of us don't avail ourselves of potentially useful techniques either because we don't know about them or don't believe in them. NASA's Academy of Program/Project and Engineering Leadership helps with the former. Disbelief and skepticism remain particularly rampant among scientists and engineers steeped in the mythology that only technical expertise and gut-level management matter.

I think those are necessary but insufficient. Even a casual perusal of failure reviews should convince you of that. So, of all the pet techniques of management gurus, which ones might work best in our frequently stressful environment? One I've found especially useful and enjoyable is "management by wandering around" (MBWA). The "wandering" is often replaced by "walking," but I prefer "wandering" as it connotes a sense of purposeful randomness and the possibility of an unexpected and fruitful chance encounter.

I was first exposed to MBWA in the early sixties with my first employer, Bellcomm, a NASA contractor hired to assist with Apollo systems engineering. My bosses frequently would stop by my cubicle and either talk about a specific topic or sometimes just chat about how things were going. I presumed that was the normal way to interact, rather than always going to the boss's office or presenting in a formal situation. (Nor am I sure that all the Bellcomm managers did it; maybe it was a quirk of the ex-pat Brits in the company.) In any case, it seemed normal and added a personal touch to interactions. They would comment on things on my desk or wall and I'd get the chance to discuss subjects I'd normally not raise in a formal environment. That they were genuinely interested in me as well as what I was working on was a big boost to me as a novice in the workplace. Their approach was not called MBWA in those days—it wasn't called anything until popularized by the management guru Tom Peters in the early eighties. (And I missed an early opportunity to become a rich management consultant myself.)

When I joined NASA's lunar program in 1972, I was struck by the fact that MBWA was not the norm. I generally didn't see my boss or boss's boss except at meetings or when I was called to his office. However, when I became associate administrator for Space Science in 1974, I started to use the practice myself, enjoying the opportunity to break out of my confines and go to a person's office

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either for a one-on-one meeting or simply to drop in and chat about what they were doing. I was struck (retrospectively, as I don't recall ever thinking about it as a technique) that the informality of such encounters increased interaction and information transfer. In contrast, being called to the boss's office can create a stiffness that inhibits effective conversation; the setting lends itself more to monologue than dialogue.

Of course there are exceptions. In 1972 Rocco Petrone, Apollo program director, called me into his office to talk about science on the Apollo missions. Our thirty-minute meeting extended to three hours as Rocco—interrupted by short phone calls with Jim McDivitt about lunar module problems—philosophized about the impact of space science, especially astronomy, on civilization and asked me more questions than I had answers to.

In stark contrast, Rocco could be a tyrant in the formal meetings. On one occasion he demanded I tell him if it was a Phillips-head or a straight-head screw in the box under discussion. I annoyingly responded, "How the hell would I know?" Years later I deduced that this was Rocco's technique for getting you to the point where you'd best say, "I don't know," rather than try to fake it and was part of his "pay attention to detail" mentality. This is not your typical MBWA story, of course, but it demonstrates that talking one on one abrogates the need to playact for the audience. And the fact that nobody is writing up what is said makes it possible to say more. But usually meeting on neutral ground or in the other fellow's environment is best, getting away from the intimidation factor of the boss's office and the desk separating the two of you.

After developing an eye twitch at HQ, I left NASA in 1979 for a new career as director of the Smithsonian National Air and Space Museum. I didn't know a thing about what a museum director does and didn't immediately have to, as the staff was skilled and good. It was an unbelievably different environment from NASA, however. Instead of focusing on making viewgraphs (they really were in those days), writing Congressional testimony, or worrying about the launch of Solar Max, my challenge at the museum was to focus on the next 100 years and work with the staff to ensure an ongoing orderly mix of permanent and evolving exhibits. There is no better way than using the MBWA technique to find out what people really do.

Coming in early (not to get more work done, but to avoid Washington traffic) I'd get to talk with the people who made the museum tick: the security folks and the janitorial staff. Security had the essential job of protecting exhibits and the public, all the while being pleasant to the visitors. Janitors made the museum hum, cleaning it thoroughly after closing and before opening the next day. Clearly, the importance pyramid was upside down relative to the organizational one.

I stumbled upon another MBWA technique that I'd like to be able to say was deliberate and skillfully planned, but it wasn't. One very snowy evening I decided not to go home but to camp out in the museum. This was an eye-opening occasion to talk with the folks and see, for example, how they got that damnable chewing gum off the carpets (hit it with a burst of liquid nitrogen and off it pops) and the meticulous care given to sprucing the place up before the morning opening.

Three years later I was privileged to become director of Goddard Space Flight Center. Goddard was, and is, an immense organization of more than 3,000 dedicated and capable civil servants and many thousands of contractors. When information flows up through four or five layers of management, you don't know what really goes on. Every layer filters information in one way or another. So, break out the MBWA. For half an hour once a week or so, I would wander into a building and office at random and chat with the occupant. Initially, some of the directors were nervous and would try to intercept me. (I never deciphered their early-warning system.) When they found out I was really harmless, they stopped and let me do my thing, including having breakfast meetings with their immediate reports. Lesson learned: the success of MBWA is based wholly on trust, without which you are in reality a spy.

As at the museum, I spent a night at Goddard during a large snowstorm (who in his right mind would travel the Beltway in a big storm?), riding for hours in the cab of a snowplow and seeing what an incredible art it is to plow without boxing yourself into a corner of the parking lot. Those folks had the lots cleared by midnight and I found out that plowing is above my pay grade.

MBWA can be especially useful in gaining insight into major issues that are bothering folks and that would not normally be evident. This was brought home to me when I queried a manager as to why we were having so many issues with HQ and another center. Our informal chatter soon led to his telling me that he was dealing with extreme problems at home. Clearly that was affecting his ability to function well at work. This helped me devise a graceful way to reassign him, removing management pressures and enabling him to devote more time to family matters. This was not a one-time occurrence. During my career I found numerous instances of nonwork issues being a root cause of management problems; developing a sensitivity to this can often help to resolve those problems.

There is a fantastic multiplier effect of MBWA. Word gets around rapidly and, if you listen to the stories, you'd believe that I spent my full time doing it. It also had an interesting reverse effect at Goddard: people felt comfortable coming unannounced to my office to get some tidbit off their chest. It also led in part to managers writing more openly in the Goddard Weekly Report, which, largely unencumbered by protective editing, grew to fifty or sixty pages.

After an abortive return to HQ in 1987, I joined Martin Marietta at their headquarters in Bethesda, Maryland, transferring to Denver two years later. Here I was fortunate to associate with Norm Augustine and yearn for a gene transplant. Norm is a most unusual leader with, in addition to superb technical abilities, an incredible talent for gauging an audience, using pointed humor and incredible speech skills. Norm uses "management by thinking around" and leaves the listener mesmerized by his superb knowledge and logic.

I continued using MBWA in Denver and found a downside. I thought I knew what was going on in my organization. I did not. The traumatic failures of the two 1998 Mars Surveyor missions left me wondering how I could have missed or ignored so many signs of a fatally stressed project. Indeed, in my conversations with folks working the project, I did not pick up on the individual stress that many felt. They put on a "can-do" face: after all, isn't the impossible and challenging "what we do?" That issue came up in the failure review in a pointed exchange between two highly regarded senior members: one said he wants a "can-do" team, the other questioned the wisdom of unmitigated "can do." Yes, it is a balancing act, but we were way off center.

Clearly MBWA gives the practitioner insights not obtainable in any other way. MBWA has the corollary benefit of letting you get to know your people as people, not technical automatons, and letting them know you value them as people. The bafflement is why so many managers do not practice MBWA. *Caveat emptor:* MBWA is not a cure-all. As is true of any individual management tool, it must be augmented and complemented by a host of other proven techniques. But it can tell you things that you as a manager need to know and can't learn by reading reports or hibernating in your office. ●

WHEN INFORMATION FLOWS UP THROUGH FOUR OR FIVE LAYERS OF MANAGEMENT, YOU DON'T KNOW WHAT REALLY GOES ON. EVERY LAYER FILTERS INFORMATION IN ONE WAY OR ANOTHER. SO, BREAK OUT THE MBWA.

NOEL W. HINNERS consults for NASA, the aerospace industry, and 4-D Systems, which supports the NASA Academy of Program/Project and Engineering Leadership. He currently serves on the executive committee of NASA's Mars Exploration Program Analysis Group and chairs the External Advisory Board of the University of Colorado Aerospace Engineering Sciences Department.

Balancing Security and Knowledge Sharing

BY RYAN AVERBECK, JOHN DAY, AND G. A. GADDY

The Fall 2007 issue of *ASK Magazine* generated a lot of discussion among those of us involved in the NASA Exploration Systems Mission Directorate (ESMD) Technology Protection Program. William Gerstenmaier's "On a Need-Not-to-Know Basis" made us ponder the overwhelming, ubiquitous onslaught of information that constantly bombards the NASA family. As he stated:

> During a single week in October 2006, the NASA Headquarters e-mail servers delivered approximately 1.25 million e-mails. With roughly 1,000 people at Headquarters, this works out to 1,250 messages per person. The nasa.gov domain has approximately two million distinct Web pages residing on its servers. This yields roughly thirty-two Web pages for every civil servant and contractor in the NASA family.

Viewed from an information-overload perspective, this shows just how much NASA information is exchanged, transferred, and requested on a daily basis. These same facts, viewed from a slightly different perspective, raise another question: How much of the information in this flood should in fact be protected? NASA, the world's premier space agency, often leads advances in space-related sciences and engineering. If NASA were a commercial entity, the knowledge possessed by civilians and contractors could be called proprietary information; in certain instances it would manifest itself as intellectual property, with the ownership rights that term implies. Thought of in this manner, the intellectual property is knowledge that gives NASA a competitive advantage in space sciences, engineering, and exploration.

NASA has a deservedly proud fifty-year history of sharing innovation at an astonishing rate. The National Aeronautics and Space Act of 1958, as amended, calls for "… the widest practicable and appropriate dissemination of information concerning its [NASA's] activities and the results thereof …." This same Act, though, also requires NASA scientists and engineers to

> … contribute materially to:
>
> The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;
>
> The preservation of the United States' preeminent position in aeronautics and space through research and technology development related to associated manufacturing processes …

The balancing act between sharing information and protecting it is further complicated by the 2006 National Space Policy, which states that space capabilities are vital to the nation's interests and the United States will "take those actions necessary to protect its space capabilities." Many of the requests for information that come to NASA come from foreigners.

To contribute to this balancing act, NASA's ESMD developed a Technology Protection Program and has devoted time and effort tailoring the program to specifically address NASA needs, charter requirements, and national strategies compatible with the current global environment.

To help mitigate the challenges associated with the establishment of the Technology Protection Program, ESMD enlisted our services to form the core of the Mission Critical Information (MCI) assessment team. The MCI assessment team is the “nervous system” of the ESMD Technology Protection Program. Ryan Averbeck’s technology protection experience related to the Department of Defense and commercial sectors comes from an extensive background as a counterintelligence agent and service as an assistant director at the Army Research and Technology Protection Center (ARTPC). John Day is a board-certified security management professional and has extensive experience implementing security programs at NASA. G. A. Gaddy brings extensive experience and insight as a Department of Defense scientist, former National Academies of Science National Research Council postdoctoral fellow at Langley Research Center, and a senior technology protection engineer at the ARTPC. The team’s experience proved critical in the development of the Technology Protection Program processes. Our varied backgrounds and experiences provided a multidiscipline foundation for NASA to develop and implement a unique, customized Technology Protection Program.

The ESMD Technology Protection Program process requires the impartial MCI assessment team to review and evaluate all pertinent technical aspects and documentation related to the research, components, systems, elements, projects, and programs under consideration. The team’s analysis includes, but is not limited to, the daunting task of horizontal cross-referencing. This involves referencing technologies against the Militarily Critical Technologies List, the Developing Science and Technologies List, the export control criteria from the Department of State, and other sources. The MCI assessment team also conducts analysis to determine if research or technology under development is “state of the world” versus “state of the art,” and revolutionary versus evolutionary.

For example, if NASA were developing a Pentium 4 processor and the rest of the world possessed Pentium 3 processors, the technology could be considered evolutionary in nature, since Moore’s Law would lead us to believe the rest of the world would catch up with a Pentium 4 of their own in relatively short order. In this instance, the Pentium 3 processors are state-of-the-world technology, and the Pentium 4 is not a large enough order of magnitude improvement to be revolutionary or state of the art. If NASA were developing a Pentium 4 processor while the rest of the world possessed Commodore 64 processors, this technology would then be revolutionary since it represents orders of magnitude improvement.

After conducting technical discussions with NASA and contractor subject-matter experts, the MCI team presents its findings and recommendations to NASA management for an MCI determination decision. If information is designated mission critical, the team then works with NASA management and Technology Protection Program personnel to develop the appropriate procedures to protect it. Protection does not necessarily mean the information or technology cannot be shared or disclosed. In most cases, it provides the foundation for NASA management to make informed decisions regarding appropriate dissemination.

An MCI designation is not necessarily permanent. For example, during a recent assessment, a particular set of test results was deemed MCI by NASA management. This determination was largely based on the active steps a foreign entity was taking to obtain the information. When an acquisition decision was later made by NASA management to pursue another engineering solution, the MCI was no longer of great value to NASA or the foreign entity, so the Agency removed the mission-critical designation from the test results.

In light of the information overload problem described by Gerstenmaier, the Technology Protection Program assists in identifying and protecting NASA’s information from unauthorized release or inadvertent disclosure. The team helps the NASA family understand and mitigate a multitude of concerns:

WITHIN THE SECURITY AND PROTECTION DISCIPLINES, ONE AXIOM ALWAYS HOLDS TRUE: THE BEST COUNTERMEASURE TO THREATS IS AN EDUCATED AND ENGAGED WORKFORCE.

- How much of NASA-controlled information is inadvertently released outside approved channels because employees are overwhelmed by volumes of information?
- How well-trained and equipped is NASA to "know" what would require protection? We are currently charged with protecting several categories of information such as export controlled, contractor proprietary, sensitive but unclassified, classified (such as confidential, secret, and top secret) information, and the recently codified MCI, just to name a few.
- Does the NASA team (civilians and contractors) understand the nature and capabilities of those that wish to obtain our controlled information via nefarious means or by simply exploiting our information overload? When was the last time employees requested or received a threat briefing from NASA counterintelligence?
- Are we adequately prepared and staffed as an agency to review thousands of pages of information to determine what should receive protection?
- What are the benefits and ramifications of controlling versus sharing critical NASA information?

The Technology Protection Program helps streamline information dissemination by giving the NASA workforce guidance on the limits of sharing particular information. Identifying the specific information that requires protection makes information sharing easier and clearer. One of the major factors in the success of the NASA technology-protection model is the MCI team's understanding of programs' cost, schedule, and performance drivers. The entire technology-protection team respects NASA's mission, history, and culture and works hard to minimize the impact of these essential security measures on programs. The program explains why particular information is of extreme value to the Agency and the nation and should not be shared outside established protocols. Within the security and protection disciplines, one axiom always holds true: the best countermeasure to threats is an educated and engaged workforce.

To promote education and awareness of the Technology Protection Program, the team participates in meetings, including project control boards, quarterly conferences, and the PM Challenge. The team also provides tailored briefings to project element scientists, engineers, and management. The team and NASA strive to put programs and projects in direct control of their technology-protection activities. ●

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Unmanning the Fire Lines

BY BRENT COBLEIGH

Ikhana flies a test mission with the Autonomous Modular Sensor mounted in a pod under the left wing. Ikhana is a Choctaw Native American word for intelligent, conscious, or aware.

Photo Credit: NASA/Jim Ross

Ikhana piloting, system management, and FAA coordination were accomplished by the Dryden team members in the ground control station alongside the Ames team members, who monitored the AMS systems and wildfire imagery collection.

On October 18, 2007, I received an e-mail from Thomas Zajkowski, remote-sensing analyst for the USDA Forest Service's Remote-Sensing Application Center. It read, "Does Ikhana still have its wings? There are two 'high-risk days' (October 21–22) due to winds for the South Central Mountains and the Southern Mountains. If we do get a fire start, could we support it with a 20- to 24-hour mission?"

A red-flag warning had been issued by the United States National Weather Service, informing area firefighting and land management agencies that conditions were ideal for wildfire ignition and propagation in the Southern California area.

During the prior year, the Ikhana team at Dryden Flight Research Center had run a marathon that started with the delivery of the unmanned science aircraft from the manufacturer, General Atomics Aeronautical Systems Inc., and culminated in the highly successful Western States Fire Mission. That mission demonstrated the advantages of using a long-duration unmanned aircraft system outfitted with an advanced infrared sensor to image wildfires in the western United States. We had met all the objectives and had already started aircraft modifications for the next experiment. So my response to Tom's e-mail said, "Sorry guys—we held out as long as we could. We started grinding the paint and bondo channel along the wing this morning for the Fiber Optic Wing-Shaped Sensing System [an aeronautics experiment]. We won't be able to reconfigure to the fire mission."

That weekend, wind-driven wildfires erupted all over Southern California, causing an initial evacuation of more than 500,000 people. Up to that point, our missions had been technology demonstrations, but the ongoing disaster put the project team members, our careful operational planning, and cutting-edge wildfire imaging technology to the test.

Developing Ikhana

Ikhana was a Predator-B aircraft that Dryden acquired to conduct remote-sensing Earth science studies and demonstrate new aeronautics technologies. For its first mission, Ikhana had been outfitted with the Ames Research Center–developed Autonomous Modular Sensor (AMS), an infrared line scanner that could see through the smoke of a wildfire to thermally image the hottest part of the fire's front line and the warm embers left in the fire's wake, and quickly deliver that imagery in a useful format to firefighters.

The Western States Fire Mission was initiated by Dr. Vince Ambrosia from Ames. Vince, together with Everett Hinkley from the United States Department of Agriculture (USDA) Forest Service, brought together a team that included the National Interagency Fire Center, USDA Forest Service, Bureau of Land Management, and other government agencies responsible for combating and managing wildfires across the nation. These wildfire experts helped develop the requirements for the Western States Fire Mission and also served as the project's stakeholders and customers. Vince's vision was to bring the latest technologies together to increase the situational awareness of the frontline fire commanders in order to increase the safety of the fire crews and better allocate resources to the firefighting effort.

Vince's team at Ames focused their efforts in three main technology areas. The first was an advanced infrared line scanner capable of seeing through smoke and measuring the temperature on the ground with a resolution less than 1 degree. The system also included an onboard, real-time geo-rectification algorithm that combined the aircraft's position and orientation to align the measured imagery with a three-dimensional terrain map. The

Photo courtesy Brent Cobleigh

second technology was a Collaborative Decision Environment that allowed fire command teams to rapidly overlay the measured infrared imagery, weather information, satellite data, and other information onto a Google Earth 3–D terrain map. The third technology focused on how to get the autonomously corrected imagery from the unmanned aircraft to the fire command teams in the shortest possible time, ideally less than ten minutes. Up to now, wildfire incident command teams had to wait until the imaging aircraft completed its mission before the imagery could be transmitted.

In parallel with the Ames work, our team at Dryden focused on establishing the initial Ikhana flight operations and planning an unprecedented set of unmanned aircraft flight operations. The Dryden team had to complete the development of a mobile command center that integrated the pilot station with research-monitoring stations, satellite antenna systems, and fiber-optically connected command antennas near the runway. Several aircraft modifications were also required, including the integration of the under-wing AMS sensor pod, installation of instrumentation, and wiring systems.

The Western States Fire Missions challenged the Dryden team to accomplish something that had never been done before: high-altitude (20,000+ ft.), long-duration (twenty hours or more), unmanned aircraft operations in the national airspace (airspace that is not segregated for military use), covering the entire western United States from the Pacific Ocean to Colorado and from the Mexican border to the Canadian border. We needed to be prepared to launch a mission to wherever the highest-priority wildfires might be located and do it within the national airspace, where regulations on how to safely operate unmanned aircraft have yet to be written.

Through previous work with less-ambitious unmanned aircraft operations, the Dryden team had some experience—not all of it the good kind—that informed us what risk mitigation we needed to please the Federal Aviation Administration (FAA) and our own Dryden Airworthiness and Flight Safety Review Board. We developed a fault tree to identify all the possible contributors to a loss of life, either in the air or on the ground, and used that information to focus our risk-mitigation strategies.

In order to protect the public on the ground and the aircraft itself, the project identified more than 300 potential sites where Ikhana could divert in the event an emergency landing was required. The FAA restricted us from performing an emergency landing with Ikhana at public airports, so the project team

WE NEEDED TO BE PREPARED TO LAUNCH A MISSION TO WHEREVER THE HIGHEST-PRIORITY WILDFIRES MIGHT BE LOCATED AND DO IT WITHIN THE NATIONAL AIRSPACE, WHERE REGULATIONS ON HOW TO SAFELY OPERATE UNMANNED AIRCRAFT HAVE YET TO BE WRITTEN.

identified abandoned runways, dry lakebeds, farm fields, and, in some cases, remote terrain to either land the aircraft or crash it safely away from the public. A book containing satellite photos of the 300 sites along with important information on the quality of the site was compiled and kept in the mission control center during all flights. The Dryden range safety office carefully defined the moderate to heavy population centers in the western United States that were declared no-fly zones during

Imagery of the Santiago fire in the mountains of Orange County is draped over a 3 D Google Earth terrain map showing the active fire (yellow), previously burned areas (red), and unburned areas (green).

Image Credit: NASA

FROM DAY ONE, EVERY MEMBER OF THE MULTIAGENCY TEAM HAD THE SAME GOAL: DEMONSTRATING THE UTILITY OF A LONG-DURATION UNMANNED AIRCRAFT SYSTEM OUTFITTED WITH AN ADVANCED INFRARED IMAGER ON THE MANAGEMENT OF WILDFIRES.

the missions. The project team also increased the number of batteries in the aircraft to allow up to three hours of flight time in case of an electrical system failure. In most situations, this would give Ikhana enough time to come back to Dryden or divert to one of two military fields that had agreed to allow emergency landings. The team also developed a moving map display that overlaid Ikhana's position and satellite weather information on traditional aviation navigation maps so the pilots would have sufficient information to manage the mission.

The Dryden operations team worked closely with the FAA's Unmanned Aircraft Systems Program Office and air traffic controllers from all affected areas to come up with acceptable mission plans that culminated in the issuance of a Certificate of Authorization (COA) that permitted these unmanned aircraft operations in the national airspace. With the COA in hand, the multiagency Western States Fire Mission team was able to complete four long-duration wildfire-mapping missions in August and September 2007.

After significant air traffic control rerouting around dangerous thunderstorms over Nevada, the second flight mapped wildfires as far from Dryden as Idaho, Montana, and Wyoming. The longest mission lasted twenty hours and covered more than 3,200 miles. Along the route, Ikhana conducted high-resolution infrared mapping of up to eleven wildfires, passing the position-corrected imagery to fire commanders within minutes of acquisition. Our USDA Forest Service partners sent experts to some of the incident commands to help interpret the advanced imagery and instruct them on the use of the Collaborative Decision Environment.

The response from the fire commanders on the ground was immediate. The imagery was extremely useful for both strategic and tactical deployment of resources to combat the wildfires. In one case the incident commander credited the near real-time imagery with stopping the deployment of firefighters to a dangerous position between the massive Zaca fire and a secondary fire that was to that point unknown due to the rough mountainous terrain and the smoke. In another case, the imagery uncovered an unknown fire front (8 miles long) that was headed toward the town of Ojai. They immediately dispatched a team to light an 8-mile-long backfire to intercept the new fire. The Ventura County fire chief was emphatic that we had a great tool.

After the September 27 mission, Vince declared the Western States Fire Mission complete, having met or surpassed all its objectives. Over the next three weeks, the multiagency team reviewed data and caught up on well-deserved sleep. Back at Dryden, we began Ikhana modifications for the next flight experiment.

Responding to the Crisis

On Monday, October 23, it became clear that Ikhana needed to respond to the Southern California wildfire emergency, and I pulled together a team to identify and implement a quick method to patch the wing modifications that had been started. Simultaneously, Vince and Everett spun up the Ames and Forest Service teams and began deploying them to Southern California. The FAA quickly granted us an emergency extension to our COA that allowed us to fly within 10 miles of the Mexican border. By midday, we received a request from the California Governor's Office of Emergency Services to use Ikhana for airborne wildfire imagery. A day later, after fixing a failed hard drive in the AMS imager, Ikhana took off for a nine-hour mission that imaged ten major wildfires across five counties. We continued to follow our range safety rules by flying up to, but not over, the populated area boundaries. We relied on the AMS sensor's capabilities to image 3 miles to the sides of the aircraft, allowing us to collect imagery where the wildfire had traveled through canyons and into neighborhoods.

Over five days, Ikhana flew a total of four nine-hour flights. These missions imaged wildfires that surrounded the highly populated areas of the Los Angeles basin and multiple areas surrounding San Diego. Near real-time imagery and

Image Credit: NASA

Ikhana flight paths flown during the four 2007 Western States Fire Missions.

streaming video was delivered through the aircraft's satellite link to wildfire incident commanders, the California Emergency Operations Center, Air Force Northern Command, and the Federal Emergency Management Agency (which also paid for several of the flights). Close cooperation with these agencies resulted in changes to imaging priorities while Ikhana was in flight. The cooperation and coordination with FAA to make these flights occur was outstanding. Because of a declared state of emergency, air traffic control gave Ikhana flight priority in the congested Southern California airspace.

The 2007 Western States Fire Missions received multiple NASA Group Achievement Awards and the Association of Unmanned Vehicle Systems International's Operations Award. From my perspective, the success of the project was due to many factors. The first was the decision to build a strong and lasting partnership between the technology developers (NASA) and the technology users (USDA Forest Service, Bureau of Land Management, and others). This partnership was as strong during the requirements phase as during the operations phase.

The second success factor was pulling together organizations with expertise in each of the disciplines required by the project and giving each full responsibility for their contribution. The Ames team focused on the wildfire sensor system, automated data processing, networking, and mission priorities. The Dryden team led the aircraft integration, flight operations (with help from General Atomics), and mission safety. The Forest Service focused on the prioritization of the wildfire resources, the needs of fire incident commanders, and interpretation of the imagery.

The third factor was keeping the entire team focused on the goal. From day one, every member of the multiagency team had the same goal: demonstrating the utility of a long-duration unmanned aircraft system outfitted with an advanced infrared imager on the management of wildfires. Staying focused on this goal helped strip away the "nice to haves" from the absolute requirements. The project team would have prized additional science sensors on the aircraft, improved Collaborative Decision Environment capabilities, or added flexibility in the FAA-approved mission plans, but not at the expense of taking imagery of snow-covered mountains (as we often joked) because we were six months late for the fire season.

I look back at the Western States Fire Missions as one of the highlights of my career, not just because of the project's successes, but also due to the chance to work with some of the most talented and dedicated public servants. ●

BRENT COBLEIGH was the project manager for the Ikhana unmanned aircraft system, from procurement through initial flight operations. He currently serves as the Exploration Mission Director at Dryden Flight Research Center.

INTERVIEW WITH

Alexander Laufer

BY DON COHEN

Dr. Alexander Laufer is professor of civil engineering at the Technion (Israel Institute of Technology) and director of the Center for Project Leadership at Columbia University. His books include the recently published *Breaking the Code of Project Management*. He is also the former editor-in-chief of *ASK*. Don Cohen spoke with him at the College of Engineering at Columbia.

COHEN: **How would you sum up the central idea of your new book?**

LAUFER: The key is that projects must be led, not just managed. We need both leadership and management, but right now the prevailing paradigm is that projects are managed—that planning and control can solve all the problems. My studies have shown me again and again that the best projects are first of all led and then managed, or led in order to be manageable.

COHEN: **How do you define leadership?**

LAUFER: Leadership is necessary to create change. Project leadership is primarily about challenging the status quo. Because of the dynamic environment they exist in, projects are plagued with many problems. Many of them are what Ronald Heifetz would call technical problems that one can solve with a set of rules, or with available technology. But more than a few are what he calls "adaptive problems"—problems that are not well-defined and cannot be solved with a set of rules.

The current repertoire of responses is inadequate. Solving adaptive problems requires learning—at times difficult learning—and often requires changing work patterns as well as other kinds of innovation. To meet these adaptive challenges, the project manager must adjust the plans and practices or sometimes even shape the project environment. And he or she has to do it with a group of people who usually don't have much experience working together, who have different skills, functions, cultures, and interests.

> "I LEARNED **the hard way** THAT THE ON-SITE PRACTITIONERS KNEW BETTER AND **did not rush to prepare** DETAILED PLANS TOO SOON, WHEN **information is still missing** AND CHANGING."

Finding a solution to adaptive problems with a group doing a unique and innovative task in a dynamic environment by challenging the status quo requires leadership. The project leader doesn't want to challenge the status quo every day. People are not used to adapting every day, so the leader needs to be selective. But in our dynamic environment, every once in a while it is necessary. Solving these adaptive problems renders the rest of the project manageable, and this is indeed what allows the leader to apply standard project management practices. The importance of both leadership and management to the success of the project is the theme of two Forums on Leadership being held this summer at NASA HQ in Washington, D.C., and at Columbia University in New York City.

COHEN: Can you give me an example of a project leader challenging the status quo?

LAUFER: There's a story in *Shared Voyage* [written with Ed Hoffman and Todd Post]. When Terry Little from the U.S. Air Force was given a project because the previous project manager was released, the key requirement was to finish all the preparation needed to be able to assign the contract to two of the five contending contractors as soon as possible. Little told his team that they should be ready in six months. He explained later that he could have chosen seven or eight months, but he wanted them to work differently—not just harder or faster. He wanted them to learn to do things differently. He challenged the entire team to let go of the status quo. Another example: Joan Salute from NASA managed a project to study the effect of reentry on experimental materials. The air force wanted to restrict the use of the findings of her mission, but she said no, and eventually she prevailed. People in her community didn't like it, but she said, "I own the mission. This is my work, and this is what I will do. I'm working for the science community." She challenged the status quo.

COHEN: As you say, that's not the kind of thing you can do every day.

LAUFER: Which brings us to something else that unfortunately is not well addressed in our literature: the need to exercise judgment. Judgment can be improved through experience. Better judgment in the context of adaptive problems is often improved by being exposed to a variety of challenging experiences, and by reflecting on these experiences while paying attention to the unique contexts surrounding them.

COHEN: Does the drive for efficiency get in the way of reflection?

LAUFER: This is the common perception. However, one must achieve both efficiency and effectiveness. In stable conditions and in the short run, efficiency should be stressed. As uncertainty increases and the time horizon becomes longer, other dimensions, like impact on the customer and business success, become more important. The need to find the right balance between the various dimensions requires reflection.

COHEN: Your interest in leadership, adaptation, and judgment is quite different from project theories that emphasize control.

LAUFER: Most of our current theories were developed primarily by engineers almost half a century ago and have not been updated significantly. In recent years, we are witnessing an earnest quest for a new paradigm, and many theoretical articles are being published on this subject. We are beginning to see experts from other disciplines—business, management, organizational behavior—becoming involved in research on projects. I believe that soon enough, especially once researchers focus more on empirical studies of actual projects and less on developing models based on the old paradigm, we will see some useful changes that will also stress the need for adaptive leadership.

COHEN: How did you arrive at your ideas about projects?

LAUFER: Most of my ideas are based on learning directly from practitioners, usually from the best of them, and these findings were always tested and refined by feedback received in my consulting work. This mode of research started through some disturbing observations early in my career as a researcher. I was a typical civil engineer. I spent seven years in the military working as a structural engineer and a project manager of construction projects. Then I came to Austin, to the University of Texas, to do my PhD in construction management. I taught for a couple of years at Texas A&M. When my wife and I went back to Israel, I went to work for a construction company, but I had caught the research bug, so I joined the Technion in Haifa but continued to teach and do research during the summers in the states.

Based on my construction experience and my teaching at Texas A&M, I found that something didn't click. I didn't understand, for example, why my graduate students who were applying various industrial engineering techniques to improve productivity on site would come at the end of the semester bragging about the detailed construction plans they created, something I thought should have been already prepared by the construction people themselves at the beginning of construction. I learned the hard way that the on-site practitioners knew better and did not rush to prepare detailed plans too soon, when information is still missing and changing. Similar incidents later on convinced me to start working closely with practitioners, and I quickly learned to reverse the question I used to ask. Instead of, "Why don't practitioners use what researchers know?" I began to ask, "Why don't researchers use what practitioners know?"

Later, I was invited to be a consultant for Procter and Gamble for three years. I came to share my new planning concepts, to change the mind-sets of project managers at P&G. But I found that it's very difficult to do that. I also found that the best project managers there already applied my new concepts without always being able to explicitly describe them. I decided my life would be easier if I could capture their stories and share them with the rest of the community. We captured seventy stories of thirty-six project managers within Procter and Gamble, and in 1994 we published them in a book. The surprising thing is that these stories are still read and shared within P&G.

COHEN: Trying to convince people with stories is more effective than frameworks and theories?

LAUFER: Absolutely. Often you can try to influence and persuade people with an argument until you are blue in the face, but stories capture people's attention. Stories can convey complex messages in an easily digestible form, making them easier to remember while also stimulating curiosity and inducing reflection. I learned later on, especially through my extensive collaborative work with Ed Hoffman, that people change their minds based on action and reflection, and stories are an excellent trigger for reflection.

COHEN: Over the years that you've observed projects, have you seen a shift in how they are carried out?

LAUFER: Yes, but not a sufficient one. People are much more results-oriented. They don't necessarily use the right tools or theories, but I see a lot of pressure for deliverables. I also see a great deal of interest in trust and in the unique context of each project, but still not in a well-organized fashion. Experienced people are aware of the limitations of planning tools; only the beginners are not. Unfortunately, for the moment they have nothing better. In software development, on the other hand, the agile movement is offering very innovative and practical approaches.

COHEN: What needs to be done to generate a sufficient shift in the way projects are done?

LAUFER: I believe there are a couple of things that should be done. Schools and universities should do empirical studies of real projects rather than just focus on theories and tools. They need to come up with paradigms that have to do more with practice and experience. We are all influenced by paradigms; a powerful article by Sumantra Ghoshal describes how bad theories kill good practices. I think this happens in project management as well, so we need better theories. Business schools in general, and especially in this country, do not have a project management function. The field of project management can be found in operations or organizational behavior or in management, but most business schools do not have a full-time faculty member focusing on project management. We also need executives to pay more attention to project management.

COHEN: In what ways?

LAUFER: In selecting and developing project managers, in fostering a learning environment and embracing a new culture. I think it will happen one way or another because the world is becoming even more volatile, unpredictable, and chaotic, and the competition is going to be even tougher. People will have to produce more innovative products faster and cheaper. They will have to get beyond simple planning and control. It's just a question of how fast, and which country, industry, and organizations will gain a competitive advantage by being the first.

COHEN: Do you see people in projects thinking consciously about the knowledge they need?

LAUFER: Many people related to projects are keen to learn because they are aware that the context of each project is different, and they can enrich their own arsenal. I saw tremendous openness to learning at Procter and Gamble and NASA—people listening to case studies, analyses of projects, and stories because they realized that this is what they need. People craved coming to the two and a half days held twice a year [at Masters Forums] because they wanted to know how things were done at other centers and in the air force or navy. They felt hunger for this kind of knowledge—not so much general "lessons learned," but knowledge about specific projects and their context as presented to them by their peers.

COHEN: Are you suggesting that this knowledge is different—maybe less easily definable—than typical lessons learned?

LAUFER: Lessons learned in science and engineering are important and can be easily generalized. But if you take a typical list of fifty project management lessons and attempt to apply them to your specific project, you may find that twenty-five of them contradict the other twenty-five. In management, including project management, most lessons are not universal. It all depends on the context, so you want to learn the lessons within their specific context and then adjust them to your own project context.

COHEN: Let's talk a little about geographically distributed projects. Can people work successfully together virtually?

LAUFER: Don Margolies of NASA said, "Location, location, location." Goddard

“IN MANAGEMENT, INCLUDING PROJECT MANAGEMENT, most lessons are not universal. IT ALL DEPENDS on the context, SO YOU WANT TO LEARN THE LESSONS WITHIN THEIR SPECIFIC CONTEXT AND THEN adjust them to your own project context.”

and Johns Hopkins are twenty minutes apart. He said the fact that we could drive over there or they could come to us and meet face to face was gold. Many projects are done internationally and you cannot drag people all over the world, but meeting at the beginning of the project to establish trust and acquaintance is crucial. When you pick up the phone to talk to your good friend that you established trust with in the army, there is no need to be there. Some companies are very much aware of this. Early on, at the planning stage, the entire team of sixty or seventy people will be located at the client’s headquarters. When the project moves to the design stage, the entire team will be moved together to the designer’s location. They understand the significance of teamwork and trust, which is most naturally developed by being together.

COHEN: Many companies don’t want to spend the money to meet and think they can do everything virtually.

LAUFER: Nowadays, requirements are still shifting when projects start; the projects suffer from change and uncertainty throughout their life. We need to exchange information with the other party as soon as possible, as freely as possible, and as fully as possible. This happens only when trust is high. You cannot establish trust virtually. You can work virtually throughout the project once you establish it. But trust does not last forever; you have to maintain it by meeting periodically.

COHEN: John Seely Brown has described the purpose of those periodic meetings as “recalibrating.”

LAUFER: Indeed. In our current dynamic environment, projects suffer from a wide variety of changes; therefore, even a trusting team must “recalibrate” periodically to sustain teamwork.

COHEN: What do you see as NASA’s project strengths and weaknesses?

LAUFER: NASA has some of the best people. NASA has the advantage of having the coolest projects on Earth, which attracts excellent people. On the other hand, I’d say that while some centers are very well advanced and foster a culture of trust, some are not. In my opinion, the biggest hurdle for applying these ideas of leadership and adaptation is a non-trust culture. Trust and distrust are self-fulfilling prophecies. If you behave to people with distrust, suddenly you both are sure that this is the only way to behave.

COHEN: What does NASA need to do to meet the current challenges of its ambitious projects?

LAUFER: At NASA I would invest in social capital because people come here for thirty years, so the return is huge. I would also try to decouple large projects into smaller ones so if something happened I could still continue, absorbing uncertainty. I would also try as much as possible to think about how I can use the project learning for innovations applied to industry. I wouldn't focus only on the long term. I would look for deliverables that could be produced in half a year or a year. I would almost force myself to come up with a list of innovations that can be delivered at the end of every year working together with private companies. I would force myself to look for small wins and not focus too much on something that may or may not be eventually pursued.

COHEN: At NASA and elsewhere there's a tension—maybe a necessary tension—between standard procedures and flexibility.

LAUFER: I am a strong believer in the need for written processes and procedures. Even unique operations like projects share many regular, repetitive patterns of action. These written procedures prevent reinventing the wheel, save time and energy, and contribute significantly to the parties' ability to maintain cooperation efficiently, even in the face of uncertainty. The procedure manuals in advanced organizations are often prepared by the most experienced practicing project managers in the company, not by staff people, and procedures are brief and simple, allowing for and even encouraging flexibility. Moreover, these manuals explicitly recognize that the procedures are not intended to cover all possible situations, but rather only the most common ones. In recent years, project managers at P&G, for example, have had the number of procedures markedly reduced from eighteen technical standards and thirty-two standard operating procedures to only four of each.

COHEN: Before we finish, would you sum up the elements of successful project management?

LAUFER: If I think about the new world of project management, I'd say it starts with ongoing learning. Such learning is the key to effective project planning when information is missing or constantly changing, as well as to reflection during and after the project. So learning is a constant theme. Second is judgment, which always must take into account the unique project context. Context is a key because, contrary to the old project management paradigm, there is no "one best way." Number three: trust. There is no success in projects without trust. Number four is being action-oriented, focused on doing, on the deliverable. I like to quote the Persian proverb: "Thinking well is wise; planning well is wiser; doing well is wisest and best of all." Number five, the riskiest one, is courage. It's not the same courage as on the field of battle; you're not going to die. But you may risk your esteem or your career. And you need the judgment to know when to challenge the status quo, while not risking the project just because you want to be heroic. Projects need leaders, not heroes. ●

A MODEL FOR

COLLABORATION

BY KRISZTINA HOLLY

Eight torodial magnets can be seen on the huge ATLAS detector with the calorimeter before it is moved into the middle of the detector. This calorimeter will measure the energies of particles produced when protons collide in the center of the detector.

Photo Credit: The ATLAS Experiment at CERN, atlas.ch

As a leader, imagine trying to manage more than 7,000 scientists from eighty-five countries around the world—with their own languages, cultures, and expertise—on a twenty-year collaboration to create the most complex system ever built.

Technicians mount power distribution cables onto a cylinder that houses nine disks with silicon sensors while assembling an endcap of the ATLAS silicon strip detector.

Now imagine the goal is to recreate the conditions existing a *billionth* of a second after the big bang. And none of the experts on your team will get personal credit for changing our fundamental understanding of the universe. And, by the way, you don't have control of anyone's paycheck.

It might seem like an impossible management situation. But that is exactly what is going on at the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) in Geneva, Switzerland.

The LHC has garnered some attention to date: a catastrophic accident delayed the experiments for a year, myths of black holes still plague the program, and the just-released movie *Angels and Demons* features a fictitious "antimatter bomb" from CERN. But these issues distract us from the real story.

Beyond the atom smashing, leaders have special reason to examine what is going on in Geneva. CERN's remarkable innovation culture is what makes their extraordinary advancements possible. Most importantly, we all can apply these same lessons to stimulate innovation in our own organizations, no matter how big or how small.

Collective Ownership

The LHC is a wonder to behold: a circular tunnel 27 km in length with four enormous detectors, 100 meters entirely below ground. The detector for one of the four experiments, called ATLAS, weighs as much as the Eiffel Tower, has about 20 million components, uses 3,000 km of cables and 1,000 km of piping, and requires some 5 million lines of computing code to run. The Compact Muon Solenoid (CMS) weighs twice as much, and "although it is the size of a cathedral," CERN officials explain, "it contains detectors as precise as Swiss watches."

The machine has shattered technological frontiers. The team has put together the largest supercomputer on Earth, which will crunch 15 petabytes of data every year using a grid of 100,000 processors around the world. They have built the world's most powerful magnets, pushed the limits on communication speeds for radiation-hard electronics, and built a silicon detector twice as large as anything else ever built before. They have developed new technologies in cryogenics, superconductivity, vacuum systems, heat dissipation, and so on.

One would assume that a project of this magnitude would require decisive, authoritative leadership; a clear-cut, top-down management hierarchy; and a culture of individual successes and proprietary approaches.

But there are no directors. No chairmen or presidents. No corner offices. In fact, the main building is cylindrical, with every office the same size. Instead of "chief scientist" or "CEO," the leader for each experiment is unassumingly called the "spokesperson." A "resource coordinator" tracks the allocation of money and people, which come from eighty-five different countries with almost as many languages and currencies.

PEOPLE DON'T FAIL, EXPERIMENTS DO. THE SCIENTIFIC METHOD VIEWS FAILURES AS LEARNING OPPORTUNITIES RATHER THAN CAUSES TO POINT FINGERS, AND THIS ATTITUDE PERVADES THE CULTURE AT CERN.

When I first visited him in his office, ATLAS's resource coordinator, Markus Nordberg, dropped the hefty four-inch-thick binder tracking the resource allocations on the desk between us. No question his responsibilities run deep. But instead of making all the decisions himself, he nurtures them through constant discussions with collaborators. Nevermind

Collaborators from the ATLAS experiment, the largest particle detector in the world, are seen in CERN s new building 40.

that he has an advanced degree in physics and a PhD in business administration, Markus humbly claims his role is to “stand like a shepherd behind the troops, who are the real experts.”

Later, I met Bob Cousins, deputy spokesperson for the CMS, who explained that the young and experienced alike are valued for their input: “People volunteer and say ‘I’ll do that’ for any task they think they can do.”

Perhaps it’s worth noting that the concept behind the LHC was born literally over a potluck lunch in 1984. Ubiquitous gathering spaces throughout CERN serve as giant “watercoolers” for ideas to be shared. There is a sense that anything is possible, it just needs to be imagined and agreed upon. (And there is no question that good European coffee and pastries help fuel the discussion!)

The leaders create the framework for people to share and contribute. Different perspectives are valued, and decisions are made with input from everyone. How does this happen? With weeklong summits, held three to four times a year; thousands of lesser meetings, which are optional and open to the public; and an online system that allows collaborators to browse agendas and watch presentations remotely. As a result, the best ideas can be advanced. This may seem like a lot of extra overhead, but the investment up front eliminates the costly issues that would surface later if team members were not on board. Everyone feels ownership and commitment to the project from the beginning.

Trust

The entire scientific community at CERN operates with an inherent and profound sense of trust. Trust in the process. Trust in their colleagues. Trust in the science.

This trust emerges from a mutual “code of ethics” built on a culture of reciprocity. Because their community is close-knit and their most valuable currency is reputation, experimental physicists around the world know who contributes. Conversely, the few who have been too proprietary with their ideas have been ostracized. It’s like a crowd-sourced performance review.

Notably, CERN promotes the “open access” movement in scientific publishing; anyone can access the results, which are posted to the CERN library site (library.web.cern.ch/library/Welcome.html).

Experimentation

People don’t fail, experiments do. The scientific method views failures as learning opportunities rather than causes to point fingers, and this attitude pervades the culture at CERN. Notably, after one of the supercooled magnets disastrously exploded last September and delayed the experiments for a year, the CERN scientists took a hard look and learned from the problem, but so far no one has been fired. This kind of environment is the foundation for risk-taking and innovation.

It may seem like there is no room for taking risks on a project of such great scale, but, in fact, the project has evolved through a well-organized yet organic process of experimentation and peer review.

CMS and ATLAS both needed to make several very fundamental design choices in the early 1990s, such as what technology to use for the magnets. But they did not make a decision, build it, and hope for the best fifteen years later. Failure at *that* level would definitely be disastrous. Instead, two or three teams for each experiment were given budgets to prototype different technologies in parallel. After numerous iterations, CMS and ATLAS made their final bets based on years of designing, building, testing—and, yes, sometimes failing. Notably, the scientists building and advocating for the other technologies are valued and most are still working on the LHC.

Shared Vision

Perhaps the most memorable takeaway from my visit to CERN is how the scientists seem unrelentingly driven and dedicated to the same goal. George Brandenburg, former director of the Harvard High Energy Physics Lab, moved from Cambridge to Geneva to see the ATLAS project come together. Over espresso,

A view inside the liquid argon calorimeter endcap.

Photo Credit: The ATLAS Experiment at CERN, atlas.ch

he mused that because so many scientists have contributed to the project, it will be very difficult for anyone on the team to win the Nobel Prize. But it doesn't seem to matter. Somehow thousands of experts manage to keep their egos in check and collaborate. No matter what happens, they all have a common yardstick to measure everything and make decisions: what is best for the physics. In business or any other endeavor, this would translate to having an ambitious yet attainable vision for the organization that is embraced by the grassroots and embodied by the leadership.

There is a risk here: that we all look at the "organism" called CERN and think we can't learn anything because it is such a unique place. They make it look so easy, as though the LHC runs itself. But taking a deeper look at its history and the personalities, we realize that it takes careful leadership to make it all work.

Of course, egos do clash and people have a hard time giving up their ideas at times. And there is spirited competition between ATLAS and CMS to be the first to discover the Higgs particle. But the leaders cleverly avoid wasting energy on trying to control everything; they instead focus on nurturing the right environment for innovation.

As I spoke with the scientists around CERN, I was struck by the palpable sense of wonder and humility about being part of one of the most significant advancements in scientific history. But I was also struck by how simple, yet revolutionary, their approach to innovation seems.

Simple enough that we could all try it. ●

Thank you to Markus Nordberg, Robert Cousins, and George Brandenburg, who contributed to this article. A shorter version of this piece originally appeared in Businessweek.com.

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Innovating to Fly in Cleaner Skies

BY KERRY ELLIS

Photo courtesy Pratt & Whitney

The Pratt & Whitney PurePower PW1000G engine was put through its paces during 250 hours of ground testing for component performance and acoustics conducted at Pratt & Whitney s advanced test facility in West Palm Beach, Fla.

Before my conversation with Alan Epstein, the new—and first—vice president of technology and environment at Pratt & Whitney, my only concern about my flight out of the country this summer was whether I'd board on time. Now I know that my air travel will be among the nearly 10 million flights taking off from U.S. airports this year, pushing out 2 billion metric tons of CO_2, consuming about 20 billion gallons of jet fuel, and roaring out 91 to 95 decibels of noise. With Boeing and Airbus predicting that air travel will continue to grow 4 to 5 percent per year for the next thirty years, it's no wonder Pratt & Whitney and the aviation industry as a whole are dedicated to finding more environmentally friendly ways to fly.

In the past the aviation industry has concerned itself with compliance and environmental regulations, such as meeting noise and nitrogen oxide emission standards required by the International Civil Aviation Organization. There are several regulations with which the industry must comply, but with climate change concerns—and the industry itself—growing steadily, the focus is shifting from mere compliance to actively pursuing environmental improvements. A large part of Pratt & Whitney's response to this challenge was the creation of Epstein's current position. "In previous decades, our predecessors in aviation thought you could negotiate environmental standards; they were secondary. The environment is now nonnegotiable, and it's very clear the environment is as important as safety," said Epstein.

One of the ways Pratt & Whitney is making environmental safety a priority is in the development of its new PurePower PW1000G engine, which uses an innovative geared turbofan the company says will reduce noise, fuel consumption, and CO_2 emissions. Jet engines rely on a fan to pull air into a combustion chamber, where it ignites with fuel before it's pushed through a turbine to create thrust. Fans and turbines perform better at different speeds, but in existing engines the two are connected by a shaft, forcing them to turn at the same speed and significantly reducing the efficiency of both. Pratt & Whitney's new gearbox allows the fan and turbine to rotate independently at their optimal speeds.

In addition to the gearbox, which required developing a super-efficient and lightweight gear, Pratt & Whitney also developed a larger fan and lightweight ultra-low-drag nacelle, or engine housing, for its PurePower engine. "Any one of those three technologies gives about a 2 percent reduction in fuel burn," explained Epstein, "but if we have the three technologies together, it doesn't equal a 6 percent reduction, it equals 15 percent." The PW1000G engine is in the final stages of initial design with engine certification scheduled in late 2011, supporting the engine's 2013 entry into use on the Bombardier CSeries and Mitsubishi Regional Jet.

Innovation Isn't Cheap …

Developing cutting-edge technology to change how an entire industry operates is not a cheap undertaking, but senior management at Pratt & Whitney believe in the investment, which is a big reason why Epstein left his position as a professor at Massachusetts Institute of Technology to join the company.

"These products take a billion or two to develop, and this company had already spent about $250 million over two or three years on research and development, before they even had a customer," Epstein said. "In engine development, you

Photo courtesy Pratt & Whitney

Airbus test engineers conducted a rigorous 27 flight, 100 hour test of the PW1000G engine on an Airbus owned A340 test aircraft in Toulouse, France, in late 2008. The flights measured performance, acoustics, and operation under high stress maneuvers and included approximately sixty high angle airplane maneuvers with up to 2.1 G s of force.

can spend $2 million every day, and it's hard to spend it wisely. But if you spend a few thousand a day five years before development, the development goes much more smoothly."

This practice of long-term research and development is commonly known as technology readiness, a concept NASA developed in the eighties with its technology readiness levels, and Pratt & Whitney continues to follow it by investing in research for future technology that will eventually improve upon and replace innovations currently in development. But first they have to finish developing the geared turbofan and convincing customers this new technology is economically and environmentally beneficial.

… or Easy

"This is the problem with innovation: the customer doesn't have a backup if ours doesn't work," said Epstein. "If we just had a 'me, too' engine, our airframe customers could say, 'All right, we'll buy your engine and a competitor's engine, and if yours doesn't deliver, we've got the competitor's just in case.' But if we have an innovative concept that looks and operates differently, then the customer has no backup," he explained. Because of this, customers need a higher level of assurance that the new technology is ready to fly. And the best way to do that is to actually fly it.

"As an engineering professor, I didn't understand the value of flight tests," Epstein explained. "We'd done several wind-tunnel and other tests and answered all the engineering questions. What could we learn flying—which is a lot more expensive—that we couldn't by running a few more hours on a test stand?" A lot, it turns out.

Among other things, PurePower developers discovered that the drag on their larger engine was much less than they expected, and the engines performed better than anticipated under adverse conditions, which Airbus happily tested for itself by maximizing stress to the airplane through a series of windup turns. The flight tests also proved to customers that the technology actually worked. "The same people who were skeptical eighteen months ago now just want to talk about price, not whether this thing will work," said Epstein.

But It's Necessary

The United States has been a leader in aviation technology, thanks in significant part to research and technical development done by NASA in the seventies. But with less investment going toward aeronautic research, we're potentially at risk of losing that lead. "NASA and industry aren't idea or talent limited, we're resource limited. And you get what you settle for," said Epstein.

In addition to its advances in aerospace, NASA has played a large role in aeronautic innovation through its X-plane projects and test flights, which have helped convince industry that groundbreaking technology is not only feasible but factual. These NASA aeronautics projects could be pivotal in changing the current airplane configuration, which some say has reached its limit. But without the nation's investment in research, and NASA's dedication to creating and flying radically new designs, industry influencers such as Boeing and Airbus likely won't buy in. A lack of research and proven flight tests results in a lack of customers, which in turn impedes industry innovation.

"I don't know that U.S. industry has done an adequate job in voicing the value that NASA brings to the nation," Epstein said. "We've been pumping the well in industry using NASA expertise, but the well is pretty dry now. The United States having the lead in aeronautical technology has been true the past five or six decades, but there's no law that says it has to be true the next five."

Collaboration for New Ideas

Innovation doesn't just happen by locking a brilliant engineer in a room and asking him to brainstorm. New ideas require feedback and testing and other new ideas to help make them a reality. Pratt & Whitney's new gear for the PurePower engine, for example, grew out of an early idea from one of their sister companies in United Technologies, Sikorksy, which specializes in rotorcraft technology. "Now we're sharing the fundamental science of the gear we developed back with Sikorsky, because the gear science that's gone into this is just as applicable to rotorcraft and convertible aircraft," said Epstein.

THE MAJOR INTERSECTION BETWEEN UNITED TECHNOLOGIES' AEROSPACE AND COMMERCIAL BUSINESSES TENDS TO BE UNITED TECHNOLOGIES RESEARCH CENTER, WHICH IS THE SPARKPLUG FOR EXCHANGE OF TECHNICAL INFORMATION

The United Technologies companies do more than share technology and ideas, however. They also share personnel. "People go back and forth because it's easy; we're here and they're only fifty miles down the road," Epstein explained. "But it's also true for divisions out in California. If someone in one division has a technical challenge and someone in another division has deep expertise, you ask if they'd like to go to San Diego."

Many engineers rotate among United Technologies companies, gaining expertise and developing their careers. Often, they'll return to Pratt & Whitney with a new set of skills and ideas to share. Engineers tend to circulate among the aerospace companies, but employees also move between the other United Technologies companies, like Carrier and Otis. "The major intersection between United Technologies' aerospace and commercial businesses tends to be United Technologies Research Center, which is the sparkplug for exchange of technical information," said Epstein.

United Technologies Research Center has more than 300 scientists and engineers, 96 percent of whom hold advanced degrees, 76 percent of them PhDs. It serves as both an idea generator and incubator and a technical-problem solver for the corporation, delivering technology and innovation that often create product differentiation in the marketplace for the businesses of United Technologies.

That information hub could help progress environmentally friendly aviation further toward what Epstein sees as a plausible future: airplanes you can't hear that also emit 20 to 30 percent less CO_2. "It's unquestionably possible in the next decade or two that you and I could stand on the street and have a plane fly over that doesn't interrupt our conversation. The planes will run on biofuels, which will continue to drive down the price of an airline ticket," he said. "I wouldn't mind having more leg room, either." ●

Note: Statistics calculated using data from the Bureau of Transportation Statistics, part of the U.S. Department of Transportation's Research and Innovative Technology Administration.

Answering the Call:

Communicating with Soyuz

BY ED CAMPION

The Soyuz TMA-13 spacecraft approaches the International Space Station, carrying NASA astronaut Michael Fincke, Expedition 18 commander; Russian Federal Space Agency cosmonaut Yury Lonchakov, Soyuz commander and flight engineer; and American spaceflight participant Richard Garriott. Two passes to obtain data from Soyuz were made before Garriott returned to Earth on October 23, 2008, with two Expedition 17 crew members.

Photo Credit: NASA

A blind engineer at Goddard Space Flight Center in Greenbelt, Maryland, had the vision for a solution to a problem that ultimately required him to fly to Europe to obtain potentially important data on the flight of a Soyuz capsule returning two International Space Station crew members and spaceflight participant Richard Garriott to Earth.

Marco Midon is an electronics engineer in the Microwave and Communications Branch at Goddard and has been with NASA for almost eleven years. In October 2008, Midon read a memo from the head of Space Operations at NASA Headquarters asking for ideas on how the Agency could respond to a request from the Russian Federal Space Agency to provide telemetry data on the Soyuz capsule during de-orbit and reentry.

"I saw the e-mail asking for ideas about how data from the Soyuz could be received and recorded and right away I knew how it could be done," said Midon. "The real question was whether it could be done in the time that was available."

The agencywide request from the head of all human space flight efforts came after it was determined that no commercial or space station partner facilities could provide the service needed because the VHF downlink frequency is not usually used for space telemetry. NASA and Russian partners agreed that providing data beyond that which is recorded just prior to separation of the Soyuz modules might be valuable in shedding light on the spacecraft's past entry performance. Midon's proposal involved a low-cost mobile system that could be transported and deployed along the planned separation and reentry track of the Soyuz vehicle.

"In the spirit of the old NASA, the Goddard team responded to my request with an amazing 'can-do' attitude. The team was focused on the problem to be solved and let no hurdles stand in the way," said William Gerstenmaier, NASA associate administrator for Space Operations. "Good Soyuz performance is important for International Space Station operations, and any help NASA could provide helps all the partnership."

"After getting the 'go ahead' to pursue my idea, my first course of action was to verify that we could obtain the necessary equipment," said Midon. "I called one vendor about the antenna needed and then another about the pre-amp that would be required to amplify signals tuned to this particular oddball frequency and how both items were needed immediately. The answer from everyone was 'yes,' so rush orders were placed."

With less than four days before the Soyuz landing, the next step involved Midon contacting individuals at NASA's Wallops Flight Facility in Virginia to confirm that the center could support a test of the system being proposed. After getting confirmation, he traveled to Wallops and supported activities that simulated what the Russian signal would look like and verified it could indeed be received and recorded. A day later, all the equipment ordered was in place, and the stage was set for the final test to prove that Midon's idea could work.

"We took the equipment down to Wallops and set up everything," said Midon. "While we were busy doing that, other folks talked to the Russians, who agreed to turn on the Soyuz that was docked to the space station for two communication passes. Basically we were seventy-two hours out from landing and knew we would only have these two short communication passes to prove the whole thing worked."

As it turned out, the first pass wasn't successful, with little or no signal received. But Midon came up with some tweaks to the system to make it a little more sensitive, and during the second pass, good data was received. While Midon and his group continued with their efforts, other NASA engineers were busy determining the best location to place the portable system. Three potential locations were initially identified: Turkey, North Africa, and Greece. After reviewing flight path trajectories, it was decided that Athens would provide the best view to capture telemetry data.

So on Wednesday, October 22, with less than forty-eight hours before the Soyuz landing, the site for the temporary station was set. Midon and Jim Evans, a Honeywell Technical Solutions employee at Wallops, traveled to Baltimore–Washington International Airport with all the equipment. A new challenge arose when one package was determined to be twelve pounds over the airline's allowed limit. Midon and Evans decided to take most of the equipment on their flight to Greece while others worked options for getting the remaining equipment delivered. Because no commercial delivery service

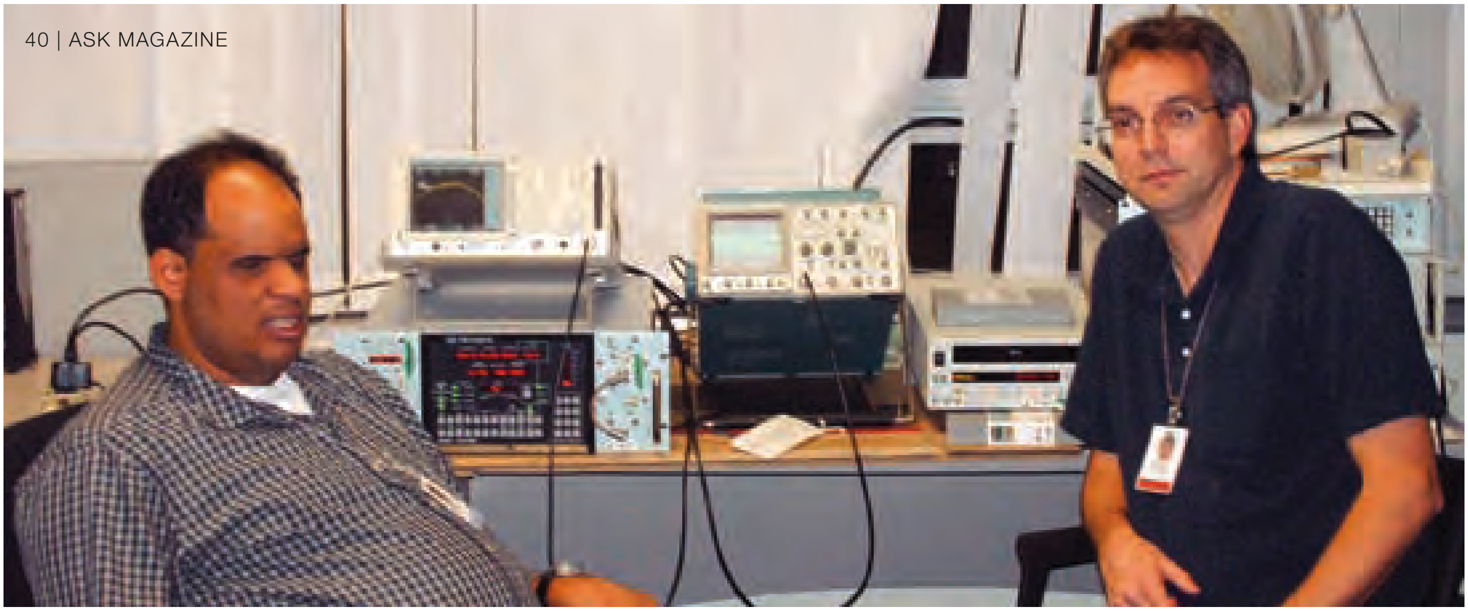

Photo Credit: NASA

Goddard Space Flight Center employee Marco Midon (left) and Jim Evans, a Honeywell employee at Wallops Flight Facility, are seen in an office at the American Embassy in Greece, where they set up equipment used to collect data during a Soyuz capsule's reentry and landing on October 24, 2008.

could guarantee the equipment would arrive in time, Harry Schenk, a Honeywell employee at Goddard who had helped with earlier efforts, volunteered to fly to Greece with the remaining items.

By the time Midon and Evans arrived in Athens, less than twenty-four hours remained before the Soyuz flyover would take place. The two went immediately to the American Embassy in Athens, which was the chosen location for setting up their equipment. Throughout the afternoon and into the evening, Midon and Evans worked to set things up while waiting for Schenk to arrive with the final pieces of equipment. By around 10:00 p.m., less than eight hours before the event, all the equipment was powered up and verified ready.

After finally checking into the hotel and getting at least a few hours sleep, the three men were back at the embassy around 4:00 a.m., local time, for the Soyuz flyover, which was planned for just after 6:00 a.m. But there was still one more issue to resolve.

"When we got back to the embassy for the event, we realized a recorder wasn't working," said Midon. "We realized that the likely cause was a heating problem because the room wasn't air conditioned. We found a marine, one of the few people around at that time of day, who found us a fan so we could circulate more air around the unit and that seemed to fix the problem."

Based on information provided by flight dynamics engineers, the antenna on the roof was positioned, and just after 6:00 a.m. the system began receiving data from the Soyuz capsule as it traveled through the atmosphere.

"The pass was very low, only 8 1/2 degrees, and we were in a valley so I wasn't sure we were going to get anything," said Midon. "At first, the signal was very weak. But then after two to three minutes, the signal got much stronger, and it was clear we were getting good data. The strong signal lasted about a minute and with processing back in the lab, we're hoping there is at least ninety seconds of good data that can be utilized."

Later, Midon had a phone conversation with Gerstenmaier, who thanked him and his group and said how much both the American and Russian flight control teams appreciated their incredible effort.

Midon remarked, "I think the real story here is that we only had two or three days to come up with a solution to something and were then able to implement it in Europe. I may have been the technical guy who figured out how to do it, but there were a lot of other folks whose willingness to pitch in provided us with an opportunity to succeed." ●

Rocketdyne: Committed to Knowledge Sharing

BY CARRI KARUHN

Steve Yows had a problem.

He was working on some rocket engine technology and hoped to find something "out there" in the industry that would help two computer software programs communicate with one another faster. But he wasn't sure what it was and didn't know how long it would take to find.

The RL10 program team displays a five-foot mock-up of the RL10 rocket engine, complete with plastic valves and combustion chambers.

Then Yows, a design engineer at Pratt & Whitney Rocketdyne (PWR) in Canoga Park, California, attended an internal technical conference, where he presented a paper on his design approach and Mathcad worksheet. During his presentation, Yows happened to mention the need to link other departments' tools to the forty other engineers attending the annual event.

Another engineer, who was visiting from the company's office in West Palm Beach, Florida, approached Yows later and said, "You might want to listen to my presentation. It's about a new tool that allows you to link your software to other applications."

"This was a total coincidence," said Yows. "You never know what you're going to find at these conferences."

The new tool solved Yows's problem—one success story in PWR's ongoing campaign to improve its ability to share and capture information and skills among employees through knowledge management. PWR holds an annual Technical Excellence Conference that showcases engineering disciplines across the company. It hosts an annual Knowledge Management Share Fair, where teams from across the company set up booths to showcase their innovations to other employees. Through its Passport to Leadership series, PWR invites outside speakers to give presentations on professional and general-interest topics. In past sessions, legendary basketball coach John Wooden discussed his famous "Pyramid of Success," and Homer Hickam, best-selling author of *Rocket Boys*, spoke about Sputnik's influence on him growing up in West Virginia as well as his distinguished career at NASA.

Then there is the Knowledge-Sharing Seminar Series, where employees give presentations on subjects including intellectual property, gasification technology, and other areas of expertise.

The eLearning team used a computer based learning model that resembled a cockpit zipping through space.

Photo courtesy Pratt & Whitney Rocketdyne

As Yows's experience shows, bringing groups of people together is valuable because you don't always know where the answers to your technical problems will come from.

It all happens in the name of transferring knowledge to create a better product—to take social and professional networking from the coffee rooms and drinking fountains into a forum where expertise can be shared and captured on a large scale. Most of the presentations are videotaped and stored on internal Web sites for employees to view later. Leadership has embraced the concept of knowledge management as a way to improve efficiency, ensure best practices, and preserve lessons learned. Employees see it as a way to share innovations, learn from others, and record their findings for generations to come.

"These events break down the silos to promote the sharing of knowledge among groups. We often don't know what other employees are working on because we're so focused on our own jobs and responsibilities," said Kiho Sohn, chief knowledge officer at PWR. "These events provide an opportunity for people to show what they have accomplished, and for people to learn something that can be applied to their own life and workplace."

Evidence that it works at PWR includes increasing attendance at each event. Attendance at the Knowledge Management Share Fair has doubled to 400 since its inception nine years ago; in the three years PWR has held the Technical Excellence Conference, the number of attendees has risen from 190 in 2006 to 248 in 2008.

PWR's investment in knowledge management was driven by the realization that its senior engineers would not be around forever. The company needed to capture their technical knowledge and expertise for future generations before it was lost forever, especially knowledge relating to the Space Shuttle main engine program and other heritage propulsion systems.

Nine years ago, PWR launched knowledge management using discretionary funds. It started by creating databases that include a directory of experts, data-mining tools, materials and fluids properties, and knowledge-capture methods. It also began training employees in knowledge management techniques and promoting a culture of collaboration.

One employee who took the training is Deanie Snell, who oversees PWR's technical library in Canoga Park, California. She attended a weeklong class through the American Productivity and Quality Center in San Diego, where she learned how to share knowledge, transfer best practices, and collaborate effectively. She then shared what she had learned with her team.

Her classroom experience led her to propose an annual event at PWR that celebrated knowledge, and thus the Knowledge Management Share Fair was born. A conference room is reserved at the California site's Leadership and Learning Center. Booths are set up, and a large tent is pitched outside to serve lunch at the Tacit Knowledge Café. Posters, banners, and internal music videos advertise the event. PWR President Jim Maser sends out companywide e-mails and appears in internal commercials, encouraging all 2,200 employees at the Canoga Park facility to attend. He and fellow executives browse the booths with the crowd, viewing firsthand the accomplishments of their staff. Last year, the Space Shuttle Main Engine Nozzle team used charts and graphs to show off its progress in the manufacture of the nozzle, while the RL10 program team displayed a 5-foot mock-up of the RL10 rocket engine, complete with plastic valves and combustion chambers.

PWR Fellow Awadh Pandey attended last year's Share Fair in Canoga Park to showcase a new high-strength aluminum alloy he invented, known as "Pandalloy," which few knew about until the fair. "It generated a lot of interest," said Pandey. "That's the whole objective. The Share Fair provides great opportunity for sharing the information about the capability of Pandalloy and how it is produced. I don't think anyone just goes to one Share Fair saying, 'This material will be used tomorrow.' It takes time for things to happen, but the fairs get the wheels of thought moving so it can be applied down the line."

The Share Fair booths are not all engineering-based. Social-networking groups like the PWR Hispanic Leadership Forum, Rainbow Alliance, and Women in Network pass out pamphlets and register new members, as does Team Rideshare, which encourages employees to carpool and take public transportation to and from work. Local universities, including Cal State Northridge's Tseng College of Extended Learning and Pepperdine University's Graziadio School of Business, are also there to recruit new students. The events are a hit, with employees taking home giveaways and more information than they came in with.

"The Share Fairs keep growing," said Snell, co-chair of the

Photo courtesy Pratt & Whitney Rocketdyne

(From left) Felix Delgado and William Bellows display their Enterprise Thinking Network at a recent Pratt & Whitney Rocketdyne Knowledge Management Fair.

event. "You know they're successful when teams ask to be part of the event—not just asking but insisting they get a table."

The teams do have various ways of encouraging people to drop by their booths, from offering baked goods and giveaways to building clever models and wearing appropriate costumes. The Program Management Office team caught people's attention by using a Rube Goldberg–type machine as a metaphor to demonstrate the movement of knowledge within an organization. The eLearning team donned U.S. Air Force flight suits to demonstrate a computer-based learning model that resembled a cockpit zipping through space.

"A lot of people don't know we have the capability to create multimedia training courses for them," said Brandan Laura, lead producer for the eLearning team. "We wanted to show them the resources we have and that we are a first-class group."

PWR knowledge-sharing videos and multimedia training courses are posted and stored on internal Web sites and learning portals, and they include lessons from technical experts no longer with the company. One includes a presentation on space nuclear thermal rockets, while another conducted by an engineer provides an overview on nuclear reactor engineering considerations, reactor physics considerations, and the effects of radiation.

Knowledge management has branched out at PWR since that first Share Fair. In 2003, PWR introduced AskMe, an internal Web-based social-networking tool that allows employees to locate experts, published documents, and previously answered questions within the company. And last year, the PWR facility in West Palm Beach held its first Share Fair, where forty teams presented projects ranging from revolutionary product design and business system improvements to cost-saving initiatives and employee-enrichment programs. More than 600 people attended.

Employees have also launched their own events.

Three years ago, Dr. Bob Jensen, an associate fellow at PWR, discovered the need to better document the company's technical innovations. He found that engineers gave excellent verbal presentations when using charts and graphs, because they were able to fill in the blanks about the nuances and reasoning that gave rise to their discoveries. When fellow engineers came back years later to review those presentations, however, all they had were the briefing charts without the nuances and reasoning.

"The things that get lost are 'Why did you decide to do it this way? What was your reasoning? What assumptions were made?'" said Jensen. "If you have the research fully documented, you don't have to reinvent the wheel each time. You can go back to something that was done five, ten, fifteen years ago, read the report, and understand the whole story."

He developed the PWR Technical Excellence Conference, where engineers from throughout the company can showcase their disciplines. It starts by having engineers from PWR's five sites submit technical abstracts. A review committee selects the abstracts for presentation and notifies the authors, who then prepare the papers, each of which can be anywhere from ten to fifty pages long. The authors present their papers at the conference, where they speak for twenty-five minutes, discussing the latest technical achievements, including proprietary information, and showing peers what they have accomplished. Topics have ranged from high-strength copper alloys for rocket engines to concentrated photovoltaic technology for space power. All the presentations are audio recorded with the slides and posted on an intranet site, together with the papers for current and future engineers.

The participating sites include PWR's facilities in Canoga Park; West Palm Beach; Huntsville, Alabama; Kennedy Space Flight Center, Florida; and Stennis Space Center, Mississippi; as well as other United Technologies Corporation business units. Government employees from Edwards Air Force Research Laboratory and various NASA offices have also been invited.

"We can leverage each other's capabilities by creating the environment for sharing meaningful summaries of research and development histories," said Jensen. "We can preserve for the next generation the details of what was done so that when future technologies are available, we can build on what has already been accomplished. When somebody looks at the research again in the future, they will find a very complete summary of what went on, and that's vital." ●

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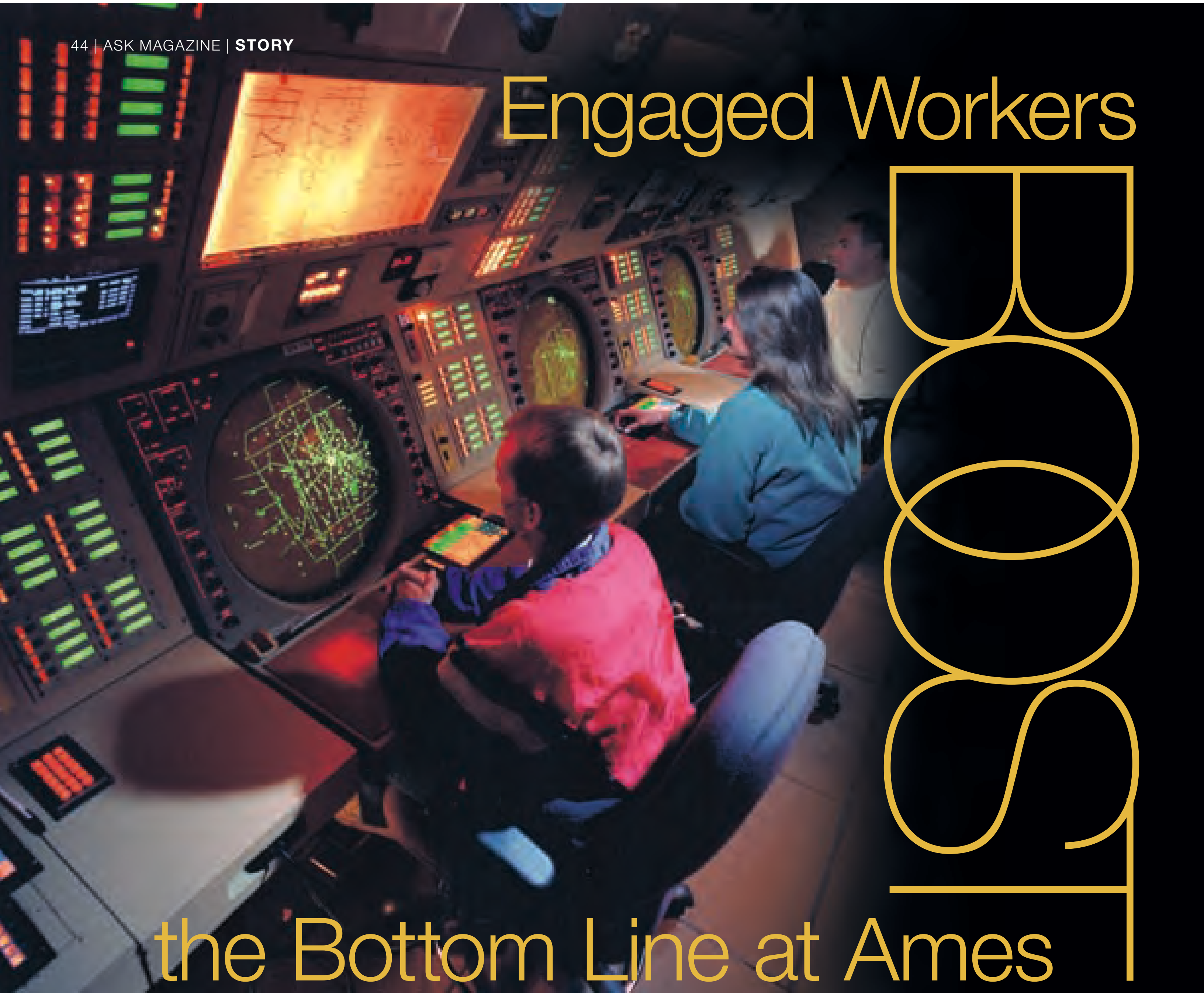

Engaged Workers BOOST the Bottom Line at Ames

BY NANCY MANGINI

In spring of 2008, midlevel managers with different professional skills working in different divisions at Ames Research Center in Mountain View, California, participated in a six-month Strategic Leadership Boot Camp management training program. As part of the course, attendees self-organized into interest groups to further study a particular aspect of curriculum. This is the story of the six Ames managers who formed what came to be known as the Engagement Team and how the work of that team resulted in a proposal that could support the case for bringing more agency work to Ames.

Six Individuals, One Common Experience

The six Ames managers who formed the Engagement Team found that despite vastly different skills and professional work environments, they had each experienced what they later described as a "wow" moment—a point in time when they were inspired, excited, and emotionally fulfilled to be doing their NASA work. For four team members, those moments took place in the mid- to late nineties at Ames and were sufficiently powerful to fuel their careers into positions of increased responsibility at the center. For two others, the moments took place during the Engagement Team work. For all of them, though, it was the Engagement Team experience that drew them together and led to the discovery that such moments could form the basis of what management science calls "employee engagement"—a human element in a technology-based work environment that can be directly linked to real-world, hard-dollar value and is an acknowledged predictor of mission and organization success.

Creative, Collaborative, Challenging "Wow" Moments

John Robinson and Todd Farley, who both hold MS degrees in aeronautics and astronautics and work as associate principal investigators in the Aviation Systems Division on the NextGen Airspace project at Ames, described their moments as stemming from different creative experiences that had similar personal impacts.

Robinson remembered the shared sense of excitement he felt in 1996 working on a "start-up-like" Ames project team that was developing a decision-support software tool for air traffic controllers to help them assign landing runways and sequences (the Passive Final Approach Spacing Tool, or pFAST). He credited an exceptionally flexible, management-supported work environment for the creative productivity of the team that resulted in a successful demonstration of the tool at Dallas–Forth Worth International Airport.

"When leaders support person-to-person collaboration among colleagues with a shared interest in solving hard problems, the workgroup environments that emerge are so productive and personally satisfying that people want to put in the extra time and effort to be successful," said Robinson. "In fact, one of the people from the FAA who was involved in that '90s test demonstration recently asked me to look into whether the maturity of our current research into unexpected compression of aircraft on final approach could be used to predict short-term conflicts in terminal traffic. So I pulled together a subteam like the one we had a decade ago to work the problem, and the positive feedback from person-to-person contact with a customer that needs the output of our product is once again driving an elevated level of engagement and productivity. Looking forward, I really hope that more people working at Ames will have the chance to experience the thrill that comes with being part of this kind of group."

Although Farley knew that moving from industry to working in research at NASA would give him a greater opportunity to pursue his long-held fascination with flight science, he was "blown away" to discover how multifaceted and creatively accomplished his coworkers at Ames were.

"I am someone who is inspired by 'ordinary' people who pursue their creative side," said Farley. "So when I met a senior scientist who turned out to be an amazing virtuoso on the trumpet, a management class colleague who wrote and performed his own songs on guitar, and peers on project teams who routinely stepped out of their professional personas to do some inspired improvisational holiday skit work, I was inspired to be in among them and became a much more engaged employee because of that experience."

Dr. Aga Goodsell preparing a prototype model of supersonic transport for wind-tunnel tests.

Photo Credit: NASA Ames Research Center

Todd Farley (on trombone) joined other NASA scientists and engineers in 2004 when the Ames Jazz Band performed at the San Jose Jazz Festival.

Dr. Aga Goodsell, chief of the Reacting Flow Environments Branch in the Space Technology Division at Ames, remembered a time in the mid-1990s when a branch chief at Ames gave her an opportunity to tackle wind-tunnel-based modeling and testing of new supersonic transport designs that required her to collaborate with a group of new people and approach problems in new ways. Experienced in a primarily computational approach to problem solving, Goodsell needed support from her new colleagues to build real-world prototypes to specifications on tight testing timelines. When the test outcomes challenged working assumptions, Goodsell's team pulled together to conduct a second testing program that resulted in a major change in the way future wind-tunnel testing would be conducted. Although personally and technically challenging, Goodsell found the experience to be uniquely fulfilling and felt that the supportive work environment created by her manager helped her to be successful.

"Now that I am a first-line supervisor in my own branch, I know that the health of my organization can depend upon the quality of workgroup relationships where team members not only respect each other's professional talent, but also care about each other as people," said Goodsell. "I try to foster this kind of work environment by encouraging after-hours social events, public celebrations of personal achievements, and structuring work-related travel as a group experience whenever possible. Also, I've identified team building, collaboration, and communication as critical elements in my employee performance reviews and try to help my people achieve high marks in these areas."

Dr. Jeffrey McCandless, deputy chief of the Human Systems Integration Division at Ames, remembered being inspired by the seamless collaboration he observed in Mission Control at Johnson Space Center during a Space Shuttle mission. He wanted to help colleagues at Ames be more open to the new experiences and work environments that support such collaboration.

"When I visited the Mission Control Center, I saw dedicated people coherently interacting to achieve a common goal of flight mission safety and success, and it was quite impressive," said McCandless. "No matter what came up, they handled it smoothly, like a choreographed dance. If employee engagement programs can help forge similar relationships, I believe our center and Agency will benefit."

Pat Hudson, procurement management IS team lead at Ames, signed up for the Strategic Leadership Boot Camp to accept the challenge of learning how to become a better manager and found that the experience of rising to that challenge could result in a "wow" moment that left her inspired and more engaged in the work she was doing.

"Engagement tends to be contagious," Hudson observed. "When someone is fired up about the work they do and the people they do it with, it spreads. When that happens, more people take the long view of their work investment in the agency and it's a win–win all around."

Antoinette Price, assistant chief of the Entrepreneurial Initiatives Division at Ames, saw joining the Engagement Team as a way to address the ever-present challenge of helping Ames communicate NASA values to employees who may then become more effective internal and external cheerleaders for the Agency.

"The more I worked with this group and learned how employees who feel valued, connected, and productive in their

PEOPLE COME TO NASA FOR THE OPPORTUNITY TO DO EXTRAORDINARY THINGS AND CONTRIBUTE THEIR TALENTS TO INVENTING NEW WAYS OF DOING THINGS AND PUSHING BACK THE THRESHOLD OF MAN'S KNOWLEDGE.

Photo courtesy Nancy Mangini

work environments can contribute to the bottom-line success of an organization, the more determined I became to overcome the perspective differences that often separate people into profession-based groups," said Price. "By rising to that challenge and advocating for improved employee engagement at Ames, I felt my own 'wow' moment of appreciation for the positive impact NASA has on our world as a whole and for my own contribution toward that impact."

The Case for Improved Employee Engagement

Beginning with an intuitive sense that their common inspirational experiences could form the basis for a strategy to improve the general level of productivity and efficiency at Ames, the Engagement Team conducted a survey of comparable organizations, both government-based and in the private sector, to determine if the benefits attributed to employee engagement in the management science literature were verifiable and relevant for Ames.

After six months of research using industry-standard, quantifiable metrics and backed by findings of the September 2008 U.S. Merit Systems Protection Board report, "The Power of Federal Employee Engagement," the team discovered that organizations adopting vetted, professionally managed employee-engagement programs realized an average first-year increase in productivity of 6.5 percent. For a 2,500-person workforce similar in size to Ames, this improvement in productivity would be like having 160 more full-time employees on staff for little or no additional cost.

To exploit this previously untapped resource, the Engagement Team developed a two-phase proposal for center management to consider starting a professionally managed employee engagement program at Ames. In the proposal, team members recommended using Robinson and Farley's Aviation Systems Division for a phase-one, twelve-month pilot program to validate anticipated improvements in productivity because the division is primarily a team-based work environment, and the division chief actively supports the project. If the division is judged to be successful, center management would have the option to use the experience to develop a centerwide program that could give Ames an advantage when NASA Headquarters considers which centers would be the most cost-effective choice for delivering on mission goals.

Dan Bufton, deputy director of Programs and Projects Office at Ames and senior management mentor for the Engagement Team, sees the team's proposal as an opportunity to enhance the already-inspiring work environment at Ames while serving the business needs of the Agency in challenging economic times.

"People come to NASA for the opportunity to do extraordinary things and contribute their talents to inventing new ways of doing things and pushing back the threshold of man's knowledge. At this level of management, though, it's easy to get a bit jaundiced and lose sight of the thrill that brought us all together in the first place. If managers can help employees increase their level of engagement through the kind of programs this team is proposing," said Bufton, "it will be a win–win–win all the way around—for employees, managers, Ames, NASA, and the human community we all serve."

While the logistics of implementing the proposed pilot plan are currently under review by human resources, center management has made it clear that Ames is committed to finding new ways to do more with current resources. As a result, the concept of inspiring greater employee engagement to achieve greater productivity is gaining ground as a low-cost investment that could realize a substantial return for NASA while simultaneously boosting the bottom line at Ames. ●

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Bidding Your Way to the Launch Pad

BY RANDII R. WESSEN AND DAVID PORTER

A Titan IVB/Centaur carrying the Cassini orbiter and its attached Huygens probe launches October 15, 1997. An international effort involving NASA, the European Space Agency (ESA), and the Italian Space Agency, Agenzia Spaziale Italiana (ASI), the Cassini mission successfully used a market based system to manage resources.

Photo Credit: NASA/JPL/Kennedy Space Center

One of the many challenges of growing up as an identical twin, as one of us (Wessen) did, is learning how to share. My twin and I tried many approaches to this age-old problem, some successful and some not. One of our more innovative approaches was "whoever cuts the cake, the other chooses." Unbeknownst to us, this technique has been used for centuries and provides an incentive for the "divider" to cut the pieces as fairly as possible. After all, if one slice is larger than the other, the "chooser" will pick the larger piece. We inadvertently stumbled on the fact that incentives powerfully affect human behavior.

Today, incentives are often used to move society in positive directions. One common example is the use of deposits on cans and bottles to remove them from our streets. Incentives are used to reduce atmospheric pollution and to establish migration routes and estuaries. Successful incentive-based systems need to be designed to attain the desired results and to minimize the impact of unintended consequences. It is the job of "market" engineers to create the proper incentives to harness society's interests for efficient outcomes.

As a system engineer for NASA, I (Wessen) became interested in using incentive-based systems to allocate space system resources. I didn't realize that economic researchers were already working on this class of problems. As a matter of fact, economists from the California Institute of Technology had been called in by NASA Jet Propulsion Laboratory's Cassini program to solve an allocation problem involving the development of the program's science payload.[1]

To understand if incentives could indeed be a more efficient way for allocating resources, we first have to understand how allocation usually happens. There are basically two approaches. The first is the "benevolent dictator" approach. One individual (for instance, the project manager, flight system manager, or ground system manager) is given a set of resources to distribute to a group of users. The success of this approach depends on the information provided to the decision maker, his knowledge, and his ability to allocate resources and adjudicate conflicts to get the most out of the mission.

Unfortunately, the only recourse available to a user who doesn't like his allocation is to make his case to the manager or the manager's manager. This appeal process happens all the time, since those not getting their entire request are often unhappy with their allocation. Other than some time and the effort to produce a few viewgraphs, they have nothing to lose. If the appeal is rejected, the petitioner is no worse off than before.

This approach has another liability. Individuals know that they're going to get less than what they want in an oversubscribed system so they "over-request" resources. This makes a bad situation worse. Since the manager has limited information, he will probably either try to give everything to everybody or "hurt everyone" equally. Neither strategy works very well.

The other technique for allocating resources is a committee-driven approach. A board of knowledgeable individuals (typically the ones requesting the resources) are asked to work together to solve the problem in a collegial manner. It is usually a difficult process to watch and even more difficult to be involved in. Everyone describes their "needs" and explains why they are more important than everyone else's. These discussions usually go on until a predetermined deadline rears its ugly head, at which point the dominant participants try to force their solution onto the committee. Here again, the only recourse is to appeal to a higher authority and hope for the best.

Market-based systems, sometimes called incentive-based systems, have several advantages. A big one is that they do not require a third party to solve resource conflicts because individual participants make these decisions through their bids.

Market-based systems come in two flavors: property right (sometimes called primary markets) and aftermarkets (also known as secondary markets). In property right markets, participants begin by bidding to express demand for needed resources. Resources in high demand get more and more expensive; those in low demand remain less dear. Users' bids signal which resources are the most desirable. This gives users an incentive to find alternate approaches using less expensive resources for solving their problems.

Of course, they first must have something to bid with. The solution is to allocate "tokens" to all users. One potential issue is how to allocate them. There are no perfect answers, but some sensible guidelines have emerged. Tokens can be given out equally to all participants; allocations can be based on the budgets from past years; or allocations can be based on past-year allocation of a particular resource. Each project is different and requires its own assessment of how to distribute initial budgets. But it is much better to solve one problem (the initial bid budget allocation) early rather than multiple

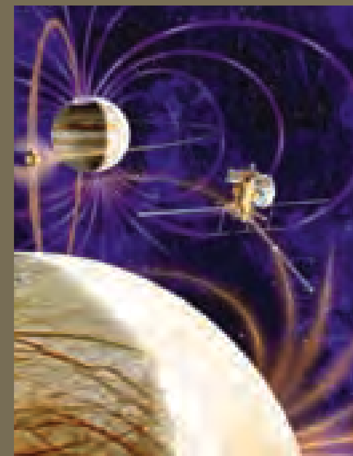

Image Credit: NASA/JPL

Artist Michael Carroll s concept of the Jupiter Europa Orbiter, part of the Europa Jupiter System mission, one of two Outer Planet Flagship missions currently planning to use market based systems to build their science instruments.

problems (conflicting demands for limited resources) later on in the process.

Once users have their budget of tokens, they bid for the resources they want. They can bid as often as they like and continue until no other bids are made. Then the trading (aftermarket) begins. Participants trade among themselves to improve their situations, offering what they have in excess in return for resources they require. Since trades are only executed when both parties agree, all trades are "win–win," and there is no need for time-consuming appeals to a higher authority.

A typical trade might be a straight swap (for instance, investigation A gives 15 minutes on orbit 1 to investigation B for 25 minutes on orbit 2 plus 100 kilobits of data storage). Or they can be more complicated "chain" bids (instrument builder A might trade mass to instrument builder B who trades dollars to instrument builder C who trades power back to instrument builder A). The Cassini program used this aftermarket approach. A Web-based aftermarket tool removes the tedious task of users having to find these trades. All the user has to do is request a certain amount of resource X in exchange for resource Y and the tool does the rest. If no takers are found, the initiator can either put up more of resource X or request less of resource Y. Projects can use either a property rights market or an aftermarket system, but market-based systems work best when both are employed.

Market-based systems have been used for eons. The first individuals who gave thirty shells for an arrowhead or maybe a goat for a calf were doing market-based trades. Today market-based systems are used everywhere. They're used by the Chicago School of Business to set up graduate interviews with prospective employers,[2] by the FCC to allocate frequency spectra to broadcast companies,[3] and as cap-and-trade systems for controlling pollution emissions all across the world.[4]

What's new is their slow yet steady migration into the world of space exploration. Like every application of a tool to a new area, first attempts are met with some skepticism and hesitation. The earliest attempts included using proposals to use markets to determine prices for International Space Station payloads in the late 1980s and to allocate antenna time on NASA's Deep Space Network. In both cases the approach may have been ready but the environment was not. Individuals saw how it could work but believed the consequences of it not working would just be too great. The first successful application of a market-based system to a space exploration problem was on the Cassini program in 1995 (see *ASK*, fall 2007, "The Cassini Resource Exchange"). The program's twelve science-instrument development teams

LIKE EVERY APPLICATION OF A TOOL TO A NEW AREA, FIRST ATTEMPTS ARE MET WITH SOME SKEPTICISM AND HESITATION.

used an aftermarket system to build their science "boxes." This approach controlled costs to less than 1 percent of the initial estimates and the payload mass growth actually decreased by 7 percent from what was initially proposed by the investigators.

Many NASA projects have experimented with the idea of using market-based systems to solve their resource-allocation problems. Some managers decided the time was not yet right for such a system. In other cases, loss of an earlier spacecraft resulted in the cancellation of the project considering this approach, or a change in NASA priorities (changing an active project to one that remains a study) reduced their interest in using a market-based system. But market-based systems are here to stay. The Earth Observing System (EOS AM-1) used a market-based

Terra (EOS AM 1) used a market based system to build its instruments, including the Moderate Resolution Imaging Spectroradiometer (MODIS). MODIS captured this image of Alaska on June 15, 2000.

Photo Credit: NASA/Jacques Descloitres

[MARKET-BASED SYSTEMS] MOVE THE DECISION-MAKING PROCESS BACK TO THOSE WHO HAVE THE INFORMATION; REMOVE THE NEED FOR TIME-CONSUMING MEETINGS AND APPEALS; AND, IF IMPLEMENTED WITH A WEB-BASED TOOL, CAN BE GLOBALLY DISTRIBUTED TO ALLOW INTERNATIONAL PARTICIPATION.

system to build its instruments. Again the results were extremely positive.[5] All instruments were built successfully and delivered on time. Currently, both Outer Planet Flagship missions plan on using these methods to build their science instruments.

Market-based systems are not for everyone, and it's difficult to prove in advance that a decentralized system will work for a particular problem. A project would have to judge whether results from an experimental environment accurately represent how the system will work in "real life." But market-based systems have too many benefits to be ignored. They move the decision-making process back to those who have the information; remove the need for time-consuming meetings and appeals; and, if implemented with a Web-based tool, can be globally distributed to allow international participation.

In fairness, it should be said that market-based systems, if not well thought out, produce some scary results. For instance, trying to reduce the number of mid-air airplane near misses by giving air traffic controllers a mandatory week off with pay if three incursions occur in any one-month period creates the wrong kind of incentive. Market-based systems must be designed carefully and include experiments to validate their design.

All cultures tend to fall in love with their current approach to solving problems and resist change. Innovation can come from anywhere, but it takes leadership to put innovative ideas into practice. A decision to change, which includes risk of failure, is not for the faint-hearted. There also will be resistance from all those who are skilled at using the current approach and don't want to change to a new system, even if it is a better one. Five hundred years ago, in *The Prince*, Machiavelli wrote,

> It ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new.

Whether you're trying to allocate spacecraft resources, manifest Space Shuttle middeck lockers, or just trying to divide a piece of cake for two hungry twins, people should always keep an open mind about new ideas for solving old problems. After all, innovation is what's needed to move society forward. ●

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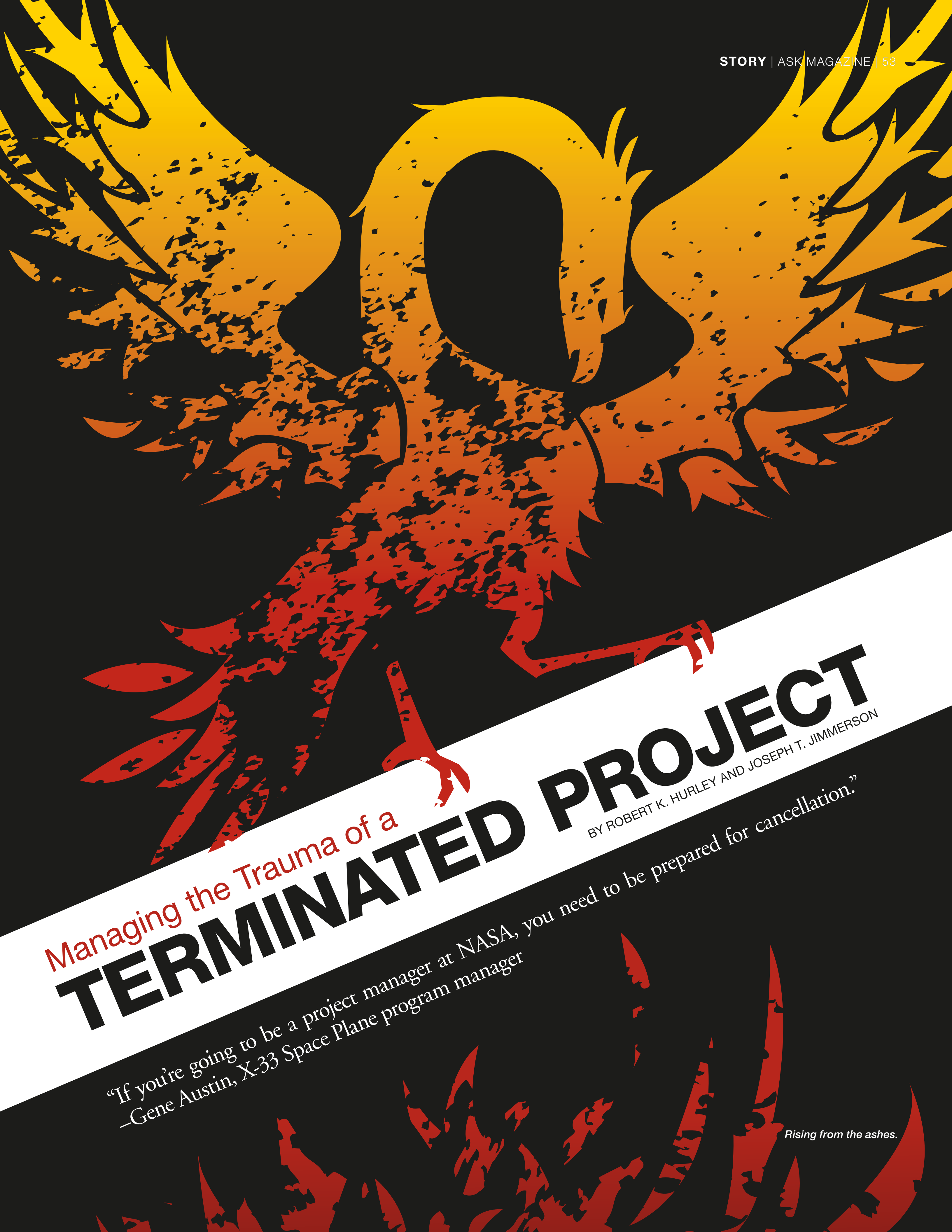
3. J. Banks, M. Olson, D. Porter, S. Rassenti, and V. Smith, "Theory, Experiment, and the Federal Communications Commission Spectrum Auctions," *Journal of Economic Behavior and Organization* (2003).
4. T. Ishikida, J. Ledyard, M. Olson, and D. Porter, "The Design of a Pollution Trading System for Southern California's RECLAIM Emission Trading Program," *Research in Experimental Economics* (2001).
5. Telephone conversation with Raynor Taylor, EOS-AM1 Instrument Accommodation Manager, March 2007.



Managing the Trauma of a TERMINATED PROJECT

BY ROBERT K. HURLEY AND JOSEPH T. JIMMERSON

"If you're going to be a project manager at NASA, you need to be prepared for cancellation."
–Gene Austin, X-33 Space Plane program manager

Rising from the ashes.

When projects are closed on time, on budget, and within scope, and they meet or exceed stakeholder expectations, the process of closing out contracts, handing over deliverables, and releasing project resources is a rewarding conclusion to a successful project. Even when projects are closed under less than ideal conditions (maybe overbudget or late), closure can be rewarding, especially for large projects or those of historic significance. Many projects end before they reach fruition, however. In fact, project cancellation is common. An April 2009 Project Management Institute (PMI) survey indicates that the number of companies canceling or delaying projects continues to grow as the economy struggles to recover. More than half the 1,000 randomly sampled PMI members and credential holders reported that their companies had canceled or delayed projects during the previous four months.

NASA's history offers plenty of examples of projects that have been canceled or significantly delayed. NASA Procedural Requirement (NPR) 7120.5D lists factors for canceling a project, including anticipated inability of the program or project to meet its commitments, unanticipated change in Agency strategic goals, and unanticipated budget changes. Recently, the NASA Presidential Transition Team asked Agency officials to provide the latest information on Ares I, Orion, and the planned Ares V heavy-lift cargo launcher, and to calculate the near-term closeout costs and longer-term savings associated with canceling those programs. Even if project managers and team members are doing everything right, it is important to remember that no project is completely safe from cancellation, but project teams are often so focused on completing projects that the cancellation announcement comes as a shock. Cancellation is often out of the hands of a project manager and is usually externally initiated, but that does not relieve the project manager of the responsibility to manage the closure of the terminated project effectively. Proper project management and senior stakeholder involvement can minimize the negative effects on employees and the organization.

Information on the emotional impact of project cancellation on individuals and the organization is limited for two main reasons. Whatever the reason for project cancellation, employees often hesitate to share their experiences. Also, organizations do not pay sufficient attention to the impact of cancellation on employees. But the effect can be great and damaging. According to project management authorities Mantel, Meredith, Shafer, and Sutton, the "cancellation of a project, particularly a long and difficult one, is akin to the breakup of a family and may well be stressful, even to the point of grieving."[1] Project cancellation is often traumatic.

Jerry B. Harvey, Professor Emeritus of Management at George Washington University, found that project managers and team members are susceptible to experiencing anaclitic depression, a particular, circumscribed form of melancholy that we often experience when the individuals, organizations, or belief systems that we lean on for emotional support are withdrawn from us.[2] The severity of this depression is likely linked to the length of time spent on the project, and the personal sacrifices made. As John Muratore recollects, for instance, "Seven years of my life were devoted to the X-38 Crew Return Vehicle project, and when it was canceled, it was a major grieving process." Many project managers and team members also suffer from feelings of separation and abandonment. "I literally did not feel like going to work for three weeks, and I did not after receiving word that the Solar Electric Propulsion (SEP) Stage project had been canceled in 1976," said Gene Austin, SEP team member and future X-33 Space Plane program manager. The range of emotions can vary from anger to grief. "There are hundreds of people in this country and Europe who have worked on the Dawn project for four years and had committed another decade to it, and now it is dropped. What can I say, it makes me cry," said Lucy McFadden, Dawn team member.[3]

The widespread effects of cancellation can damage the organization as a whole. Michael Boomer and Victor Pease,

"THERE ARE HUNDREDS OF PEOPLE IN THIS COUNTRY AND EUROPE WHO HAVE WORKED ON THE DAWN PROJECT FOR FOUR YEARS AND HAD COMMITTED ANOTHER DECADE TO IT, AND NOW IT IS DROPPED. WHAT CAN I SAY, IT MAKES ME CRY."

professors of management at Clarkson University, researched the impact of project termination on productivity and found a significant loss of productivity for months beyond termination. Steve Cook, current manager of the Ares Projects Office and former acting program manager for Next Generation Launch Technology (NGLT), agrees with their findings and feels four to six months of employee productivity was lost after projects under the NGLT program were terminated.

Nonproductive time has a significant economic impact on the entire organization. Improved management during project closure can reduce the financial impact and increase productivity of team members. Dr. Harvey also found that an unhealed employee may never work with the same sense of enthusiasm, loyalty, and commitment.[2] When terminations are perceived as a negative experience, employee commitment may never return to pretermination levels.[4] This not only affects the productivity of the individual whose project was canceled, but also those they work with. An anonymous Stennis Space Center employee says that every time they work on a project, one of their team members tells them not to get too connected and reminds them of the canceled Advanced Solid Rocket Motor project. Steve Cook felt it took two years for team members to buy into the Ares program after being taken to the edge of the abyss after projects under the NGLT program were terminated.

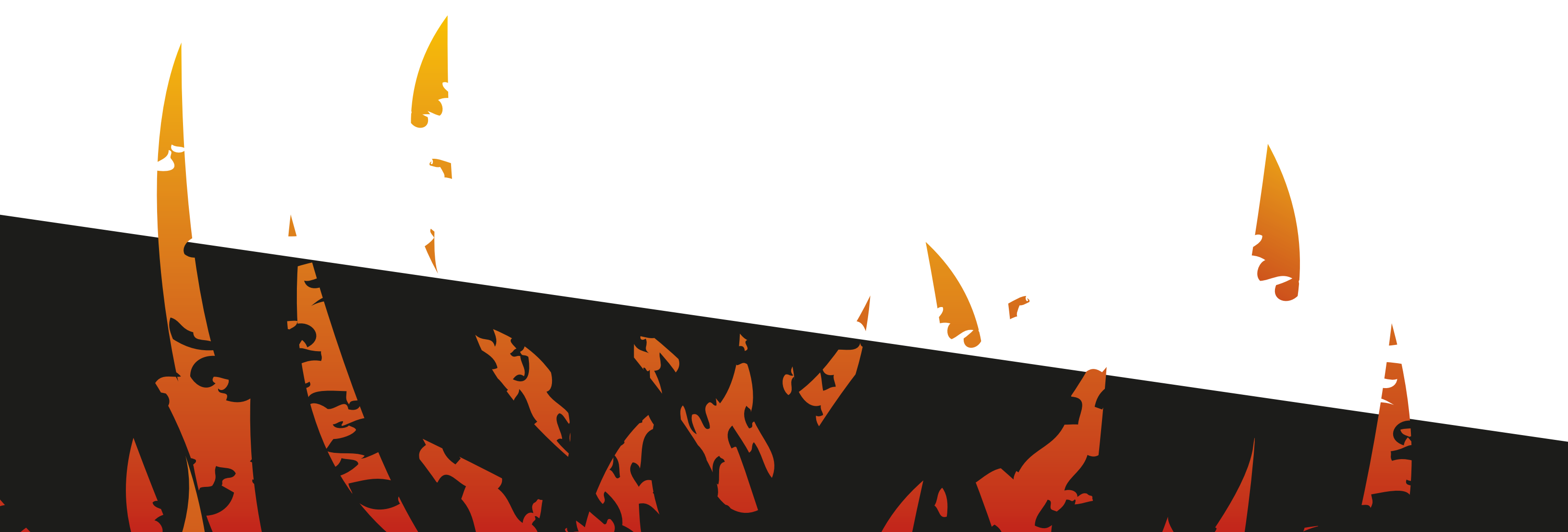
Project termination sometimes also creates a negative work environment. Project managers or team members of canceled projects inevitably serve as a visible reminder of what could happen to other projects.[2] "You're considered radioactive when you're leading a project or program that is terminated. Colleagues think they will get infected and don't want to be near you," said John Muratore. Meir Statman and David Caldwell, professors at Santa Clara University, reported that though companies acknowledge that project termination causes employee pain, they ignore the pain of employees who are retained while their projects are terminated.

Mishandled project termination also negatively affects the perception of the organization from the outside. Terminated government projects create a perception that taxpayer dollars have been wasted. Technical capabilities and leadership are also questioned when programs are terminated. These misperceptions can all be better controlled through proper closeout of the terminated project, which would include lessons learned and reports demonstrating the knowledge gained from the project, despite the cancellation, in addition to capturing the cost savings over the long term.

Project closeout processes are well documented in project management references, but they focus on completed projects, not terminated ones. Closing out a terminated project requires more finesse and talent on the part of the project manager. In fact, successfully closing out a terminated project could be viewed as a greater achievement than closing out a successful one. There are several factors to focus on during this process. The most important one is to include the team in the termination decision process.

The Termination Review specified in NPR 7120.5D can produce a positive effect for future projects. X-38 team members, for instance, were given additional time to learn from hands-on experience after the project was canceled. The valuable experience they gained by continuing some work for an extra year on that project is now being put to use in leadership roles on Constellation.

The team should be made aware of the rationale behind the termination well before the official announcement. The team (and project manager) should be reminded that project termination does not always indicate project mismanagement. Because NASA mission projects are explorative and often unique, requirements (and consequently schedule and cost) may grow beyond the resources available to support them. As Ed Weiler, associate administrator of the Science Mission Directorate, stated, "These science missions are not the



DESPITE A PROJECT MANAGER'S BEST EFFORTS TO CAPTURE THE SUCCESSES OF A TERMINATED PROJECT AND ASSURE THEIR TEAM THAT THE PROJECT CANCELLATION DOES NOT SIGNIFY FAILURE, SOME PROJECT MEMBERS WILL STILL TAKE THE NEWS HARD.

one millionth copy of a Toyota."[5] Nevertheless, there is always something to be learned. The scores of terminated projects in NASA's history probably have lost a wealth of information that could have helped future projects.[6]

To capture valuable knowledge and demonstrate the benefits of even terminated projects, team members should be allowed and encouraged to document accomplishments and status. Boomer and Pease's research found the accomplishments of terminated projects were generally not recognized. The project manager should identify how the work completed will contribute to future projects and hold a celebration of the team's achievements. Recognizing everyone's efforts and accomplishments helps leave the project team ready to continue to do good work, not despondent that they somehow failed and may be doomed to do so again.

Despite a project manager's best efforts to capture the successes of a terminated project and assure their team that the project cancellation does not signify failure, some project members will still take the news hard. These members should be offered employee assistance program services. These services can help them cope with the range of emotions they experience. Gene Austin points out that "project cancellation is a risk that we all take in this business, and seeking out and obtaining new project assignments is what gave me closure after serving on projects that were canceled." The project manager should work with functional managers to reassign personnel to new projects and present team members' plans for future assignments. These reassignments should be into comparable or higher positions, to eliminate the notion that the canceled project reflects on their capabilities. The managers may also take this time between projects to offer training opportunities as a step to more important roles on bigger projects.

Closure of a terminated project requires more effort than closure of a completed project. To aid in the process, this phase may be thought of and executed as a project in itself. The project manager must secure senior management's involvement and support and may decide to appoint a termination manager. Since there is little time to plan when termination happens, planning for this phase deserves to be incorporated into the project planning cycle in the event that it becomes reality. Planning should produce clearly defined tasks, agreed-upon responsibilities, closeout schedules, a budget, and a list of outstanding or available deliverable items. The closeout must ensure that all contractual requirements are satisfied and all records properly stored. Finally, project resources must be released in a well-coordinated manner. The project manager owes it to the project team to deliver a final report detailing the project's history, successes, discoveries, process improvements, applications to future projects, accomplishments, and lessons learned.

It is never easy to let go of a project, and even more difficult to have one pulled away, but by following the recommendations outlined in this article, project managers can turn a terminated project into a success story and prepare team members for even higher achievements. ●

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Process Improvement for Space Flight Safety

BY FAYSSAL M. SAFIE

After the *Columbia* accident, I was asked to lead the statistical data analysis team for the external tank foam in support of the Space Shuttle external tank return-to-flight team. Two weeks later I gave my first presentation to one of the external tank return-to-flight engineering boards. My initial findings clearly indicated that the manual foam spray process had inadequate process control. As a result, an astonishing number of defects (such as voids) existed at many critical locations on the external tank. The frequency and size of the defects were hard to characterize statistically because of the extreme variability of the process. The results shocked me and the engineering community. It was even more shocking to hear one of the lead engineers say to me, “Dr. Safie, it looks like you are not going to be able to help us.” My quick response was, “No, I am here to help you, and I am helping you as we speak.” After some discussion, I did get the message across. Everybody understood that a process control problem existed, that more data needed to be collected, and that a safe return to flight would depend on process-control improvements.

Engineers use a template and protective sheets to carefully begin dissection of the bipod ramp foam after the Columbia *accident.*

CAIB Photo by Rick Stiles 2003

The redesigned external tank for the Return-to-Flight mission is raised above its transporter in the Vehicle Assembly Building at Kennedy Space Center.

ADEQUATE PROCESS UNIFORMITY IS CRITICAL FOR ADEQUATE AND VALID CHARACTERIZATION OF THE PROTECTION SYSTEM MATERIAL, AND HIGH PROCESS CAPABILITY IS CRITICAL TO PRODUCE THE MATERIAL THAT CAN MEET THE SPECIFICATIONS.

Photo Credit: NASA

The difficulties and sensitivities of the manual spray process for the Space Shuttle external tank thermal protection system that contributed to the *Columbia* accident are a dramatic and tragic example of the potential negative impact of inadequate process control on component reliability and system safety. The thermal protection system is a foam-type material applied to the external tank to maintain cryogenic propellant quality, minimize ice and frost formation, and protect the structure from ascent, plume, and reentry heating. (Although the tank is not reused, the thermal protection system is important during reentry because structural overheating after separation from the orbiter could result in a premature tank breakup with debris landing outside the predicted footprint.)

Integrated Process Control

The reliability of the thermal protection system is broadly defined as its strength versus the stress put on it in flight. High reliability in the thermal protection system means less debris released and fewer hits to the orbiter, reducing system risk. Process control is a critical factor in achieving high reliability and low system risk. In simple terms, the aim of process control is process uniformity and process capability. Adequate process uniformity is critical for adequate and valid characterization of the protection system material, and high process capability is critical to produce the material that can meet the specifications. Good process uniformity and high process capability yield fewer process defects, smaller defect sizes, and good material properties that meet the engineering specifications—the critical ingredients of high reliability.

Engineers frequently think about process control only in terms of statistical process control, which mainly involves control charts with upper and lower limits intended to maintain process within those parameters, but that is only part of what is needed to ensure process quality and reliability. In response to the *Columbia* accident, the external tank project team formulated an integrated process control plan for the tank's thermal protection system to ensure that consistent processes would be employed. In addition to statistical process control, the plan involved manufacturing-material control, contamination control, supplier process control, process-change verification control, process monitoring, training and operator certification, and configuration management control. The aims of the plan included standardization of spray techniques, early detection of changes in materials, video reviews, process parameters (for example, for temperature and humidity), data recording, quality-control inspection, and comprehensive training for technicians, operators, and quality-control engineers and technicians.

Implementation of the integrated process control plan was not an easy task for the external tank project. No contractual requirements for the plan were in place at that time, additional skills and resources would be required to execute the plan, and many external tanks had been built and sprayed prior to the plan's creation. Even with these challenges, however, the external tank project successfully implemented the plan, to the extent possible.

Redesigned foam applications were performed within more tightly controlled process environments. Process validation and verification activities determined the optimal temperature and humidity ranges that would produce foam that minimized both the size and number of voids. Thermal protection system spray technicians and quality inspectors performing all complex geometric redesigned thermal protection system operations were trained and certified for spray applications to specific parts and locations. Quality-control inspections were increased to ensure independent verification of critical process steps. Quality personnel either witnessed or verified that an operation had been proficiently performed within a specified time prior to applying foam on a flight article.

As a result of the external tank project implementing the integrated process control plan to redesigned foam areas, the sprayed foam quality was significantly improved. The applied foam had fewer and smaller voids and greater strength and density.

Broader Implications: A Systems Approach

After spending two years analyzing external tank thermal protection system foam data and working with the return-to-flight engineering community, I realized that, in addition to the impact on reliability and system safety, lack of adequate process control could have a devastating impact on our engineering understanding of the failure physics and the validity of our engineering analyses across the board. Engineering models and engineering analyses based on highly variable and unstable data (that is, high sample-to-sample variability) due to lack of adequate controls could lead to erroneous conclusions and poor decisions. Lack of process control could also reduce engineers' ability to characterize their engineering parameters with a high probability of accuracy to validate their requirements. On many occasions during my support of the external tank thermal protection system return-to-flight team, engineering models did not hold, engineering data could not be characterized, and engineering specs could not be evaluated. A significant source of these difficulties was the inadequate process control of the external tank thermal protection system foam. We simply did not have the consistent, reliable data needed to make these analyses and judgments.

The clearest lesson of the *Columbia* accident and the external tank thermal protection system foam experience is that understanding the relationship between process control, component reliability, and system safety is critical. This systemic approach needs to be taken at the beginning of the design process, ensuring that we are designing for manufacturability—that the vehicle can be built with the required level of quality and consistency.

Our experience with external tank foam issues has provided critical lessons for the Ares I design community. The Ares I Upper Stage project team has given extensive attention to process design and process control and has involved quality engineers in the early phases of the design process.

THE *COLUMBIA* ACCIDENT SHOWED THE IMPORTANCE OF INTEGRATED SYSTEM FAILURE ANALYSIS.

It is equally critical to understand potential integrated system failures that start at the component level with no immediate catastrophic or even critical consequences, but propagate through the system across subsystem interfaces to cause a system failure. The *Columbia* accident showed the importance of integrated system failure analysis. Ares I has been expending significant effort on identifying and evaluating potential integrated system failures using physics-based modeling early in design and development. The thrust oscillation study and the first stage–second stage separation study that provided critical information for management to seek optimum design solutions are examples.

The *Columbia* accident is a devastating instance of a design problem made worse by a process control problem, ill-defined requirements, and lack of understanding of the external tank foam failure mechanism. Having a good and well-defined set of requirements, understanding the system capabilities and system interactions, understanding the failure physics, and—most importantly—putting in place the process controls that are relevant to the failure physics are critical for designing and manufacturing reliable and safe launch vehicles. Learning the lessons of *Columbia* is essential to making sure that our future launch vehicles and spacecraft are as safe as we can make them. ●

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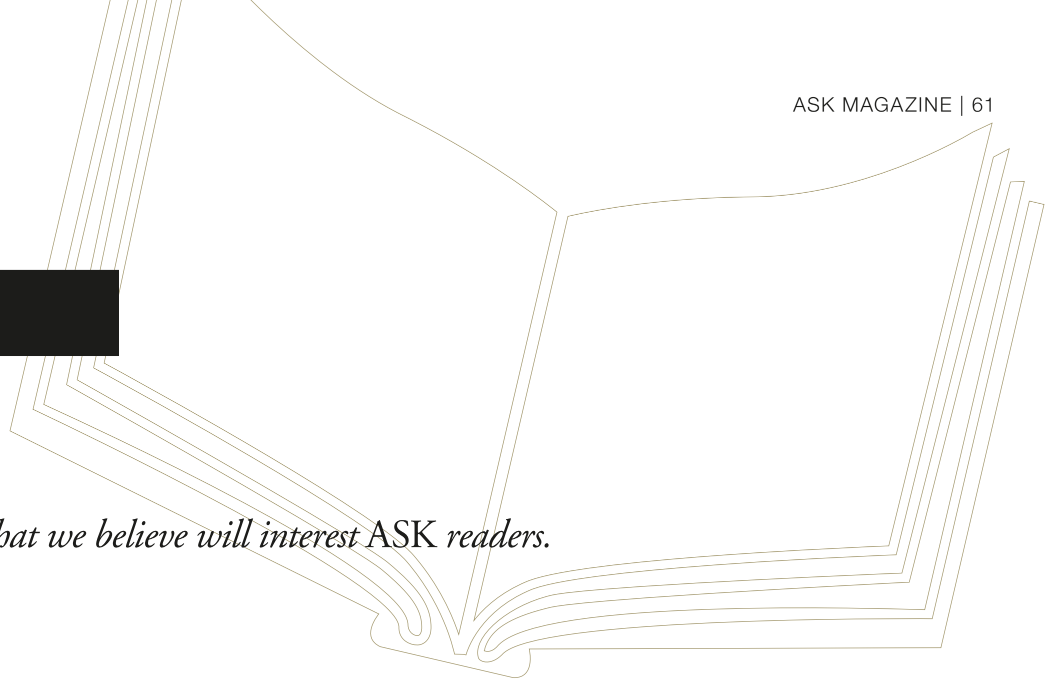

ASK Bookshelf

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

Managing Flow: A Process Theory of the Knowledge-Based Firm, by Ikujiro Nonaka, Ryoko Yoyama, and Toru Hirata (New York: Palgrave Macmillan, 2008)

Ikujiro Nonaka is the most famous management theorist you have probably never heard of. He played a (or the) most important role in developing and propagating the idea of the knowledge management movement and served as an expert guide and "sensei" to many who have worked in the field for the past few decades. Because he is Japanese and not surprisingly has an affinity for Eastern formal philosophy as well as Western ideas, his books are not as popular in the United States and Europe as they should be. Nevertheless—to give just one small example—many of the ideas focused in the past decade or so on the tacit nature of knowledge have been strongly influenced, when not actually inspired, by the writings of Professor Nonaka and several of his colleagues.

In this new book, published last year, Nonaka and his colleagues provide some new insights into the nature of knowledge and how it works in organizations. Rather than offer a full-blown review, it might be best in this short space to focus on just two points that are to some degree the central focus of this new work.

One is the emphasis on *phronesis*. This is a classical Greek term, used prominently by Aristotle and recently brought back to life by commentators on knowledge and organizations. Most commonly translated as "practical wisdom," it is often used to refer to the skill of successful politicians and other leaders who can make quick, accurate assessments of situations. This is a form of knowledge that cannot be codified or even really taught, but only gained through experience. Another characteristic of *phronesis* is the ability to sum up the essence of a situation and share it with others. While some have called this a communication skill, it is really more complex than that. It entails a deep and rich understanding, closer to intuition than reasoning, of how things work in this world. Winston Churchill and Franklin Roosevelt used it to lead their countries through crises. We could use more *phronesis* in these difficult days.

Another, perhaps more familiar, term to those who follow current thinking in the realms of knowledge is the concept that lies behind the Japanese word *baa*. This complex concept has no direct English equivalent. It essentially means creating a space where common meaning can be built. That does not necessarily have to be a physical space. The authors discuss cyberspace and social spaces as well as open areas and other physical spaces. But *baa* invariably has a social element. It always refers to at least two people working together toward a goal of creating a commonality. This word, with all its rich connotations, is very useful in figuring out how to work effectively with knowledge in organizations. This concept was scarcely mentioned in any language before Nonaka introduced it to Western readers. It has become one of the most innovative and interesting conceptual tools in the knowledge managers' toolkit.

We hope this brief review inspires *ASK* readers to look at this and other works by the "Peter Drucker of Japan," a man who is surely and deservedly one of the most influential management thinkers in the world today. ●

The Knowledge Notebook

Knowledge and Judgment

BY LAURENCE PRUSAK

During the recent financial crisis, many people asked how such well-educated and highly trained traders, analysts, and brokers could have made such awful decisions. After all, they were the "best and the brightest"—often recruited from the best schools, where they majored in difficult and sometimes incomprehensible subjects and still graduated at the top of their classes. They were brilliant, so how could they have been so wrong? What happened?

Well, those of you as old or nearly as old as I am know that we last heard about the "best and the brightest" during the final years of the Vietnam War, when a great reporter, David Halberstam, wrote a book with that title. In it, Halberstam described how some exceptionally smart people brought about that failed war and its terrible aftermath. They were smart, but their judgment was faulty.

No doubt you have your own favorite examples of failures of judgment by people who, it seems, should have known better. But that assumes a causal link between knowledge and judgment—a link that is by no means automatic, simple, or ever-present. In fact, many social scientists now question the relationship between the two and wonder out loud if they are connected at all.

Of course they are; good judgment requires knowledge. But the quality of judgment is strongly tied to how one chooses what knowledge to use in particular circumstances. Judgment is very much a mix of knowledge, context, and circumstances. I would also add history to this mix, perhaps because of my own predilections. The late, great, Ernest May pointed out that thinking of things "in time" often leads to good outcomes.

Many, many books have been published that purport to tell us how to make good decisions. Many of them are partisan, though, in that they advocate for what they consider the one best way to make decisions in virtually all circumstances. I think the only road to success in making good judgments against the odds of complexity, ambiguity, entropy, and one's own biases is to selectively and flexibly use the entire range of your available knowledge. This includes instincts, "gut reactions," tacit and explicit rules one has used successfully in the past, your own and others' know-how, intellectual capital stored in documents and videos, analytics of all sorts and shapes, and examples offered by history. The trick is knowing when and where to use what knowledge and testing types of knowledge against each other. This isn't always an easy thing to do, to say the least.

Part of the problem is that our professional schools often give us one model for action—a kind of reductionist analytic structure that hasn't changed much since it was developed in the seventeenth century. While this way of thinking has had great success in many areas, it lacks the subtlety and flexibility needed to deal with highly complex issues that depend on understanding human motivations that are often impossible to predict or analyze fully. If you have ever managed a complex technical task that is being carried out by a group of those rascally, unpredictable humans, you probably know that you need all the tools that you can get to do this sort of work well—to make the right decisions when judgment is called for. Depending on just one kind of analysis or managing people in one, unchanging way (solely using a reward system, for example) is no more likely to succeed than trying to build a house with just a hammer.

Another sad reason for our failures in exercising judgment is that little or no history is taught in our professional schools. Problems and issues are all addressed as if they had never happened before. How can we understand management issues or any issues in a historical vacuum? How can we understand what to do without knowing what was done before in similar circumstances and what the results were? Yet the history of management thought and action is a non-starter in MBA programs. I suspect the same is true in engineering schools, with every project seen as an orphan, without parents or offspring.

One day all this will be different. Critical failures caused by poor judgment, some on a global scale, will continue and will eventually force schools, management gurus, and organizations to recognize the varied knowledge, skills, and perspectives that contribute to good judgment. They will eventually understand that there is no one right way to make decisions, that a key to good judgment is judging how to approach a particular task or situation. Teaching judgment and teaching the knowledge that supports judgment will be the norm. I only hope we don't suffer too much more in the course of learning that lesson. ●

I THINK THE ONLY ROAD TO SUCCESS IN MAKING GOOD JUDGMENTS AGAINST THE ODDS OF COMPLEXITY, AMBIGUITY, ENTROPY, AND ONE'S OWN BIASES IS TO SELECTIVELY AND FLEXIBLY USE THE ENTIRE RANGE OF YOUR AVAILABLE KNOWLEDGE.

ASK interactive

NASA in the News

To celebrate the fortieth anniversary of the Apollo program s achievements, including the first moon landing, NASA has put together a collection of historic images, videos, personal stories and recollections, and more interactive features at www.nasa.gov/mission pages/apollo/40th/index.html. Several events will also be held to honor the Apollo program, with a full list available at www.nasa.gov/pdf/318218main 40thAnniversaryAgencyEvent s%20_6 22 09.pdf.

Experience the challenge and victory of the great moon race once again, see what technology Apollo contributed along the way (www.sti.nasa.gov/tto/apollo.htm), or discover what NASA has in store for future lunar exploration in 3 D (www.nasa.gov/externalflash/exn3d/index.html).

Going Green

With climate change and the efforts to reduce our carbon footprint receiving much attention these days, many in industry, academia, and government agencies are striving to innovate sustainable practices. NASA Ames Research Center's "Greenspace Initiative" provides strategy, integration, and implementation support for alternative energy and environmental projects (www.nasa.gov/centers/ames/greenspace). Yale University has created a center dedicated to advancing green chemistry and engineering practices (www.greenchemistry.yale.edu) and partnered with several organizations to help increase greener practices, including the Environmental Protection Agency, which has developed its own green chemistry effort: www.epa.gov/greenchemistry/index.html.

Web of Knowledge

Are stunning photos from space not enough to satisfy your curiosity about NASA? Find videos, podcasts, blogs, RSS feeds, and other interactive features that expand your ability to explore what NASA is working on now and in the future: www.nasa.gov/multimedia/index.html. If you haven't had your fill of amazing NASA photography, be sure to check out nasaimages.org as well.

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