National Aeronautics and Space Administration

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FALL | 2012

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Photo Credit: NASA/Bill Stafford

ON THE COVER

Liz Rampe, a planetary geologist and postdoctoral researcher, pilots the Multi-Mission Space Exploration Vehicle (MMSEV) down to asteroids spinning at different rates as part of the 2012 Research and Technology Studies (RATS) at Johnson Space Center. One of the RATS team's goals during this testing is to successfully navigate to an asteroid that may be moving slowly or spinning quickly and maintain a set distance from it with the MMSEV—a challenging piloting feat. Another part of mission testing involves astronauts collecting rock samples from an asteroid during a spacewalk. These tests help scientists and engineers design, build, and operate better equipment and establish operational requirements for future human-exploration missions.

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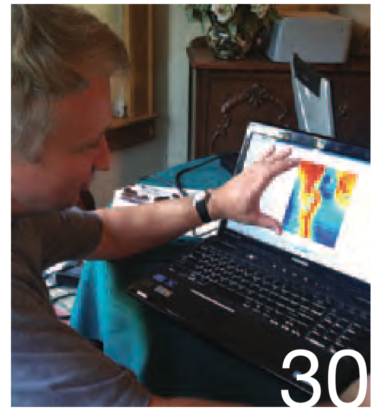

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Issue No. 48

Staff

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

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

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

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In This Issue

ASK Magazine is one small part of NASA's varied and extensive efforts to share the knowledge needed to carry out the agency's projects and programs successfully. We hope that the stories and reflections published here will help readers think about their own work in new ways and will inspire them to learn—by seeking out our authors, by trying something new, by discussing what they read with their peers. Recognizing that knowledge is obtained in many ways and that reading a magazine is not at the top of the list, we think of *ASK* more as a spur to knowledge creation and acquisition than as a "container" of knowledge.

Ed Hoffman's comments on his role as Chief Knowledge Officer ("From the Academy Director: Knowledge and the Practitioner's Mind-Set") give a sense of just how diverse NASA's knowledge is, both in terms of what people know and how they learn it. He recognizes that his job is to champion and facilitate the agency's wealth of successful practices, not impose one limited idea of how to "do" knowledge. Laurence Prusak also discusses the complexity of organizational knowledge, suggesting, in "The Knowledge Notebook," that it exists in a range of forms and places: in individuals, in groups, in practices, processes, and routines.

Many of the articles here speak to the variety of what people need to know at NASA and how they get that knowledge. In "Getting the Most from Your Mentor," Richard McDermott recommends mentoring relationships as sources of technical, managerial, and career knowledge. The authors of "Building the Goddard Career-Path Tool" describe an online map that supports knowledge about how to manage your career. The International Project Management course Angela Marsh attended ("Understanding International Project Management") combines book learning, discussion, and shared activities to give participants a sense of the complexities of working across cultures.

Barbara Fillip's "Project Knowledge in the Moment" explains Goddard's powerful Pause and Learn sessions, which use reflection and conversation in the course of projects to identify and share important lessons. Pause and Learn is an important extension of learning by doing—reflecting on what you've done being an essential step in learning from experience.

Without question, learning how to do something by doing it (especially with knowledgeable colleagues or guided by mentors) provides deep knowledge about how things really work that can't be acquired in any other way. Thomas Horn's story of a cultural change effort at Dryden shows you sometimes only discover the right way to do something difficult by trying what turns out to be the wrong way first. And Lynn Cline's conversation about her four years negotiating Russian participation in the International Space Station includes important real-life lessons she learned from that experience.

"Learning from the NuSTAR Launch Delay" tells the story of how the efforts of NASA and Orbital Sciences to solve a problem with Orbital's Pegasus launch vehicle taught the participants a great deal about how to work together and—to Prusak's point about knowledge embedded in practices and routines—contributed to NASA's developing processes for working with a new generation of partners.

Don Cohen
Managing Editor

From the Academy Director

Knowledge and the Practitioner's Mind-Set

BY ED HOFFMAN

Who is responsible for the knowledge that NASA creates?

Since being named NASA's Chief Knowledge Officer (CKO) at the beginning of 2012, I have given this question a lot of thought. Every center and mission directorate now has a CKO or point of contact who can speak to their organization's approach to capturing and sharing lessons learned and best practices, tools and repositories, and other aspects of the trade. So there is a community of individuals with titles that indicate some responsibility for knowledge at NASA.

But the circle of stakeholders is far broader than the individuals tapped with formal responsibility for knowledge. Mission success at NASA requires expertise in a wide range of disciplines beyond project management and engineering, including safety and mission assurance, acquisition, and human capital, to name a few.

Knowledge has always been the province of every practitioner. Knowledge is not a process or policy; it means a commitment to excellence based on daily decisions to share expertise, ask questions, collaborate with colleagues, and maintain vigilant commitment to continuous learning. It is also the search for innovation, technological and social.

Knowledge creation and sharing go on all the time among NASA's 18,000 civil servants and tens of thousands of partners in industry and academia. Think of the dozens of lectures and brown-bag lunches that happen every day. The papers and conference talks. The wikis and posts on Yammer or Reddit. There is no way a centralized knowledge organization could keep up with—let alone manage—the sheer volume of it.

In other words, knowledge thrives through our people and happens everywhere across the agency.

So what role should the CKO play?

I believe there are two important advocacy roles: facilitator and champion.

Facilitator. The CKO should leverage, nurture, and highlight formal and informal work happening across the agency. As I mentioned in an earlier column, it was eye-opening to learn of the sheer volume of ongoing knowledge activity when we convened representatives from the knowledge community for the first time in February 2012. Since then, we have begun a more formal process of mapping existing knowledge services at NASA's centers and mission directorates. When complete, the map will provide a major tool for practitioners looking for critical knowledge. It will also help us identify gaps and set a forward-looking agenda that addresses some of the agency's top strategic priorities, such as the shifting demographics of the workforce and the changing relationship with industry in human spaceflight.

Champion. The CKO should serve as the conduit between workforce and leadership to ensure the workforce has the tools and resources necessary to meet NASA's most pressing knowledge challenges. This is a two-way street: the CKO should also raise awareness among the workforce of the importance of developing a knowledge mind-set. As with safety, all of us are responsible for NASA's knowledge; the CKO is responsible for not letting the rest of the agency lose sight of that essential fact.

The CKO role is still evolving, but given NASA's decentralized nature, facilitation and advocacy are foundational capacities that will help establish effective ways of working with the broadest possible range of stakeholders. These roles need to support the ultimate goal of having an organization that encourages reflective practitioners who openly and honestly share their ideas and the lessons they learn. In the end, a CKO's influence is limited; we are each responsible for developing a knowledge mind-set. Our health as a learning organization depends on it.

Photo Credit: NASA/JPL-Caltech/Orbital

Engineers in the final stages of assembling NuSTAR.

LEARNING FROM THE NUSTAR LAUNCH DELAY

NuSTAR, the Nuclear Spectroscopic Telescope Array, contains the first focusing telescopes designed to look at high-energy X-ray radiation. It is expected to contribute to a better understanding of collapsing stars and black holes.

BY DON COHEN

Because NuSTAR is designed to function in an equatorial orbit, it launched on a Pegasus XL rocket from a point south of Kwajalein Atoll, in the Marshall Islands, on June 13, 2012. Built by Orbital Sciences Corporation, the Pegasus is carried to approximately 39,000 ft. by an L-1011 aircraft. Released at that altitude, the three-stage, winged rocket ignites its first-stage motor to continue its journey to orbit.

The June launch came almost three months after a planned early March launch date. The story of that delay—why it happened and what both NASA and Orbital Sciences learned from the experience—offers insight into how NASA deals with technical risks and into the agency's developing relationships with commercial providers of launch vehicles and spacecraft now and in the future.

Why the Launch Delay?

Two issues needed to be resolved before NuSTAR could be approved for launch. One involved the Pegasus fairing—the streamlined shell at the nose of the rocket that protects the payload during its climb to orbit. The Pegasus fairing hardware was similar to that of the Taurus XL, which had failed to separate on two recent NASA missions; its added weight kept the Orbiting Carbon Observatory and the Glory spacecraft from reaching orbit. The cause or causes of those failures had not been definitively determined—the rockets fell into the sea so there was no physical evidence to examine. The Pegasus fairing had been somewhat redesigned to reduce the likelihood of a similar failure, but that created its own uncertainty, since the new design had never been tested in flight.

A second issue had to do with the fact that the flight computer aboard Pegasus and the associated flight software and simulation software were new. This change was a jointly funded reliability improvement by Orbital and the NASA Launch Services Program (LSP) to replace an obsolescent, out-of-production industrial microcomputer (albeit with two decades of excellent performance) and bring the flight software and simulations up to current standards. Initially, the fairing issue seemed the more serious of the two. That expectation changed. The team studying the fairing issue concluded that the risk of a malfunction was minimal; the software concerns proved harder to resolve. NASA's software team expressed growing concern over the lack of adequate simulation and test data.

Reliable simulation data are essential. Omar Baez, NuSTAR's launch director, notes, "Rockets are not forgiving," and Director of Launch Services Jim Norman adds, "All the vehicles need to reach 17,000 mph. Errors are amplified by the energies expended." And, as NASA Chief Engineer Mike Ryschkewitsch points out, the only live "test" for a rocket is an actual launch. New aircraft, by contrast, can be tested bit by bit through a series of increasingly demanding flights that start by determining basic airworthiness and eventually map the limits of safe performance. Simulations matter for aircraft design and construction, too, of course, but not as critically.

Although data were arriving late from Orbital, the LSP technical team worked extremely hard to execute the plan during February and early March, and the mid-March launch date still seemed achievable, provided no further serious issues were identified. Unfortunately, as the date for the all-important guidance, navigation, and control review approached, both Orbital and LSP were finding that simulations exhibited far too many failed cases to proceed.

With Orbital management responding to the magnitude of the problems, the contractor was providing large quantities of data and the LSP flight-analysis team demonstrated an ability to process it quickly and accurately. Suspected errors identified by NASA were being confirmed by Orbital right up until the night before the Flight Readiness Review (FRR). Both the LSP and Orbital teams put in extremely long hours that did not compromise the rigor and careful technical review and risk analysis. The LSP flight-analysis team held a final five-hour peer review on March 14, where every finding was either closed or identified as still open. Their rigor and diligence in the face of a launch deadline is an example of technical excellence not compromised by schedule pressure.

Late on March 14 it became clear that Orbital could not resolve all the remaining items without making changes to the flight code and simulation models. The technical team informed management, and the launch opportunity was scrubbed.

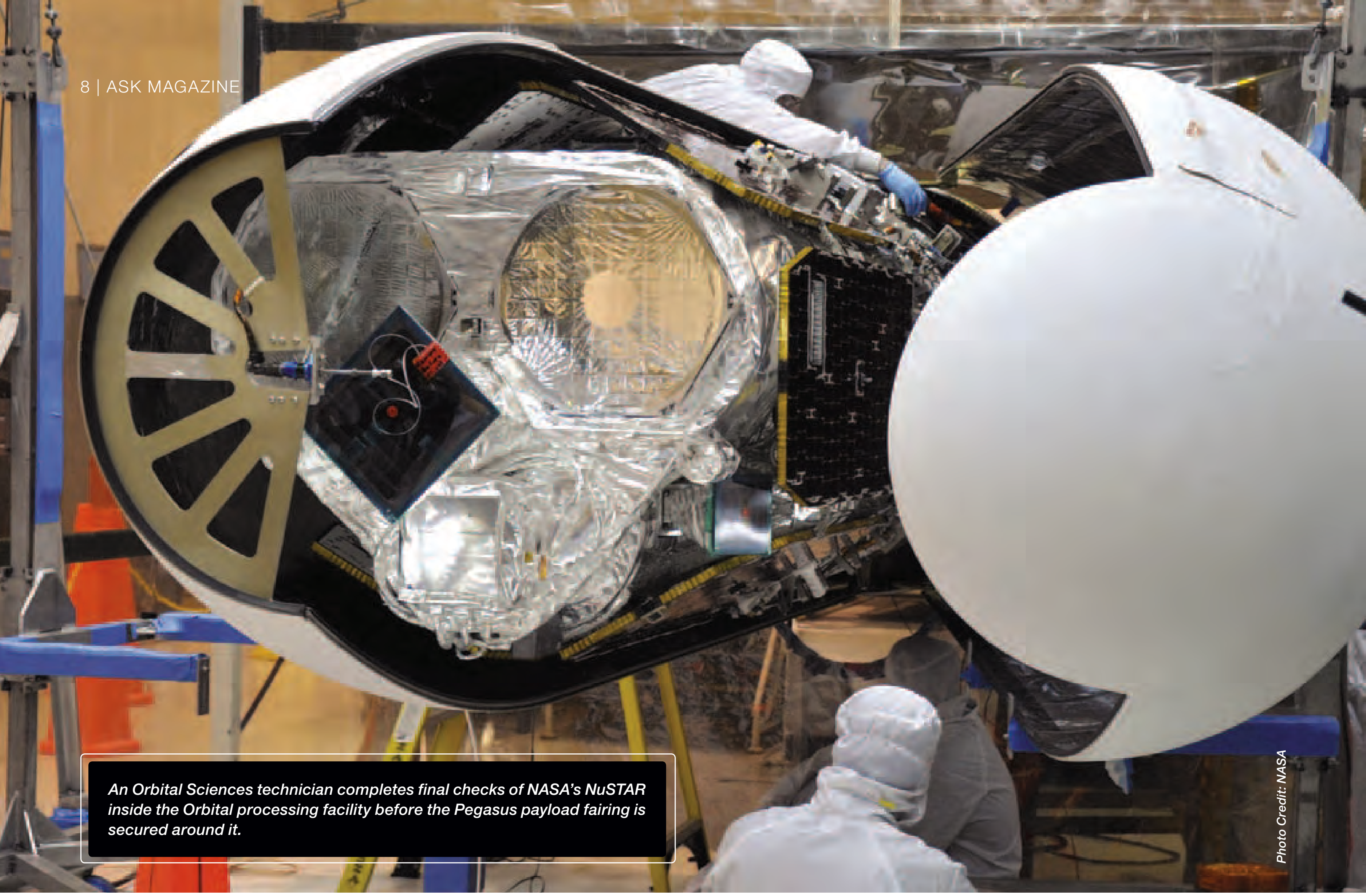
"Take the Time to Do It Right"

Part of the NuSTAR story is about the support the mission team got for carrying out the analytical work that needed to be done, even if that meant a delayed launch. Because the Kwajalein Atoll launch site was reserved for a classified mission after the NuSTAR March launch window, taking more than a few extra days to resolve the technical issues would force the mission to wait months to launch the spacecraft. Realistically, the team was looking at a delay of at least three months and the extra costs associated with it.

NASA has long been sensitive to the tension between technical risks that need study and possible mitigation and the desire—sometimes the pressure—to launch on schedule. The 1986 *Challenger* disaster brought the issue into tragic prominence. Reluctance to delay that launch was one of a complex of organizational factors that led to the disaster. Since then, the agency has improved its FRR process and practice to ensure all technical issues are heard and discussed, and that "launch fever" does not drown out voices expressing concerns about unresolved

Technicians review their checklists after joining NASA's NuSTAR spacecraft with the Orbital Sciences Pegasus XL rocket.

Photo Credit: NASA/Randy Beaudoin



An Orbital Sciences technician completes final checks of NASA's NuSTAR inside the Orbital processing facility before the Pegasus payload fairing is secured around it.

Photo Credit: NASA

risks. (See "Getting to 'Yes': The Flight Readiness Review," by Matthew Kohut and Don Cohen, in the Winter 2010 issue of *ASK Magazine* for the story of a series of FRRs and technical work done before STS-119 was cleared for launch.)

Virtually everyone involved with NuSTAR agrees that technical teams got strong support for doing the work necessary to ensure a successful launch. Some individuals say they heard "mixed messages" from leadership—both "take all the time you need" and "hurry up and get it done." Certainly the desire to solve the problems and launch as soon as possible was clear, but the strongest and most consistent message seems to have been "do it right."

NuSTAR mission manager Garrett Skrobot recalls the meeting where Ryschkewitsch said, "If you guys need the time, take the time to do it right." Recalling the delay discussion later, Ryschkewitsch commented, "It was a hard conversation, but not really that hard"—suggesting that, although no one welcomes a launch delay, it was clearly the right choice in this case.

Mike Luther, deputy associate administrator for programs in the Science Mission Directorate, communicated the same message, saying, "We won't launch until we're ready."

Amanda Mitskevich notes that the project carried out regular extensive teleconferences with stakeholders about progress on the technical issues. The entire NuSTAR community (which included Goddard Space Flight Center, Jet Propulsion Laboratory, Orbital Sciences, and NASA Headquarters, among others) knew what was happening: why the delay was necessary and what was being done to resolve the software issues. So there were no groups within NuSTAR pushing for an earlier launch or expressing frustration because they were out of the loop and did not understand what was going on.

As a result of extensive support and good communication, Mitskevich believes, the teams working on the technical issues were not especially burdened by what she calls "additional pressure" to solve the problems faster—that is, in addition to their own internal drive to do the work thoroughly and as quickly as possible.

As soon as the specific nature of the difficulties came to light, the Orbital and NASA engineering and management teams blended complementary technical approaches to identifying and solving problems. The mutually reinforced technical rigor overcame problems in a relatively short time, while the management teams cooperated to delay the launch to give the engineers the breathing room they needed to implement all necessary fixes and validations.

If Orbital was initially largely "reactive" to NASA's concerns, it soon became much more proactive and constructive. What could have been an adversarial situation developed into a partnership. Both Orbital and NASA software teams worked "tremendous hours" to solve the problems, according to Baez.

And Orbital began reviewing simulation software for other vehicles on its own initiative.

Later in the spring and comfortably before the rescheduled launch date, NASA and Orbital had made enough progress to be confident they would be ready to OK that June launch.

Some Lessons

Baez notes that the NuSTAR experience was "a software education for a lot of people." Certainly the problems were a reminder that software has grown to be an increasingly complex and absolutely critical element of all space missions. Failing to give it the attention it deserves invites disaster. (For a good analysis of this issue, see "Is Software Broken?" by Steve Jolly in the Spring 2009 issue of *ASK*.) The generally high morale of the NuSTAR technical team was tempered by the nagging suspicion that if software testing had occurred sooner—a prudent approach for new code and simulation tools—many of the problems could have been caught and corrected earlier.

In the case of Pegasus, NASA and Orbital failed to fully anticipate the difficulty in maintaining communication, continuity, and comprehension of the full software and simulation as a coupled system. This complexity added to the now obvious rationale to start simulation and software testing sooner.

The more general lesson, Skrobot points out, is that *any* new element in a launch vehicle should be looked at as early and as thoroughly as possible. Figure out what the hard questions are, says Skrobot, and ask them.

Toward a New Way of Working

The NuSTAR launch delay experience is important beyond this particular mission because it is a step toward defining NASA's developing working relationship with the commercial providers of launch vehicles and spacecraft that will be an important part of NASA's future. Both NASA and those companies are in the process of learning what they need to do—individually and together—to produce launch vehicles that are reliable but also relatively economical and profitable for their creators.

NASA has never developed rockets on its own, of course. Boeing, Douglas, Lockheed Martin, and other aerospace companies have had a major role in designing and building the Atlas, Saturn, Delta, and other launch vehicles the agency has depended on until now. But those vehicles were the products of extremely close (and expensive) cooperation between NASA and those contractors. In effect, those vehicles were jointly designed and extensively tested by both NASA and contractors.

Today, commercial companies like Orbital Sciences and SpaceX are building new rockets with much less direct involvement and oversight from NASA. The agency needs to be sure that these new vehicles are reliable, but must do it in ways that allow those companies to keep their costs down, ultimately reducing the cost to NASA as well.

In other words, NASA needs to develop—and is developing—some version of what Ryschkewitsch calls "parenting mode," trying to find the right balance of guidance and help on one hand and letting commercial providers make and correct their own mistakes on the other. Being too involved—asking for too much documentation or too much testing to prove reliability—reduces risk but drives up cost when the rationale for the new relationship with commercial developers is to find less expensive ways to send cargo and crews into space.

The NuSTAR experience is helping NASA *and* Orbital learn to define that balance. For a time, NASA may have been *too* hands-off in regard to the software issues. As Skrobot suggests, it is important to ask the hard questions. The lesson for NASA may be to carefully target its "parental" oversight—to identify the potential problem areas early and focus attention and resources on them. Asking tough questions about everything would be intrusive and wastefully expensive; asking the right tough questions is essential. Knowing what those questions are is not necessarily easy, though, except in hindsight. James Wood, LSP chief engineer, says, "I don't know how to ask the mythical 'hard questions' and neither does anyone else."

As NASA reduces its traditional high level of oversight, Orbital and other commercial providers need to ensure *they* devote the resources necessary to ensure vehicle reliability. Having a relatively lean team is important to efficiency and therefore profitability, but they need to know when lean is too lean. As NASA's "parenting" becomes less intrusive, their responsibility for quality and performance increases.

Testing or Flight Success

There are, notes Ryschkewitsch, two ways of determining acceptable risk: testing and documentation, or a history of flight success. Seventy to eighty successful Soyuz flights are a reasonable substitute for a lot of testing and documentation. Vehicles recently developed or under development obviously don't have that kind of flight history. Building a record of success through flights whose failure would not harm crews or programs is one strategy for developing the next generation of vehicles. So, for instance, NASA was willing to let SpaceX take responsibility for the launch of the Falcon 9 and Dragon that carried cargo to the International Space Station in May and October 2012. NASA's main involvement was ensuring that the approach and docking would work and not endanger the station. The success of that flight is (ideally) the beginning of a track record that will give NASA confidence in the reliability of a vehicle designed without extensive agency oversight.

Photo Credit: NASA/JPL-Caltech/UCB

The L-1011 "Stargazer" carrier plane that gave NuSTAR and its rocket a lift to their airborne launch site is seen at sunrise on Kwajalein Atoll in the Pacific Ocean. NuSTAR and its Pegasus XL rocket are strapped to the bottom of the plane.

Similarly, the successful NuSTAR launch helps build confidence in the current version of the Pegasus. That success and all the testing done are important preparation for the next Pegasus-based mission. The fairing analysis done for NuSTAR similarly will serve future missions. As part of the analysis, the NASA team removed a tiny piece of the frangible joint of the Pegasus fairing hardware to test its hardness. This made NuSTAR people unhappy, as would any change to their launch vehicle, no matter how small, but the information gained will benefit the Interface Region Imaging Spectrograph, which is expected to launch via Pegasus in 2013, and later missions.

But the flight-success criterion is not always as straightforward as it sounds. Pegasus had been in operation for more than twenty years before the NuSTAR launch and has had more than forty successful flights—the kind of success record that normally inspires confidence. But the modified fairing design and new flight computer and software had *not* been flight tested and therefore needed oversight. And this is far from a unique or even an unusual problem; long-lived launch vehicles frequently have some elements that become obsolete or unavailable and must be replaced—and tested to ensure their reliability.

An additional way to manage the new oversight relationship, Ryschkewitsch suggests, is to have NASA engineers sit in with commercial designers as companies develop their new vehicles or new vehicle elements. If the NASA people are satisfied with the design process and testing within the company, they recommend the appropriate (limited) amount of documentation NASA should require.

Shaping a New Partnership

Whatever ultimately characterizes the relationship between NASA and the developers of future launch vehicles, it is certain that it will be shaped by experiences like NuSTAR and the Falcon 9 program. The general outlines of what will be required are clear now—less control by NASA, more responsibility taken on by the commercial companies. But precisely how the partners should work together—the details that fill in that general outline—can only be developed through multiple experiences of facing and solving problems like the NuSTAR software issues.

Since every NASA mission has some unique elements, that learning process will continue, with better and better understanding of the potential and pitfalls of the new relationships. In the new environment the agency is operating in, NASA's Launch Services Program is both the pathfinder and the partner in a new way of working. ●

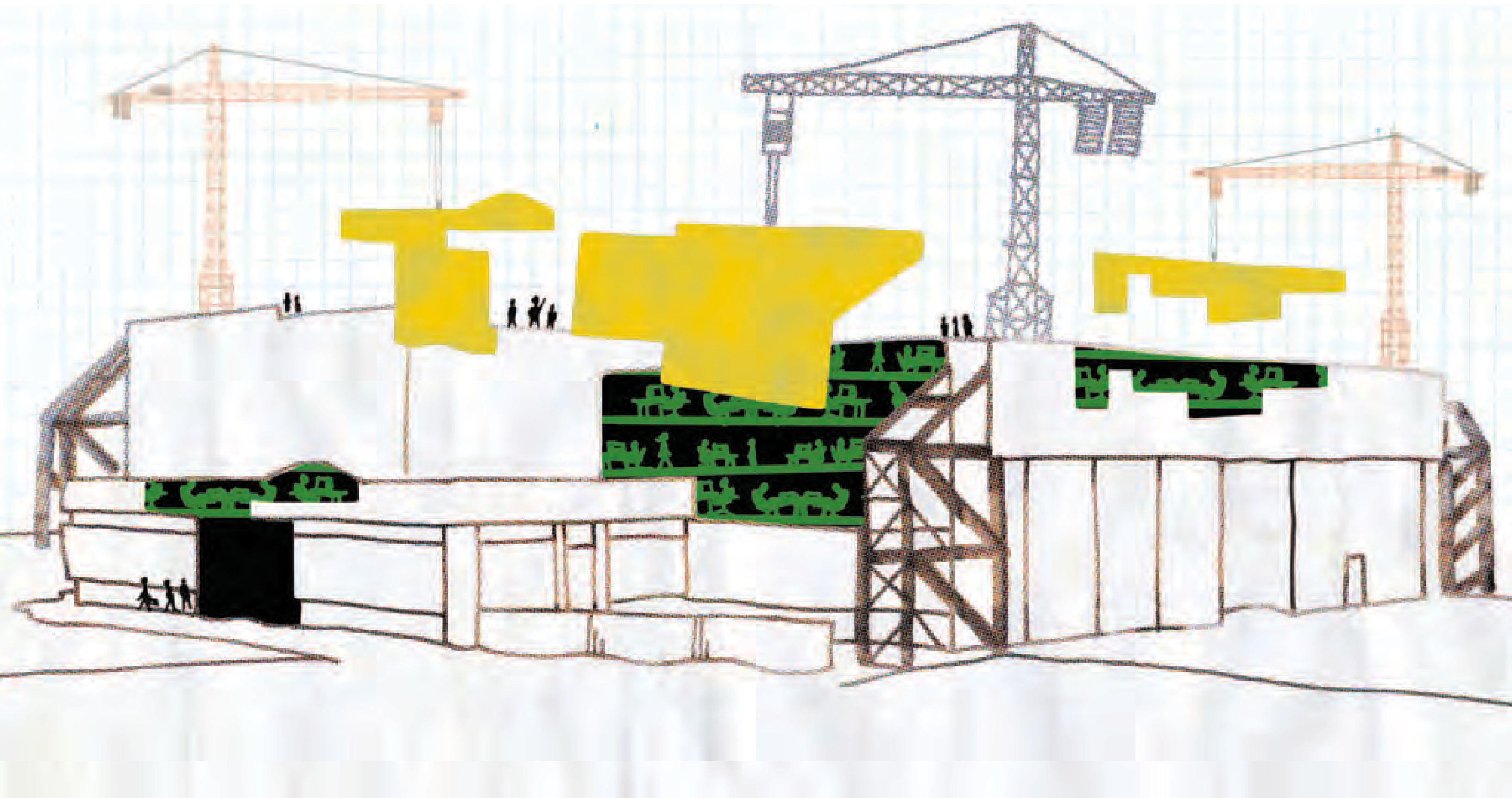
Changing the Project Execution Culture at NASA Dryden

BY THOMAS J. HORN

A series of audits and workforce surveys at Dryden Flight Research Center in 2009 and early 2010 identified declining on-time performance and workforce morale as major issues at the center. Dryden's senior management decided that something had to change in the way we managed our projects.

The center has been delivering high-quality flight-research projects for more than six decades. Budget realities and changing mission assignments have changed the center's focus from a relatively small number of major flight-research projects to a plethora of airborne science missions and generally smaller (in terms of budget, staffing, duration, and research focus) research projects. Old ways of tracking and managing the center's work were no longer effective and workforce stress was skyrocketing.

Dryden was the poster child within the agency for high levels of multitasking both at an organizational and individual level. Change had to happen and had to be deeper than using some new software tool to gather data to tell us what we already knew. That had been tried before. Real change also had to change the project management philosophies that had guided successful operations for many years. This wasn't going to be easy.



TO CHANGE THE PERCEPTION THAT RAISING ISSUES WAS PUNISHMENT, MANAGEMENT ALTERED HOW WE PROBED THOSE ISSUES. AS AN ENGINEERING AND RESEARCH ORGANIZATION, WE TENDED TO ASK "WHY" THINGS DIDN'T WORK THE WAY WE EXPECTED. BUT "WHY" QUESTIONS GENERATE DEFENSIVENESS AND CAN TURN DISCUSSIONS OF ISSUES INTO INTERROGATIONS.

Dryden's senior management chose to implement the tools and philosophies of critical chain project management. (A web search will provide many sources of information on CCPM.) I was asked to lead that effort through the first year of implementation. As expected, we experienced challenges during that initial phase. I hope this description of Dryden's experience will provide some valuable lessons for others.

Facing Workforce Resistance

The first two challenges we faced were directly related to the central CCPM tenets of rapid issue resolution and limiting the amount of "work in progress" at any given moment. Management's efforts to probe issues surrounding slow progress on projects were perceived as punishment. Efforts to limit work in progress generated perceptions of micromanagement in a workforce that prided itself on keeping "all the plates spinning." We did not intend either to punish or micromanage, but those perceptions led to resistance in communicating issues up the management chain and even reluctance to communicate information about what work was being done.

Regardless of our good intentions, we could not simply figure out what was wrong with the workforce and then change it. In fact, we could only control, and therefore change, our own behaviors and actions with the hope that those new behaviors and actions would change workforce perceptions.

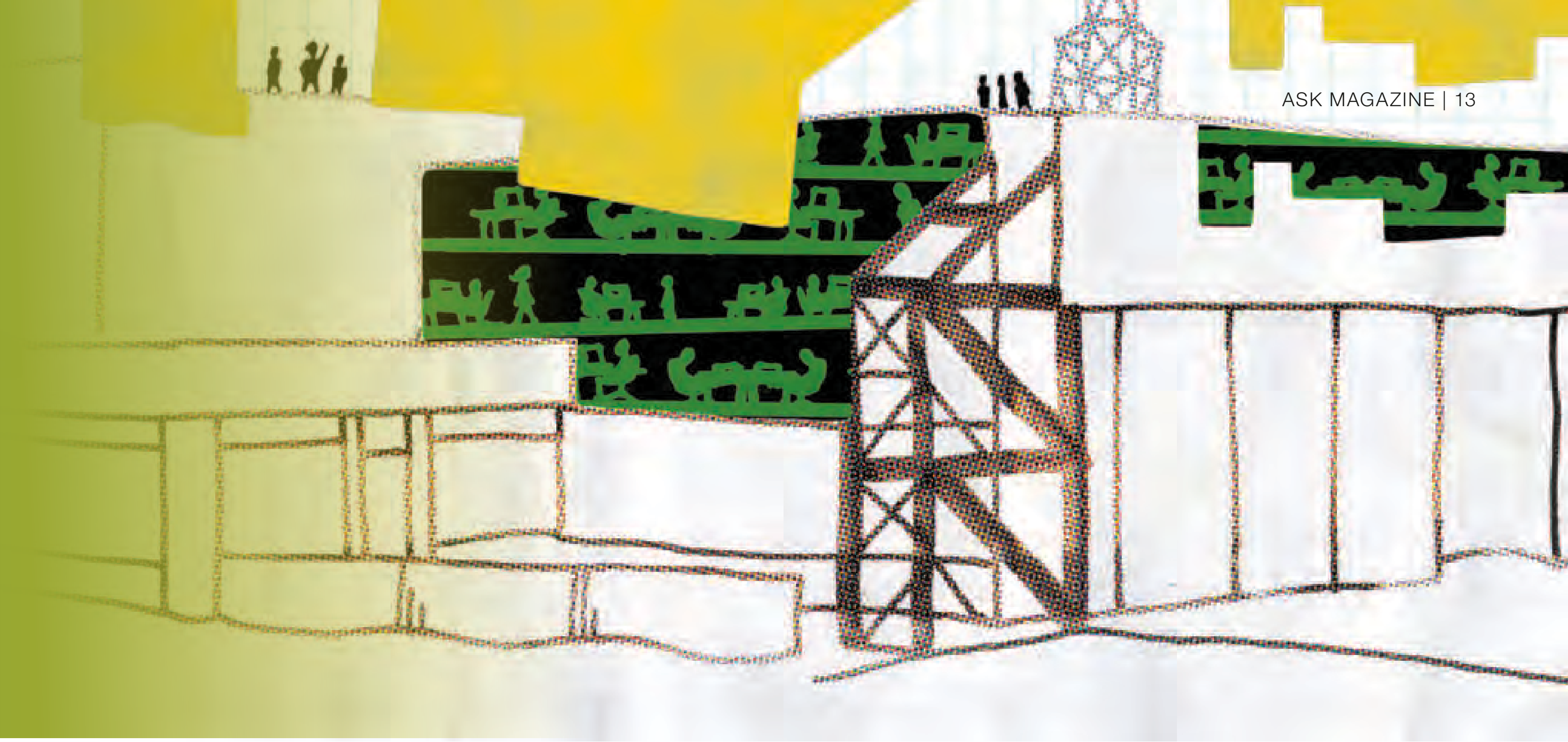
To change the perception that raising issues was punishment, management altered how we probed those issues. As an engineering and research organization, we tended to ask "why" things didn't work the way we expected. But "why" questions generate defensiveness and can turn discussions of issues into interrogations. Turning "why" questions into "what" questions tends to focus the conversation on understanding the issue and moving forward—as long as we stay away from questions along the lines of "what were you thinking?"

A second key behavior is to provide timely help to resolve issues. Perceptions change when the workforce sees issues being effectively resolved before they become big, difficult problems.

Early in our CCPM implementation, one of our flight projects needed to replace a faulty pressure transducer required for research. This issue was identified at our weekly center work review as preventing progress on the project. Questioning focused on what was needed to acquire the replacement. Much to everyone's surprise, the director for Research and Engineering said he had sufficient funds in his budget to cover the $1,500 cost and told the project to submit their purchase request. This seemingly simple resolution made everyone in the room sit up and take notice: raising the issue resulted in concrete, immediate help instead of an inquisition.

The perception of micromanagement is much harder to change. Any change—not just the work scheduling aspects of CCPM—can arouse feelings of micromanagement as organizational leaders try to prescribe, motivate, enforce, and otherwise develop new processes and behaviors. Large changes are often, if not usually, driven by long-term goals that may not begin to manifest their benefits at the workforce level for months or years.

Dryden's CCPM implementation has several long-term goals associated with reducing workforce stress and other workforce issues. When the workforce didn't start to see those benefits after a few months of implementation, the micromanagement sentiment began to increase. I believe this situation must be dealt with in the change-planning process by carefully crafting



not only long-term goals but goals and expectations throughout the implementation process. The workforce needs to be able to see progress and ideally reap some benefit throughout the whole process. For example, Dryden's CCPM implementation may have benefited from more easily achieved and recognized goals of providing desktop access to task-priority information and upcoming tasks followed by individual multitasking targets. The ultimate goals of better on-time performance and increased time for research and skill development should have been de-emphasized in favor of nearer-term expectations.

In Dryden's case, the implementation of CCPM was intended to improve the performance of the center in part by improving our ability to move people between projects. This runs counter to Dryden's previous culture of dedicated project teams, each trying to get its project done without much consideration of their impact on other projects. In addition to the pride and *esprit de corps* felt by a Dryden project team as their project literally takes flight, there are issues of insufficient technical depth and knowledge loss encountered when people shift from one project to another.

The focus of pride and *esprit de corps* can be widened to include larger organizational goals through the choice of metrics and rewards. For instance, lateness may be measured as an aggregate organizational metric instead of an individual project metric. Rewarding individuals and projects that sacrifice a little schedule performance on their project to help another struggling project is another important strategy.

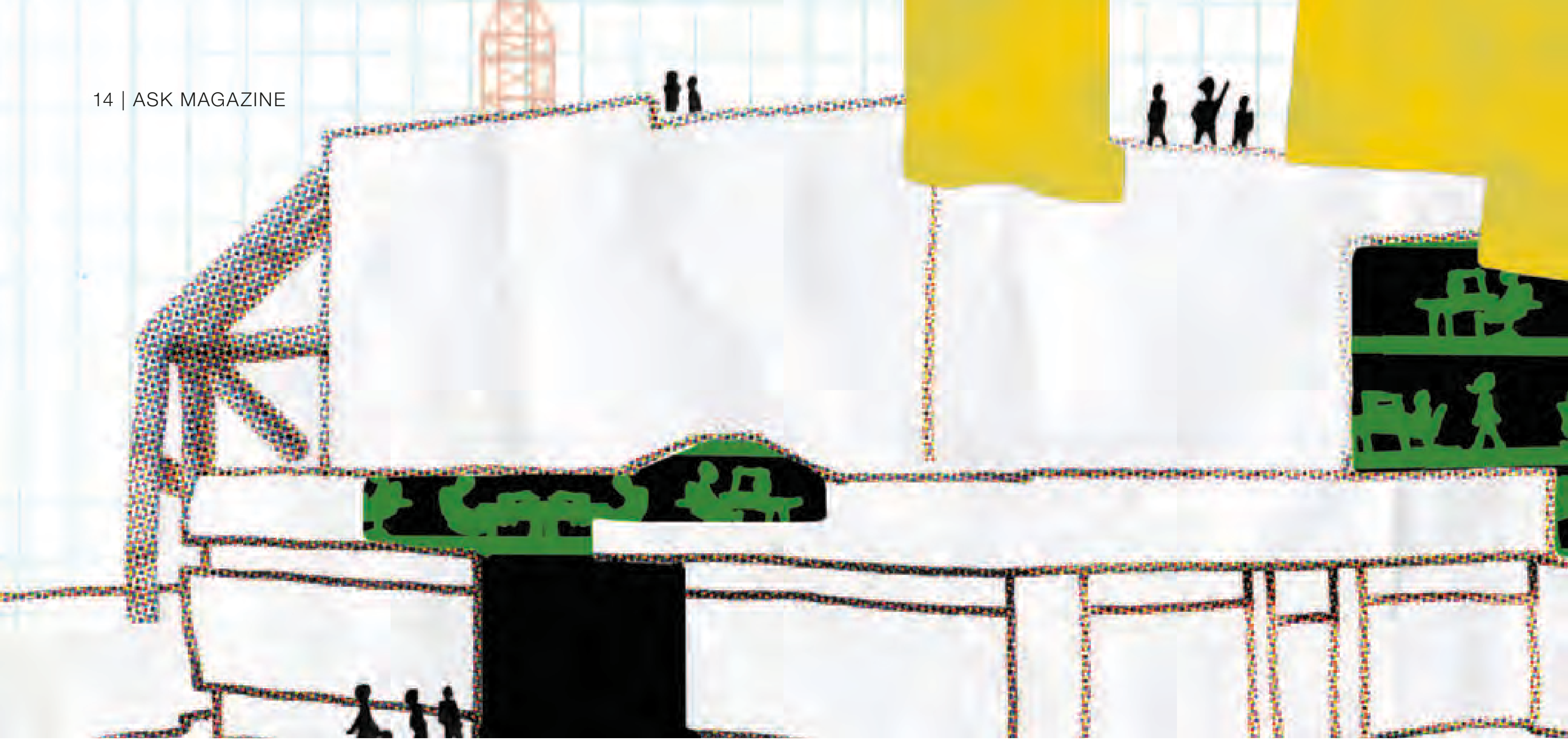
The issues of technical depth and project knowledge are far harder to deal with and can have dire safety and productivity consequences if not managed appropriately. Cross-training of the workforce and proper phasing of the organization's work can help maintain the necessary levels of expertise on each project even when skilled team members move to other projects. Our CCPM implementation has highlighted areas where cross-training would be of benefit, and it has occurred in some areas. Widespread cross-training has been limited by the costs (course tuition and time) associated with that training, however. Phasing of the work has been much more prevalent. As a branch manager, I have much better information at my fingertips to help me phase work within my branch as well as to anticipate and prepare for periods of high demand in the future.

Learning from Change

Change usually comes in the form of doing something new and different—a step into the unknown. We therefore want to make sure every detail is right before we step off that ledge so the change doesn't cause unnecessary problems and turmoil in the organization. Unfortunately, trying to get every detail right can lead to "paralysis by analysis," burdening management and the change-implementation team and ultimately preventing rather than preparing for change. Furthermore, getting every detail right isn't really possible when those non-deterministic systems we call "humans" are involved.

There are certainly some "showstopper" issues and large-scale business practices that must be dealt with prior to implementation. We should focus energy on those things that might cause the whole organization to grind to a halt.

In the case of our CCPM implementation, accurate but not overly detailed schedules were needed to provide prioritized task lists for managers and team leaders. It was therefore necessary to have a process and resources available for efficiently building and revising project schedules before going "live" with CCPM.



Rather than wasting time before implementation on imagined issues that might not actually manifest themselves, we should let the implementation itself tell us which details need attention. The key is having implementation team capacity and a plan in place to deal with the inevitable issues that arise during early implementation. Having processes in place to collect questions and problems, evaluate them, and act quickly to resolve the significant ones is critical. It is also necessary to have the capacity to coach new behaviors and revisit pre-implementation training when "book learning" meets reality. Finally, the implementation team must include people who have currently or recently performed the affected functions and understand the change being implemented. Those people have the best chance of understanding when pre-implementation planning has reached the "good enough" point. Also, they have the respect that is critical in leading their peers through the change.

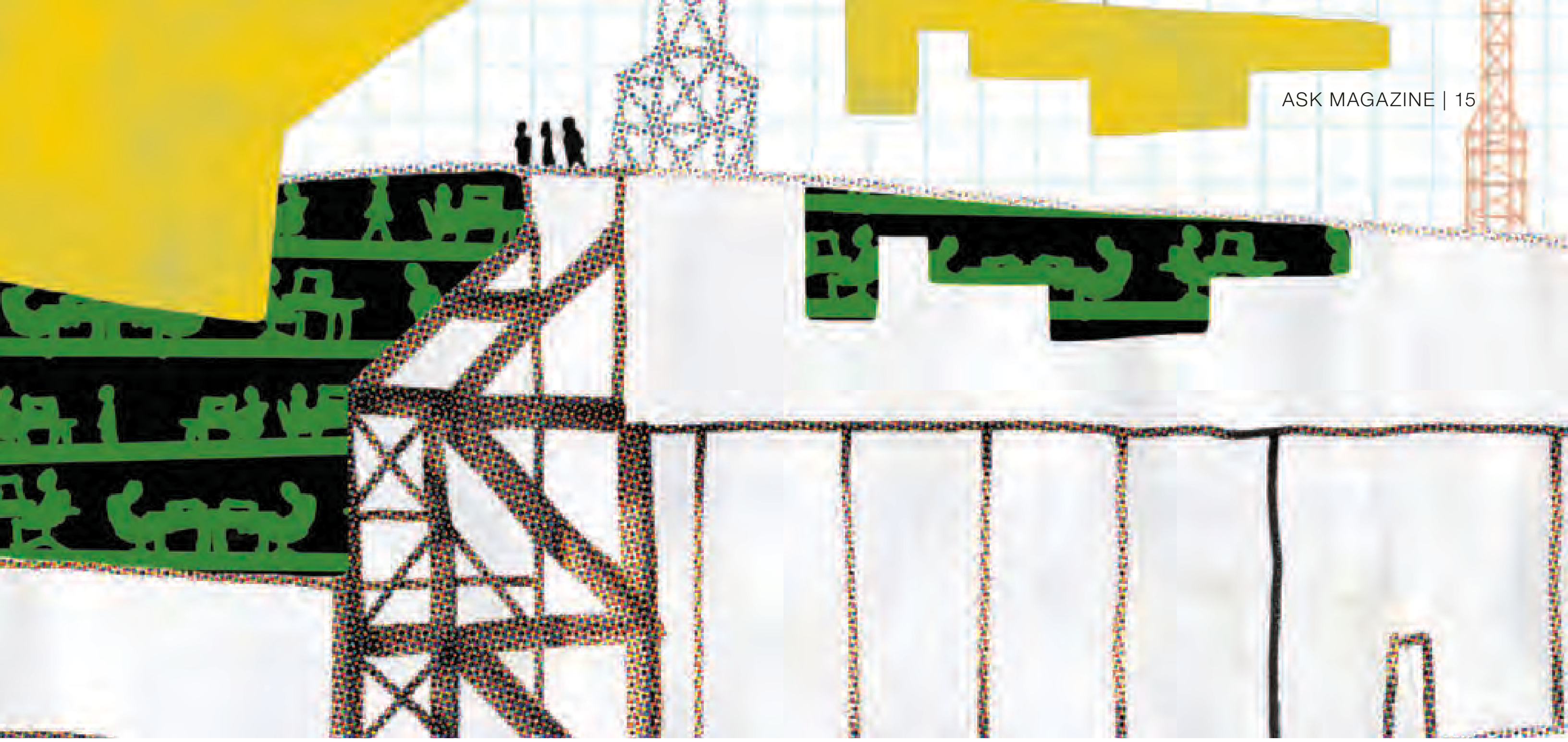
The final two challenges I want to address are phased implementation and the ability of the organization to focus long-term attention on the change. Phased implementation, though sometimes necessary for any number of reasons, has certain negative effects that a "cold turkey" implementation would avoid. A phased implementation prolongs the change process and sets up situations where different parts of the organization operate under different rules. In the case of Dryden's CCPM implementation, most of our airborne science missions were to be phased into CCPM *after* the initial implementation, which included our aeronautics research projects. This was due to the limited capacity of the implementation team and the different character of the science projects. Aeronautics research projects were prioritized based on predicted lateness while airborne science projects received no such daily prioritization. It was therefore difficult for managers and team leaders to judge the relative daily priority of tasks across Dryden's full portfolio of projects.

We learned these lessons about phased implementation:

- If a phased implementation is absolutely necessary, carefully define the scope of the essential phases to minimize the number of suborganizations that have to operate both in and out of the change.
- Whether phasing implementation or not, always err on the side of overestimating required implementation resources.
- Eliminate old processes, procedures, and ways of doing business as quickly as possible. Leaving pockets of "old ways" in the organization will only put drag on the change effort.

Increasing the duration of change implementation through phasing only makes it more difficult for organizational management to maintain needed focus on the change. Issues surrounding budgets and staffing levels and demands from Headquarters will necessarily draw management's attention away from the change effort. They will likely leave it in the capable hands of their implementation team. But that team still needs management attention to approve process and procedural changes, maintain ownership of the implementation design, and generally promote and champion the change.

It is important for a senior manager and her organization to be responsible for implementing and sustaining the change. An *ad hoc* implementation team is still important, though, to provide extra staffing to push the change design and implementation and bring affected organizations into the process. Management must lead the change by example, and only management has



the authority to change the underlying rules, processes, and procedures of the organization.

Progress and Lessons

After nearly two years of implementation, Dryden is still working to fully implement the processes and philosophies of CCPM in all its projects. Several things have helped achieve the desired change:

- Having representation from each affected directorate on the initial implementation team
- Providing solutions when issues are raised
- Management taking ownership and responsibility for continued implementation of the change

Some things I would do differently if I were doing this work over again:

- Instituting near-term goals, metrics, and rewards for the initial implementation to provide motivation through the challenging times of initial implementation
- Including two representatives (instead of one) from each affected directorate on the initial implementation team; this would allow one to focus on solution design and the other to focus on training and coaching

I want to leave you with some key points that I hope will make your next change implementation more successful:

- True change that significantly improves the performance of our organizations comes from changing how people think about and execute their jobs at all levels of the organization. This is hard.
- It takes a lot of resources, particularly people, to implement the change. Don't underestimate those requirements.
- Choose near-term and ultimate goals, metrics, and rewards carefully. They need to be constructed to demonstrate and celebrate early progress toward ultimate goals and drive the desired new behaviors.
- Once change is launched, execute implementation quickly. Purge old ways of doing business from the organization and make the new philosophies and tools the way the organization operates.
- Senior management must lead the way through communication and action. Questions to their staff should force people to think about going forward into the change, not looking back to justify past actions. ●

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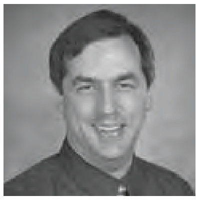


SCaN TESTBED:

BATTLING FLIGHT-SCHEDULE "KILLERS"

BY ANN OVER

System thermal-vacuum testing performed on the SCaN Testbed.

Photo Credit: NASA

The Space Communications and Networking (SCaN) Testbed (STB) is a flight and ground system delivered on a fast-track schedule by Glenn Research Center. As its name suggests, the SCaN Testbed is a technical and programmatic advancement of communications technology that will pave the way for future space-communication architectures. It consists of reconfigurable software-defined radios that give mission planners the ability to change radio functionality while on orbit.

The STB team overcame many "schedule-killing" technical issues to meet the launch schedule. They succeeded thanks to careful schedule management, heroic technical efforts, and a bit of luck.

At the time of the preliminary design review (PDR), the team needed to design, fabricate, and assemble almost one thousand pounds of flight hardware and half a million lines of software code for shipment in less than two years. To add to the complications, two of three software-defined radios were obtained via cooperative agreements, which were not traditional contracts with incentivized deliveries. SCaN Testbed was the first International Space Station payload installed on the Express Logistics Carrier on orbit, and the Japanese H-II Transfer Vehicle (HTV) interface was a new design.

Schedule management did not come easy. Because STB was "just a technology project," not one of the more visible science missions, the scope of the effort was readily underestimated. Just prior to September 2009, at the time of the PDR, the schedule had four months of "negative slack." In other words, if all went right, STB would miss its scheduled ship date by four months.

At that time, the team adopted a new philosophy that infused the project for the rest of the development cycle. The schedule was optimized to fit the available hardware and software by challenging traditional NASA testing paradigms. For example, we were told you cannot do tracking and data-relay satellite system compatibility testing until the entire system is assembled. We conducted most of our compatibility testing before antennas were installed, accelerating that test by more than six months. That new approach created a positive two weeks of margin.

Two other management techniques were deployed to maintain the schedule. First, schedule risk consequences were analyzed and ranked in terms of weeks, rather than months, as for most NASA schedule risks. Second, an aggressive tracking, reporting, and corrective-action system was put in place. Weekly schedule meetings focused on the critical tasks, milestones, and interface points that were drivers for the next two weeks of work. If a date slipped, a corrective-action plan was presented and approved on the spot. A key tenet was delegation of authority and resources to the subproject managers (work breakdown structure leads) and their test managers for critical tests. This rigorous schedule management demanded discipline, hard work, and emotional perseverance. Many times it was one step forward, two back, and the team often worked overtime to get that "step" back. Finally, through it all, there was humor—you just had to laugh because maintaining the schedule seemed so impossible at times.

Most complex spaceflight developments have technical challenges and issues. STB had more than most, each one capable of killing the schedule. The schedule was certainly wounded more than once. The team was ultimately successful thanks to four factors: exemplary guidance and execution by the chief engineer; passionate commitment by the team; proactive reaching out to the wider community of experts to solve issues; and effective decision making by project management.

Resolving Killer Problems

There were dozens of major issues. These three are representative of the problems and our approach to solutions.

Problem 1: Requirements

The HTV carrier was in co-development with STB, so requirements at the interfaces were not well defined. To save schedule, the radio structural-load requirements were estimated to allow work on them to proceed, but they were set too low. Post-PDR, the first coupled-loads analysis showed the payload system, including the radios, had numerous negative structural margins. Also after PDR, the International Space Station carrier discovered a structural analytical issue that was corrected by multiplying all the launch loads by a factor of 1.6, making the problem that much harder.

The project recovered by conducting a structural test to validate the dynamic model, redesigning the thickness of

Photo Credit: NASA

The SCaN Testbed undergoes system electromagnetic-interference testing.

radiator plates, adding a significant number of fasteners, working with radio vendors to increase loads tolerance via analysis and test, updating the model using a better carrier-interface model, and implementing force-limiting for testing and analysis to achieve flight certification—all hard, time-consuming, painful activities. Force-limiting is a way to concurrently simulate the acceleration and launch forces to avoid overtesting on a rigid mount; force-limiting for analysis is a state-of-the-art practice used to qualify structures when margins are tight.

To save costs, projects often use donated or heritage designs. STB was no different. Given the amount of heritage technology, we attempted to build system requirements from the subsystems, via a “bottom-up” approach. This led to issues later.

We used heritage “flight-qualified” designs from Lunar Reconnaissance Orbiter (LRO), including the traveling wave tube amplifier and the antenna pointing system (APS). The traveling wave tube amplifier, fortunately, was not an issue (a good-news story for heritage hardware). The special challenge was the APS, since it was not required to be safety critical for human-rating on LRO, nor was it designed for our structural or thermal environment requirements.

Recovery involved a significant redesign, including thirteen purchase-order modifications and cost growth from \$3.4 million to \$6.6 million. The entire system schedule was adjusted to accommodate a twelve-month delivery slip, including production of a high-fidelity vibration simulator for system vibration testing and other simulators for system performance testing. But the critical-path schedule never had downtime waiting for the APS; the vibration simulator was a significant cost, but it bought seven months of schedule to allow system vibration testing without the APS.

Here’s the takeaway: Beware of heritage flight-qualified hardware, especially for use in human-rated systems that generally have stricter requirements. Do not use a commercial purchase order if the heritage hardware needs to be modified. This procurement type is not designed for changes and, typically, the contractor takes on more risk and the government pays higher overhead.

Problem 2: SpaceWire

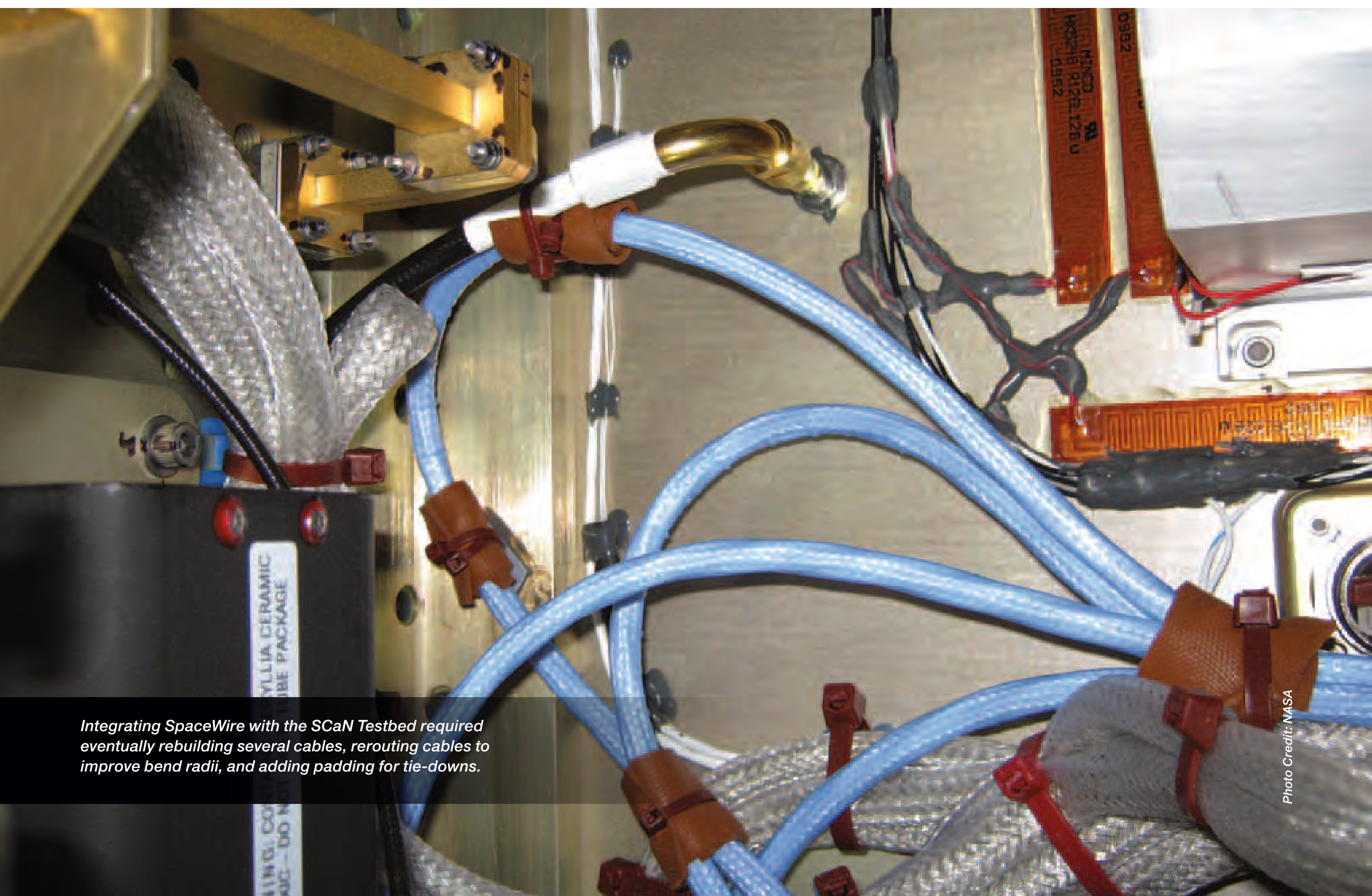
Given very high data-rate requirements and the other NASA successes with SpaceWire, STB chose it for the internal communications architecture. Several issues were uncovered during development. SpaceWire hardware is not robust and interface standards are not mature. The cables failed after simple transportation events, and at one point the high data rates worked but low rates didn’t.

Given that success of the project depended on SpaceWire functioning properly, we took several parallel actions to recover. STB conducted nondestructive and then destructive testing

… BEWARE OF HERITAGE FLIGHT-QUALIFIED HARDWARE, ESPECIALLY FOR USE IN HUMAN-RATED SYSTEMS THAT GENERALLY HAVE STRICTER REQUIREMENTS.

of the hardware at Glenn and the Naval Research Laboratory, and eventually rebuilt several cables (including an *in-situ* replacement while on a vibration table), rerouted cables to improve bend radii, and added padding for tie-downs. Resolution of the data-rate issue that involved both firmware and software was more elusive.

Two generations of tiger teams external to the project team were deployed to investigate performance issues. We consulted experts within NASA and in industry. Using systematic testing and analysis, STB eventually found the major cause of interface incompatibility between the firmware elements. These efforts lasted almost a year. During that time, system testing proceeded using the capability available with very little retesting required. (Retesting would have delayed shipment a year.) For example, a late field-programmable gate array (FPGA) upgrade was necessary after system thermal and electromagnetic-interference testing; recertification was accomplished with analysis and subsystem testing only.

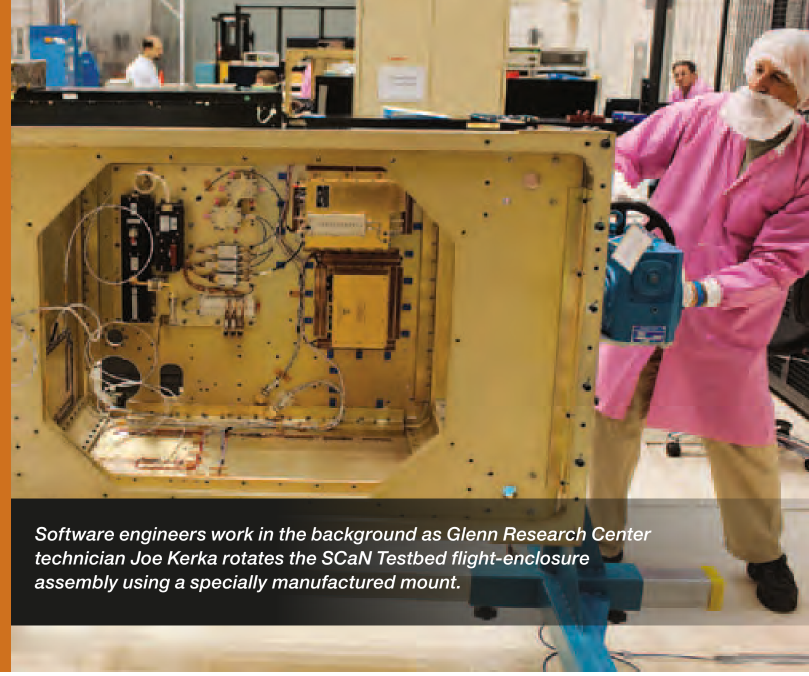


Integrating SpaceWire with the SCaN Testbed required eventually rebuilding several cables, rerouting cables to improve bend radii, and adding padding for tie-downs.

Photo Credit: NASA

… WHEN YOU RUN INTO A TECHNICAL PROBLEM THAT THREATENS MISSION SUCCESS, MOBILIZE ALL AVAILABLE RESOURCES TO SOLVE IT; INCLUDE EXPERTISE OUTSIDE THE TEAM.

Photo Credit: NASA/Quentin L. Schwinn



Software engineers work in the background as Glenn Research Center technician Joe Kerka rotates the SCaN Testbed flight-enclosure assembly using a specially manufactured mount.

Four major lessons: SpaceWire performance is great, but buyer beware, since the hardware is not robust and firmware/software interface standards/algorithms are not mature. Second, for any FPGA use, target FPGAs that are reliably reprogrammable without removal from the system. Third, when you run into a technical problem that threatens mission success, mobilize all available resources to solve it; include expertise outside the team. Finally, past success of components on other missions doesn't mean you won't have problems with them.

Problem 3: Safety

Meeting human-spaceflight safety requirements is one of the hardest engineering jobs at NASA. For STB, the Phase 0/1 flight-safety review was conducted after PDR when the avionics subsystem design was firm, limiting the design options to adequately address safety hazards identified during the review process. A significant new issue was identified for safety during Ka-band operations, requiring flight software to provide two controls to verify power was off when crew or vehicles were within line of sight. If the beam of the Ka-band antenna were to directly line up with an astronaut or vehicle, it could potentially cause personal injury or equipment failure.

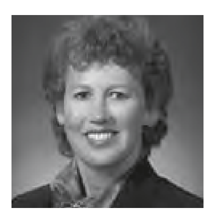
In response, significant project resources were expended to modify the SpaceWire architecture to implement two verifiable and independent inhibits within a single central processing unit (CPU) and to develop the associated safety-critical software. Ultimately, STB became the first space station payload to demonstrate adequate control-path separation for two independent inhibits to be controlled by a single CPU. We implemented this capability incrementally to be able to meet the system testing schedule.

The lesson: Safety requirements should be part of the design process, including input and review external to the project by the applicable safety-certification group. For example, complete the Phase 0/1 flight-safety review before the designs are solidified. Reliance on safety-critical software for primary controls in a human-rated space environment is expensive and time consuming; hardware options are generally easier to design and verify.

Luck Matters, Too

The final factor in the success of the SCaN Testbed was luck. We were lucky that the launch date moved much later to give us time to reduce risk with more testing. We were lucky to have a supportive management within NASA and at the vendors, especially the NASA Headquarters SCaN Program Office and Glenn senior management, who supported us every step of the way, including finding the resources to fix the issues. Finally, we were extremely lucky to have such a dedicated, passionate team, who worked very hard for the mission and—more importantly—for each other.

The NASA and industry partnership proved up to the challenge of meeting an extremely tight schedule. The team overcame many issues to meet the HTV-3 launch schedule. Key to meeting schedule was to make progress with the available functionality and to assign a talented and dedicated team. The testbed was successfully launched from Japan on July 20, 2012, and installed on the International Space Station. Initial checkout operations were also successful and science operations are expected to begin in October. ●



ANN OVER has worked at NASA for twenty-nine years on a variety of spaceflight projects. Most recently she was the project manager for the SCaN Testbed and is now a supervisor of other project managers. She is certified at the senior/expert level for the Office of Management and Budget Federal Acquisition Certification Program/Project Management.

INTERVIEW WITH

Lynn Cline

BY DON COHEN

During her thirty-six-year career at NASA, Lynn Cline led U.S. delegations to the United Nations Committee on the Peaceful Uses of Outer Space and served as NASA's lead negotiator of the agreement that resulted in Russia becoming a partner in the International Space Station (ISS). At the time of her retirement at the end of 2011, she was NASA's deputy associate administrator for Human Exploration and Operations.

COHEN: How did you become lead negotiator for Russian participation in the ISS?

CLINE: I was in the office of international relations, involved in early discussions of cooperation on human spaceflight, when the Soviet Union became Russia. Because I'd done that, my boss decided I should be the lead negotiator for the revision to the ISS agreement that was required to bring Russia in.

COHEN: What was especially challenging about the negotiations?

CLINE: The multilateral dynamics. The original partners with whom we had legally binding international agreements did not want to become an afterthought or be viewed as less important just because they had a smaller budget or weren't providing as large an infrastructure as the Russians. Group relations changed from when you were speaking bilaterally to when you were speaking multilaterally and depending on which combination of partners you had in the room.

COHEN: Was there an element of good-cop bad-cop in the multilateral negotiations?

CLINE: Absolutely. As lead negotiator I most often had to be the bad cop because the original partners—Canada, Europe, and Japan—were nervous that they would somehow lose rights and obligations by bringing in this larger partner. So when we were meeting without the Russians, either multilaterally or bilaterally, I would

"WHEREVER WE WENT, THERE WAS SOMEBODY who organized a dinner OR SOMETHING THAT we could do together. WE GOT TO KNOW WHO WAS married, WHO HAD kids, WHERE THEY WENT ON vacation, WHAT THEIR hobbies WERE."

hear, "You can't let the Russians do this, we insist on that, we can't change this, we must have that." When we got in the room with the Russians they would rely on me to do the talking. There were times when partners would play off of one another's views. I could do it, too. I could tell the Russians, "Gee, I'd accommodate you but then I'd lose the Europeans." Or "the Japanese can't change." The other partners did the same thing. It was a challenge to understand what were the real issues and what were negotiating tactics.

COHEN: What were some of the challenging issues?

CLINE: In the first round of negotiations, before Russia was brought in, there was a provision that said we'd endeavor to minimize the exchange of funds. If the U.S. was going to be the primary operator of the station and everyone was sharing the operational cost, then the partners would need to pay us their share. They did not want to send cash to the U.S. to meet those financial obligations; they wanted to provide goods and services instead. Out of that came things like the European Automated Transfer Vehicle. They wanted to spend their money on jobs with European industry and provide cargo services to pay part of their operating costs rather than send money to the U.S. Once we agreed to that understanding with Europe, Japan wanted to do the same. That's how we ended up with the HTV [H-II Transfer Vehicle], the Japanese cargo vehicle. What we did in the discussions was ensure that the European and Japanese cargo vehicles were quite different to make them complementary. Similarly with the Russians, we did not want to be sending them money and they did not want to be sending us money. So we had to figure out how many things we could barter back and forth to help balance out those financial obligations. We ended up trying to trade off and come out even. We both have a mission control, one in Houston one in Moscow: let's call that even. We both train astronauts: let's call that even. We tried to balance everything out. In the end, there were some remaining financial obligations over and above the things that we traded off.

COHEN: For instance?

CLINE: A lot of it ended up being U.S. payments to Russia for certain things. If we had nothing left to trade against, then we'd pay for it. The first element of the space station that was launched was built by the Russians but actually paid for by the U.S., and in the legal agreement is considered a U.S. element.

COHEN: There were so many moving parts in the negotiations; it's amazing it all came together.

CLINE: It was definitely a challenging and complicated process. Keep in mind that the negotiations took four years to accomplish. The invitation to the Russians to join the partnership officially was issued in 1993, and I guess it was '97 when the negotiations were finally completed. Then the language of the negotiations had to be verified and so on. It was early '98 when the signing ceremony was held.

COHEN: How much time did you spend actually meeting and negotiating?

CLINE: I was on the road very frequently. There were multiple negotiations ongoing. At the top level, I was one of the NASA representatives to the intergovernmental agreement negotiations. That was a State Department–led political multilateral agreement above the space agency–level memoranda of understanding. We met periodically, one meeting in the U.S., one overseas, one in the U.S., one overseas. At the space agency level, they are all bilateral agreements. If Europe asked for changes, I would have to convey them in turn to Canada, Japan, and Russia and get all those countries to agree before I could agree to them. In the end, even though there are separate bilateral agreements, there are certain provisions that have to be identical across the board because you can't have five different management approaches. Since we were meeting bilaterally, it was a highly iterative process. You had to come back to the same points over and over. How many rounds do you have to go before everyone is on board for the same compromise for that particular provision? It was very time consuming.

COHEN: Did you enjoy the process?

CLINE: At times. At times I was ready to tear my hair out. One of the things we agreed to at the beginning of our negotiations—here is a lesson in human nature—was that it would be good for us to get to know each other as human beings outside the negotiating room. We agreed that whoever was hosting a round of negotiations would organize a social event. Everybody would pay their own way. Wherever we went, there was somebody who organized a dinner or something that we could do together. We got to know who was married, who had kids, where they went on vacation, what their hobbies were. It made it a pleasure to work with these people. You could disagree across the table—everyone respected that we were representing what our agencies needed—and then you could leave the disagreements on the table and go out and enjoy one another's company. I made so many friends and learned so many things. I don't regret doing it at all, as difficult as it was.

COHEN: Were there wrong turns or dead ends in the negotiations?

CLINE: The most difficult issue was the allocation for operations and utilization. In the first round of negotiations, before Russia joined the partnership, there was a calculation done of the approximate value of each partner's on-orbit contribution. Everybody had a certain percentage allocation and that percentage number determined how much crew time you got, how often you were allowed to fly an astronaut from your agency. It determined your cost obligation as well. We tried to figure out how to bring Russia into the scheme and could not do it. No matter what I proposed to the Russians as the basis for valuing their contribution, they had a different view. We couldn't figure out how to reallocate all the resources after adding in Russia. That was a major sticking point. We pushed to fully integrate Russia into the rest of the program and make it a single, unified, cohesive international space station. In the end, we backed off and ended up with what we refer to as the "keep what

WE STARTED OUT fighting over principles THAT WE THOUGHT WERE GOING TO BE really important, BUT ONCE PEOPLE START working together AND build trust AND respect FOR ONE ANOTHER, THEY FIGURE OUT HOW TO work together WITHOUT HAVING TO GO BACK TO chapter and verse OF THE AGREEMENT …

you bring" solution. The Russians get to keep all the allocation of operation and utilization resources and obligations for elements that they contributed. On all the rest of the station, we maintained the sharing on a percentage basis from the original negotiations, though the percentage shares evolved over time. That was one issue where we never could reach a common understanding, so we ended up with these two parallel approaches.

COHEN: Does that mean there are resources not shared with the Russians and vice versa?

CLINE: Yes, but the allocation agreements allow for barters of various sorts. As the program evolves and things change, we have made trades across those borders. For example, the U.S. negotiated with Russia for the U.S. to provide power from the U.S. power system to operate the Russian segment elements, rather than them bringing up a whole separate power system. As difficult as they were to negotiate when everything was on paper and hypothetical, those allocations are only starting points.

COHEN: Am I right in thinking that you undertook this work without a technical background?

CLINE: That is correct. My background was French language and culture. I came into the international office as a co-op student when I was in college. As lead negotiator, I was not expected to be the technical expert. I had a whole team: someone from the program office; someone representing the science community; someone from Houston who did a lot of the coordinating with the different elements at Johnson Space Center—the crew office, the safety office, the engineering folks, etc. I had someone from the legal office for all the legal terms and conditions. We had pre-meetings and we had a postmortem after each negotiating session. I relied on the other members of the team to make sure we understood what concerns other organizations at NASA might have that we needed to represent. We had constant feedback on all those sorts of things.

COHEN: So lack of technical knowledge was not a problem?

CLINE: Keep in mind that the agreements at this level are not highly technical. They're more about the management structure, the rights and obligations. In parallel with what we were doing, there were ongoing technical discussions. We did have feedback going back and forth between those two levels. As an example, one of the things in the memoranda of understanding is a list of what each partner is providing. It was pretty well fixed for the U.S., Canada, Europe, and Japan because we had been at this for a while. I had a list of elements the

Russians were going to provide. When I got to the next round of negotiations, I'd be told the list wasn't correct any more because they had discussions with JSC [Johnson Space Center] and decided to change a few things. The technical guys were off doing their technical thing. Sometimes I was ahead of them, and sometimes they were ahead of me. We just tried to keep in communication.

COHEN: In retrospect, would you say the ISS agreements have been an effective basis for operating the station?

CLINE: The framework I inherited from earlier negotiations is flexible. One of the things you need to avoid as a negotiator is getting too precise because things change, especially on a long-term program. Technical issues will arise; the policies of governments will change; administrations will change. I think these agreements have been remarkably flexible. We started out fighting over principles that we thought were going to be really important, but once people start working together and build trust and respect for one another, they figure out how to work together without having to go back to chapter and verse of the agreement and insist on what it says in Article 4, Chapter 3. It just becomes people working together who have a common goal. There were huge concerns in negotiations about would the U.S. ever exercise its right to make a decision even if the partners objected. Those were very important principles during the negotiations and certain rights were part of the agreement. But the fact of the matter is everything one partner does affects the others. The incentives are there to compromise and make things work. Once you get the politicians and the negotiators out of the way and you let the program people run the project, there's a lot of freedom to make the program work the way you need it to.

COHEN: The shared goal is so important.

CLINE: We each came to it with a slightly different perspective and so the goal may not have been flavored identically for every country, but we all shared that vision. The program has evolved and survived some very difficult things. One was the fact that the Russian element—the first element—was delivered eighteen months late, I think it was. That pushed back the entire schedule. Then we had the *Columbia* accident. I think it's amazing that the partnership was strong enough to keep going by relying on the Russians and reducing our crew size to limit the logistics requirements. We came through that and resumed assembly.

COHEN: Are there lessons from this negotiating experience that apply to other kinds of international issues?

CLINE: There are common elements to international negotiations. Some are common sense things: understanding, for instance, what your partner's objectives and needs are. You can't just be a dictator and say, "This is how it's going to be." You have to have that give and take and listen and understand the other person's perspective. A lot of it is basic good communication and building trust and relationships.

COHEN: Aside from good communication and building trust and understanding, are there other lessons you'd pass on to other negotiators?

CLINE: Sometimes what you think is the issue may not be. There were a couple of articles in the agreement that the Russians knew were really important to the United States. They were provisions on which I had zero flexibility. The Russians refused to agree to any of those terms. Toward the end, my counterpart Alex Krasnov and I could have traded places and given one another's speech on one article, we'd done it so many times. When we reached the last round of negotiations, I put on my flak jacket and was ready to go through it again, expecting no change. But the Russians had finally got everyone on board internally; they were ready to sign the agreements. I started on my normal talking points and my counterpart from Russia said, "OK, no problem." I almost couldn't talk for a minute. That happened three or four times. Things that were really tough sticking points for me, that I had no flexibility on, they took advantage of to keep the negotiations going until they got the other things that they needed and did whatever they needed to do domestically to get everyone on board. I thought they really cared about those points, that they really meant it when they were fighting me tooth and nail about all those clauses. They didn't. What a negotiator is telling you across the table might be what they really need but it could also be a negotiating tactic.

COHEN: Before he agreed …?

CLINE: There were times I wasn't sure we

"THE SPACE STATION AGREEMENTS didn't happen magically. THERE WERE years of pre-discussion THAT IDENTIFIED COMMON INTERESTS."

would ever get there because I couldn't come up with any more arguments to use.

COHEN: So the lesson is, hang in there because circumstances may change.

CLINE: Right. And suppose those were points I *did* have flexibility on. I might have compromised and agreed to things I didn't need. If you have a principle that you feel strongly about, it's worth sticking to.

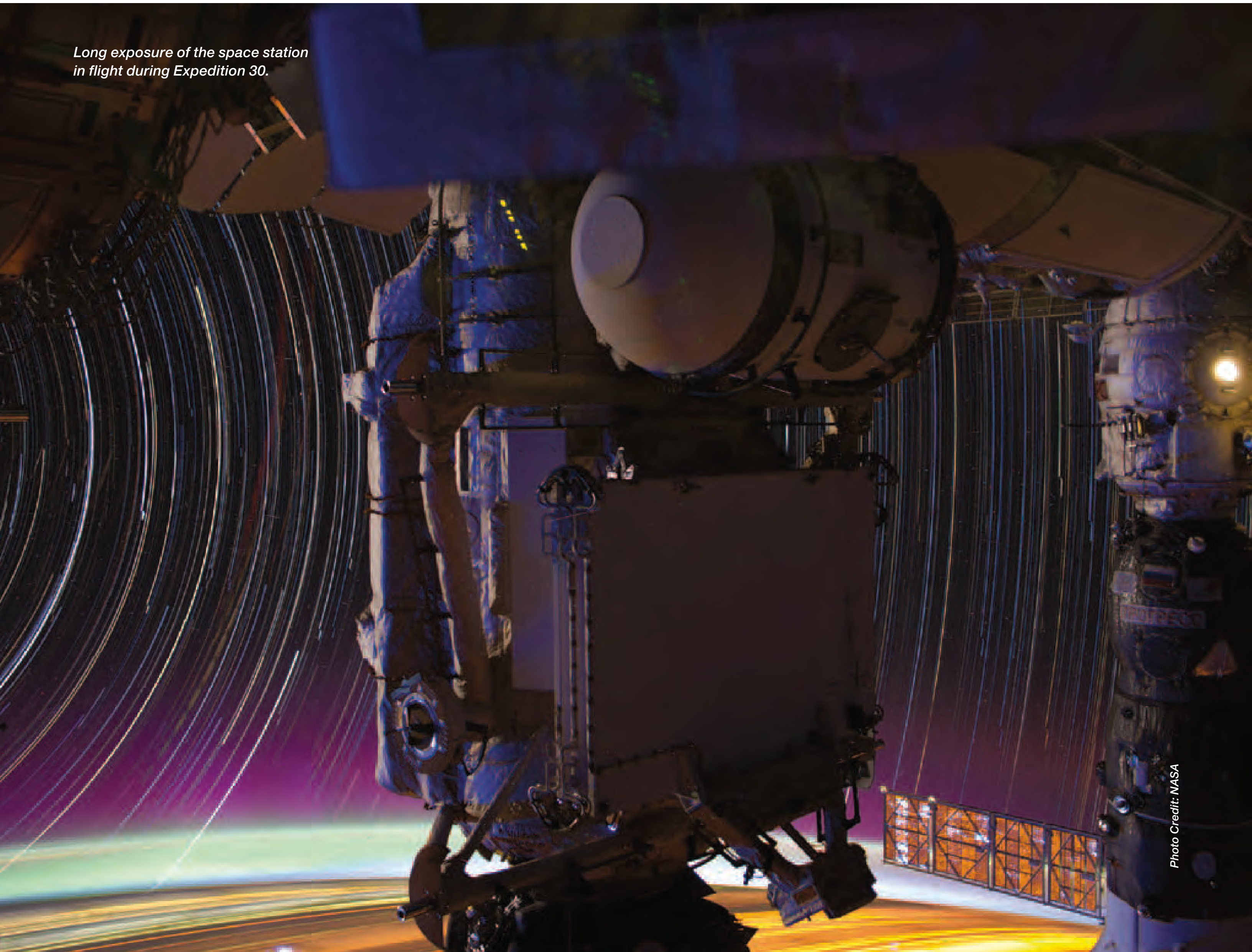
COHEN: Are there opportunities for future international space negotiations coming up?

CLINE: It's not clear to me how soon. The most important thing is to keep the dialogue open so that when real opportunities do become available, you've already built the foundation. The space station agreements didn't happen magically. There were years of pre-discussion that identified common interests. Groups like the International Space Exploration Coordinating Group, which has fourteen space agencies in it, talk regularly about what sorts of things they're thinking about. No one has a specific plan; they're not negotiating agreements. They're carrying on the dialogue. When there *is* a desire to do the next human exploration spaceflight activity, they're poised and ready and know what the various countries' likely interests are and where they can contribute. ●

Beyond the ISS

THIS ARTICLE IS EXCERPTED AND ADAPTED FROM "STRUCTURING FUTURE INTERNATIONAL COOPERATION: LEARNING FROM THE ISS," BY L. CLINE, P. FINARELLI, G. GIBBS, AND I. PRYKE

In September 1988, the United States, Canada, Japan, and ten member nations of the European Space Agency signed agreements that established what was originally the Space Station Freedom (SSF). Renegotiated agreements, which brought in Russia and established the International Space Station (ISS) program, were signed in January 1998. As the largest, most complex international scientific and technological cooperation undertaken, the program offers lessons that can help future large-scale international space endeavors.



Long exposure of the space station in flight during Expedition 30.

Photo Credit: NASA

SOMETIMES DIFFICULT TOPICS NEED TO BE FINESSED WITH LESS-THAN-PRECISE LANGUAGE—LANGUAGE THAT IS OPEN TO INTERPRETATION OR MAY REQUIRE FUTURE NEGOTIATION, BUT THAT ALLOWS NEGOTIATORS TO GET BEYOND AN IMPASSE.

Peaceful Purposes: Constructive Ambiguity

In any partnership, common terms may have different meanings and context depending on the partners' field of expertise, experience, and culture. Creating a common definition can help avoid confusion down the line. For ISS, defining the term "peaceful purposes" from the 1967 Outer Space Treaty, and what activities honored that commitment, differed among partners. The ISS contributing nations debated the exact meaning of this phrase without resolution long before the space station negotiations.

In SSF negotiations, the U.S. Department of Defense insisted they be able "to conduct national security activities on the U.S. elements of the station without the approval or review of other nations," which was consistent with the U.S. interpretation of "peaceful purposes" that permits non-aggressive military activities in space. Canada, Europe, and Japan, on the other hand, demanded the agreements refer to "a civil space station for exclusively peaceful purposes," implying no military-sponsored activity whatsoever. The issue arose again in ISS negotiations, with the Russian Federation government adopting much the same position as the United States.

The solution in both negotiations was that each partner would define "peaceful purposes" as related to the use of the elements it supplied, in its own manner. For example, any U.S. plans to use the laboratories supplied by Europe and Japan have to be approved by Europe or Japan, respectively, based on their own interpretations of peaceful purposes.

Sometimes difficult topics need to be finessed with less-than-precise language—language that is open to interpretation or may require future negotiation, but that allows negotiators to get beyond an impasse. Such "constructive ambiguity" is not original to the ISS agreement, but it is a standard device used to bridge otherwise insurmountable divides in many negotiations.

Barters

Early in ISS negotiations, we knew we would need a way for partners to reimburse each other for various goods and services required for successful program implementation. Once we realized that political processes in various partner states would look unfavorably on the transfer of actual funds, we included language noting the intent to minimize the exchange of funds and permit barters of goods and services.

For example, the European partner required a NASA shuttle launch to deliver its Columbus laboratory to the station. In return, the European Space Agency financed the development and delivery of two station nodes. Europe's investment gets "spent" within European industry, NASA gets two station nodes that do not impact ISS budget, and the Columbus laboratory gets launched: a win–win situation.

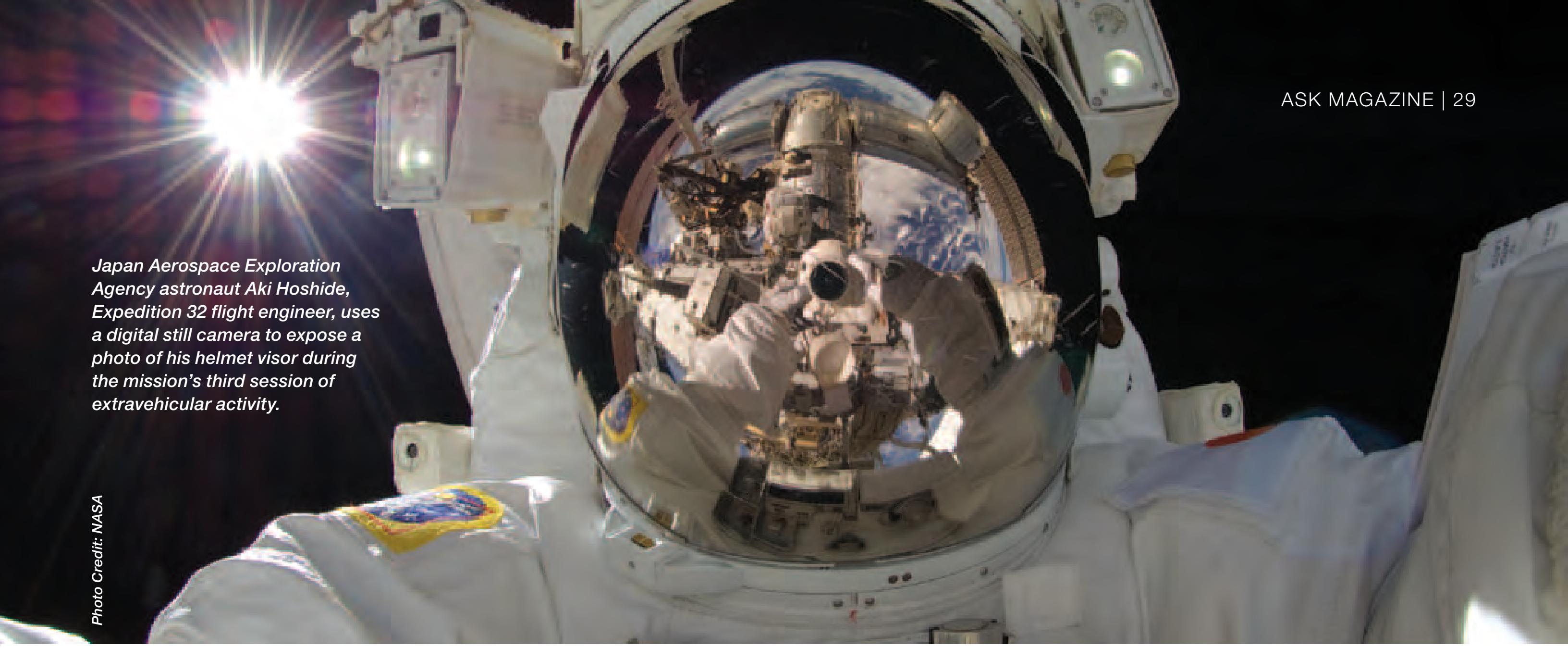
Creating a successful barter network requires partners agreeing that they are not established on a "dollar value versus dollar value" basis, but on perceived equality of the goods and services to be exchanged. Finding barter options within a program may not always be possible; therefore, mechanisms should be established to allow program-related barters to occur outside the program itself.

Bringing in New Partners

One major oversight of the original set of agreements that established the SSF cooperation was the lack of a defined mechanism for enlarging the partnership. The nature of the program made it difficult to accommodate new partners. The ISS is a single, integrated facility with finite resources—especially volume, power, and crew time. We devised a sharing concept to allocate on-orbit elements and the resources among the partners. Because of this construct, the ISS is not a program additional countries can simply join.

When Russia was invited to join the partnership, they had a number of modifications they wanted to see incorporated into the original intergovernmental agreement (IGA). Other partners then came forward with additional suggested revisions, at both the IGA and memoranda of understanding levels.

What was originally hoped to be a minimalist exercise



Japan Aerospace Exploration Agency astronaut Aki Hoshide, Expedition 32 flight engineer, uses a digital still camera to expose a photo of his helmet visor during the mission's third session of extravehicular activity.

Photo Credit: NASA

became a complete renegotiation that lasted about as long as the original negotiation. Planning for new partners should be considered in the beginning when embarking on future cooperative projects; it could help save time and effort down the line.

Commercialization

Another unexpected evolution in the program involves commercialization. The space station agreements expected and provided for commercial use, with partners assuming such activities would require ISS research capabilities in microgravity—such as medical and manufacturing research that would benefit from advances in crystal growth and fluid physics. However, the commercial interests have been quite different and have included advertising and sponsorship, space tourism, and other areas unrelated to the station's research capacity.

This has led to another dilemma. Should each partner permit such commercialization according to its own rules, or is there merit in a common set of guidelines? Another question is whether the ISS can be marketed as a "brand," similar to the way the Olympics have a recognized brand that can be marketed by different companies in return for a fee under an established set of rules.

Russia has filmed commercials onboard the station and has a program to fly paying customers, private citizens who can afford such an opportunity. Another opportunity under discussion includes a visit to the ISS as a prize for the winner of a contest. Is this legitimate commercialization, or inappropriate exploitation of a government-funded facility?

The partners have agreed to discuss common guidelines for commercialization but have not yet reached closure on this matter. When discussing commercial opportunities for future projects, consider that opportunities outside the box might appear and include a plan to address them.

Looking to the Future

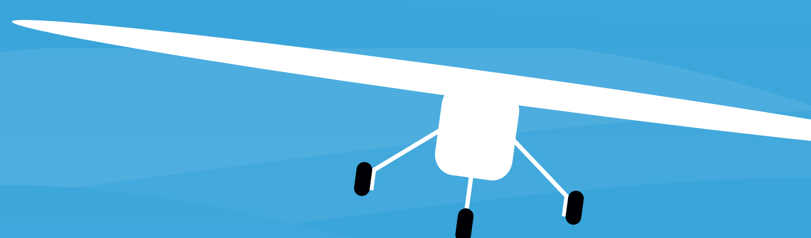
It is optimistic to think one could craft the perfect agreement to flexibly accommodate all contingencies. However, the political decision-makers who approve large investments need to understand and commit to specific program elements or goals. Establishing key parameters is important, but so is including flexibility in such areas as evolution of the program and the addition of partners. Future changes and requirements are not easily predicted, so establish flexibility by defining a process to address downstream changes rather than trying to craft language for every possible new development. Below are some additional elements future negotiators may wish to keep in mind:

- Determining the overarching agreement structure is important. Should it be thoroughly multilateral or would bilateral approaches be more advantageous?
- Giving all partners a voice should be recognized and incorporated in the decision hierarchy, but the need to avoid decision deadlock, especially on operational matters, must also be taken into account.
- Establishing a means for other nations to accede to the agreement, apply for membership, or be sponsored by an original partner should also be considered. Non-partner participation could prove crucial for involving nations that are not major space powers but who wish to be involved in large-scale human spaceflight programs.
- Determining a financial contribution system is also important. Unless defined contributions from the outset are considered the complete "deal," bartering to offset financial obligations can play an important role.

And it's important to keep in mind that, regardless of best intentions, some aspects may have to be renegotiated.

Whether you're establishing agreements or renegotiating, approach matters with an open mind. It's impossible to identify every contingency in advance, but including "flexibility" in future cooperative agreements can help large programs adapt and thrive. ●

PROBLEM SOLVING ON THE FLY



BY MELISSA PANDIKA

Tucked in the northeastern corner of California, Surprise Valley is set amid a high desert landscape dotted with hot springs and dry lakebeds. During the first two weeks of September 2012, a team of scientists and engineers collected magnetic data using ground surveys and an unmanned aerial system, or UAS, to map the geophysics of Surprise Valley, revealing features buried below the surface.

Although some faults and fractures are visible, some remain hidden underground. And even when researchers know where hot springs are located, they want to understand how fluids flow through the network of underground pores and channels.

Investigating this geothermal fluid-circulation system includes identifying faults below the surface that might conduct the hot mixture of fluids and minerals found in the hot springs. These faults also have the potential to rupture during an earthquake. The detailed studies will help refine predictions of how likely and how damaging earthquakes could be in the region.

The U.S. Geological Survey (USGS)-led, NASA-funded project, which includes a second field session scheduled for next year, will produce a 3-D map that provides geophysical data at a level of detail yet to be achieved for the area. The Surprise Valley community and municipal government can also use the map to inform land and water use decisions, since toxic water zones have been identified, as well to help tap the geothermal system as a sustainable energy source.

The team includes scientists and engineers from USGS, Ames Research Center, Central Washington University, and Carnegie Mellon University. Over the years, they've collected a wealth of magnetic data by foot and using small all-terrain vehicles. But the areas they can safely survey on the ground are limited. They can't walk through private lands, dense vegetation, or hot springs, for example.

Geoscientists have typically addressed this challenge by hiring pilots to collect data along a specified flight path. Not only are these manned aerial surveys costly, they require pilots to fly at dangerously low altitudes. That's why the Surprise Valley team has collected data with a small, lightweight UAS known as SIERRA (Sensor Integrated Environmental Remote Research Aircraft). While flying along a preprogrammed path, the NASA-developed SIERRA relays data collected by a magnetometer in its wing to a ground-station computer.

Smoothing Out the Kinks

The first day of an expedition is typically the most hectic. The Surprise Valley team encountered its fair share of issues to troubleshoot.

After the first flight, the wireless communication system set up to download the flight parameter and magnetic data from SIERRA malfunctioned. The team had earlier discussed transferring data directly through a network cable, but with the wireless system, the engineers could avoid directly accessing the aircraft's sensitive instruments. It turned out the wireless system could not withstand SIERRA's vibrations during the flight test. With the wireless system down, the payload team developed a workaround that required the aircraft to be physically tethered to the ground station to download data after each flight.

Meanwhile, the compensation data from SIERRA's fluxgate magnetometer, which takes into account variations in magnetic fields and their direction, yielded highly unusual results. The data from a test of the fluxgate when it was first installed looked reasonable to the team, with variations not far from expected values. They noticed some anomalies, which they believed they could solve only by recalibrating the instrument or remounting it away from magnetic noise, either of which would be prohibitively expensive. The researchers hoped the remoteness of Surprise Valley, away from steel-framed buildings, electric lines, and other magnetic sources, would enable them to perform more precise calibrations to correct for aircraft-related noise.

At the end of the day, the science group—USGS geophysicist and project lead scientist Jonathan Glen, Ames researcher and project lead scientist Corey Ippolito, Carnegie Mellon University researcher Ritchie Lee, and Geometrics engineer Misha Tchernychev—spent hours poring over the compensation data, trying to pinpoint the source of the anomalies. Then an idea occurred to them: maybe the problem was limited only to the fluxgate and not dependent on the aircraft, which they could confirm by examining just the fluxgate in the house. If working properly, the fluxgate's measurements should closely reflect Earth's magnetic field, a known value. If they didn't, then the problem must be due to the fluxgate itself.

The SIERRA crew removed the fluxgate magnetometer instrument from the aircraft and provided it to the science group, who took it home for a long night of troubleshooting.

The science group camped out with the fluxgate magnetometer in the dining room, exhausted yet still talking and joking animatedly. After a few hours, the team discovered that the fluxgate could collect data in two modes—calibrated or raw. The fluxgate was currently in calibrated mode. When the team took measurements in this mode, they saw magnetic field values far from those of Earth. When they switched the instrument to raw mode, they saw the values they expected. Clearly the fluxgate's calibration needed fixing.

Valley of Surprises

Another engineer from Geometrics said he could provide them with a new, properly calibrated fluxgate. He agreed to drop

Geometrics engineer Misha Tchernychev displays a magnetic map of the 30-km magnetic anomaly based on raw data before applying the correct fluxgate calibration. While the edges of this image appear blurry, when Misha applied the correct calibration, its resolution improved significantly.

Photo Credit: Melissa Pandika

it off at a halfway point, in Redding. Meanwhile, Misha and Jonathan would determine the correct calibration themselves by recording the magnetic field strength and direction the fluxgate magnetometer measured as they moved it through a series of maneuvers. This would yield the mathematical relationship between the raw and improperly calibrated versions of the data, allowing them to convert yesterday's data to raw data. The measurements would also enable Jonathan and Misha to determine the correct calibration, which they could then apply to the raw data from the first flight day.

They spent the entire morning on the front lawn, one maneuvering the instrument while the other jotted down instrument readings on a sheet of paper. Misha then fed the readings into a computer program to generate an equation reflecting the relationship between the raw and incorrectly calibrated versions of the data. He then applied the equation to the data from the first flight.

The resulting raw data appeared as a magnetic map, showing an array of colors from bright pink to deep purple, reflecting positive and negative magnetic anomalies, respectively, resulting from magnetic sources below the surface.

Jonathan pored over the map displayed on the laptop throughout the afternoon, every now and then gathering the other USGS researchers around his screen. Meanwhile, Misha holed up at Cedarville Airport, calculating the correct calibration from the maneuvers earlier. He returned a few hours later with the correct calibration applied to the raw data. While the magnetic map based on the raw data was mostly clear, the edges appeared blurry. When Misha applied the correct calibration, the resolution of the map image improved significantly. Because the entire feature was completely buried, the team wouldn't have known about it without geophysical mapping. The airborne data provided uniform spatial-data coverage, allowing them to map the feature in fine detail.

Looking at the data, Jonathan spotted a magnetic anomaly continuing along the same direction as an anomaly he and

DESPITE THE TECHNICAL HURDLES, SIERRA NOT ONLY COMPLETED ITS MISSION ONE DAY EARLY, IT COLLECTED EXTRA DATA FROM A LARGELY UNEXPLORED REGION, ACCELERATING THE TEAM'S UNDERSTANDING OF THE GEOPHYSICS OF THE VALLEY.

Project co-principal investigator Jonathan Glen (lower left) with NASA and Geometrics engineers, troubleshooting SIERRA's malfunctioned wireless system. With the wireless system down, the payload team developed a workaround that requires the aircraft to be physically tethered to the ground station to download the data after each flight.

Photo Credit: Melissa Pandika

Anne Egger of Central Washington University had mapped when they performed a previous ground-based survey of the area. So far, the data hints that the feature may represent a single structure, but the team can't draw any conclusions before SIERRA completes the map.

Knowing whether or not the feature is continuous is important, since the magnitude of an earthquake that can occur along a fault is determined primarily by its length. The longer the fault, the larger the earthquake it causes when it ruptures. A continuous fault also means a continuous channel for geothermal fluids, a dangerous scenario, since a hazardous groundwater zone high in mineral content sits in the middle of the feature. Knowing the feature's structure will help refine predictions of how likely and how damaging earthquakes could be in the region.

As Jonathan continued to navigate through the data, two USGS researchers returned with the new fluxgate, which they handed off to the NASA engineers. That evening, they installed the instrument so SIERRA could fly first thing in the morning.

How a Radio Transmitter Is Like a Funnel

The next day the team felt confident that SIERRA would have a successful flight. But within minutes of takeoff, SIERRA began slowly losing magnetic data. The rate of data loss climbed until the ground base station completely lost the signal from the fluxgate.

Puzzlingly, the UAS had no problem transmitting the fluxgate data while the aircraft was grounded. The team probed the scientific instrumentation for loose cables that might be preventing transmission, conducted an inspection of the aircraft installation, and analyzed the instrument data logs that were recorded during the aborted flight test. Though glassy-eyed, they sounded upbeat as they discussed the issue among themselves, feeling the solution just within reach.

The team's analysis showed that the replacement fluxgate magnetometer was sending messages at a much higher rate than expected. Eventually, they deduced that the new fluxgate magnetometer instrument was misconfigured in the field for the flight test; it was configured to record samples at a much higher rate than it could transmit to the rest of the data system in real time.

SIERRA crew engineer Ric Kolyer likened the issue to pouring water through a funnel. The amount of water that can flow through a funnel is limited by the size of the funnel hole. If water is poured into the funnel faster than the funnel can drain it, the funnel will overflow. Likewise, the fluxgate was sending data to the radio faster than the radio could send it to the ground station. The data overflowed, failing to reach the ground station.

The team reasoned that they didn't have trouble communicating with SIERRA when it was grounded because they hadn't allowed it to run long enough. Using Ric's analogy, water initially flows through a funnel even when it's poured too quickly. Only after the funnel is filled does it start overflowing. Likewise, while SIERRA was aloft, the team initially saw magnetic data being transmitted via the radio link. They didn't begin losing data until several minutes later.

Having pinpointed the problem, the team reconfigured the fluxgate magnetometer's sampling rate, enabling it to sustain communication with the ground base station. SIERRA was ready to fly again.

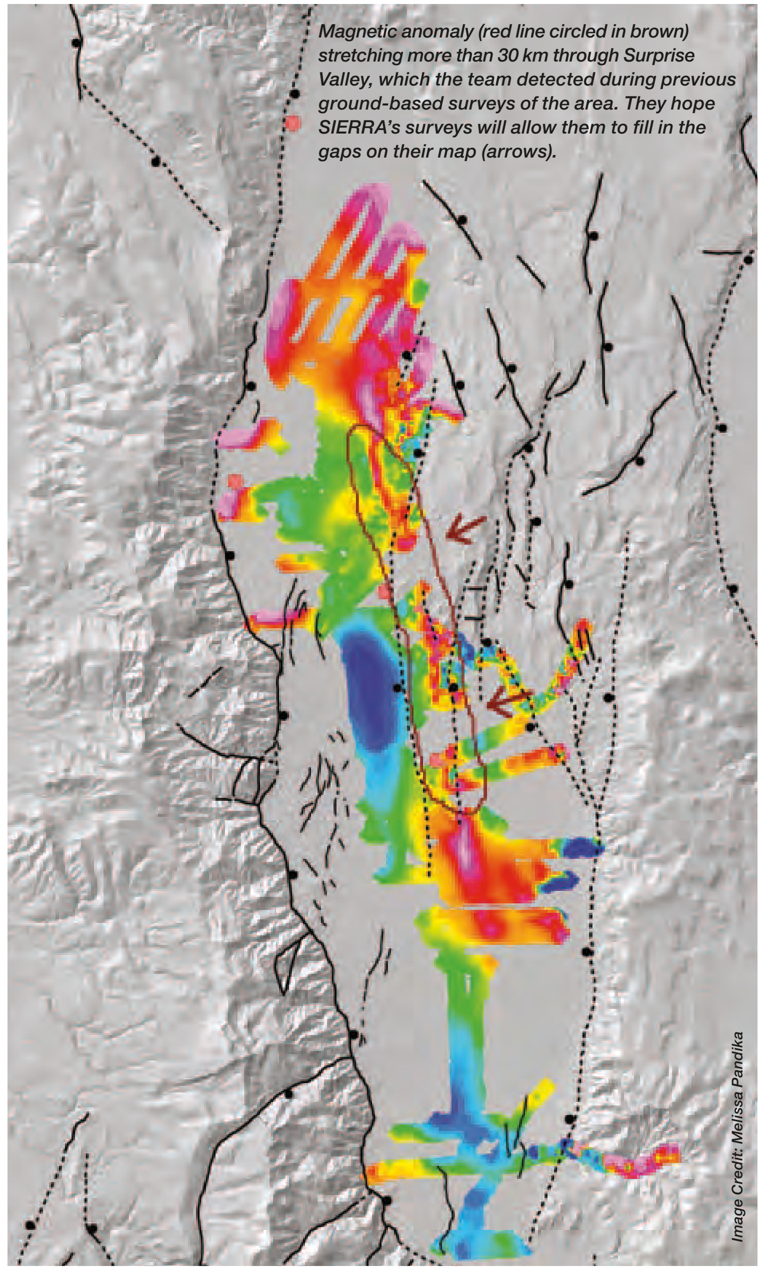
"Are We Really Done?"

The next morning, SIERRA flew smoothly through its survey of the north central detailed region and perimeter of Surprise Valley. With time to spare, SIERRA lead engineer Randy Berthold agreed to USGS researchers' requests for a detailed survey of a southern region the following day in addition to the broad survey across the entire valley they had originally planned. Despite the technical hurdles, SIERRA not only completed its mission one day early, it collected extra data from a largely unexplored region, accelerating the team's understanding of the geophysics of the valley.

"Are we really done? After all that work?" Corey asked on SIERRA's last night in Surprise Valley. "Can't we just fly the plane ten more times?"

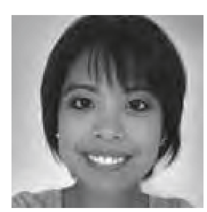
On the afternoon of SIERRA's last flight day, Jonathan drove with Central Washington University geologist and project lead scientist Anne to the east side of the valley to pick up USGS researcher Noah Athens, who had been collecting magnetic data by foot. As they stepped out of the car, they spotted SIERRA directly overhead.

"It was an amazing moment," said Anne. "We both realized that everything we had been working on for a year and a half was working. It was so satisfying, and so remarkable to feel like we were in the middle of a success. After all the troubleshooting, we really felt good about where we were." ●



Magnetic anomaly (red line circled in brown) stretching more than 30 km through Surprise Valley, which the team detected during previous ground-based surveys of the area. They hope SIERRA's surveys will allow them to fill in the gaps on their map (arrows).

Note: This story was originally published in a series of NASA blog entries, which can be found at blogs.nasa.gov/cm/newui/blog/viewpostlist.jsp?blogname=mission-ames.



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From Masters with Masters: Jack Boyd and Hans Mark

In August 2012, NASA Chief Knowledge Officer and Academy of Program/Project and Engineering Leadership Director Ed Hoffman sat down with Hans Mark, from the University of Texas at Austin, and NASA's Jack Boyd at the Ames Research Center as part of the Academy's Masters with Masters series. Dr. Mark has held several roles, including NASA deputy administrator, Ames center director, chancellor of the University of Texas, secretary and undersecretary of the air force, director of the National Reconnaissance Office, and director of research and engineering at the Department of Defense. Jack Boyd has worked at Ames for more than sixty years and is the senior advisor to the Ames center director. He has been the NASA associate administrator for management, and has also served as the acting deputy center director for Ames.

Ames engineers (left to right) Allen Faye, Merrill Mead, and Jack Boyd discuss aircraft design and handling.

Photo Credit: NASA/Ames Research Center

At a farewell party for Dr. Hans Mark, Ames center director from 1969 to 1977, are (left to right) Alan Chambers, Dale Compton, Jack Boyd, Hans Mark, Lloyd Jones, and John Dusterberry.

Photo Credit: NASA/Ames Research Center

Hoffman: How did you start working together?

Boyd: I got a call from the about-to-be administrator, Jim Beggs, saying he had this young fella he wanted me to show around Ames. So Hans came and spent a day.

Mark: When I came to Ames in February of 1969, I was clueless. The person in the director's office who taught me how to do things is Jack Boyd, because he was Harvey's executive assistant. And then both of us worked for Edie Watson for some years, which really got us started.

Hoffman: You're both extraordinary leaders. What do you think are the characteristics of being an exceptional leader?

Mark: I think the critical thing is the creation of an atmosphere where people can develop themselves and things can happen. Occasionally, I like the term "management by exception"—that is, you manage when you think something is going wrong and say, "Okay, we have to do something." But, by and large, you hire people who are smarter than you are, and that works by itself. I've had that as a principle for sixty years now.

Boyd: I like to look for someone who loves what they are doing. Also, and I have done this most of my life, you've got to rely on other people to get things done. If you don't get along with other people, you're not going to get things done very well. We have a saying at NASA, which I mostly agree with: "Failure is not an option." I think failure is an option in the technology world because you've got to try new things and sometimes you are going to fail, but don't let that stop you from doing things. Don't give up.

Hoffman: One of the key aspects of leadership is how effective are you in times of transition, crises, and change. Both of you, at different points in NASA history, have dealt with that. What should NASA be doing today to be able to respond to a time where there is a lot of uncertainty?

Mark: Many people sitting in this room today remember the crisis we were in in 1969, after we had successfully landed on the moon. People began to say, "OK, you've done it. What is next?" For the next two years, there was a genuine crisis in the sense that we were cutting back, and we were doing things that were really no longer part of what administrators had in mind. I think that we got out of the crisis by changing the emphasis of the center from the Apollo program, which we all contributed to, to what we were good at. Of course, aeronautics came up first. One of the things that Roy Jackson, our boss at the time, did was initiate a new experimental aircraft program. In the eight years I was here, we developed five or six experimental aircraft. The tiltrotor aircraft came out of that. I think that is an example of making a change that revived our ability to hire people and to do things.

Hoffman: Is NASA as comfortable taking risks today as when you were providing leadership a few decades ago?

Boyd: I think generally not, but I should say that with some hesitation because we just saw one with MSL [Mars Science Laboratory], which was one hell of a risky thing to do, and we did it successfully. In the NACA [National Advisory Committee for Aeronautics] days—remember we were a very small organization—we weren't very high on anyone else's radar screen. So we could do what seemed to be dumb things and get away with it. Some of those dumb things turned out to be remarkable activities.

For example, R.T. Jones, who developed the swept-back wing that is on every airplane that flies anywhere in the world, was not permitted to publish his paper when he first talked about it. They thought it seemed like a dumb idea: birds don't have swept-back wings, why should we? Harvey Allen and his "blunt body," which is on every spacecraft that goes into planetary atmosphere, we did that here.


Quadrant of ILLIAC IV, the first large massively parallel computer, with V. Tosti (standing) and S. Kravity.

Photo Credit: NASA/Ames Research Center

I don't think we're quite in a mode today of taking those kinds of risks, but I am going to say MSL was one heck of risky activity, which was wonderfully successful.

Mark: I would answer your question by saying the biggest risk we took programmatically when I was here was to take on the development of the first large massively parallel computer, the ILLIAC IV, because no one knew how to program the thing. But we had Harv Lomax here, we had Dean Chapman, we had R.T. Jones, and then we brought in Bill Ballhaus and Paul Kutler and Ron Bailey, and a bunch of people that then sat down and made the thing work. So what did we do? We hardwired it, basically. We didn't have an operating system or a program, but we showed that the parallel computer configuration could do a calculation in 15 minutes that took the CDC 7600 several days to do. Today, every large computer has parallel architecture. I think that had an enormous impact, and we started it right here.

Hoffman: What are your thoughts about the vision for NASA? What are some of the things that you hope for the future of what we're doing?

Boyd: I'll quote our Russian friend, Konstantin Tsiolkovsky who said, "The earth is a cradle of humankind, but you can't stay in the cradle forever," so we've got to go outside. I think Von Braun said, "Let's do it for the fatherland." Carl Sagan said, "Let's do it for science." And a guy named O'Neil, who Hans knew quite well and used to come visit us, said, "It is human destiny to explore; exploring the solar system is human destiny." That is the way we got to do things. Now, how you go about doing it, what processes you use, what steps you take, I've got my own thoughts about. I'm not sure they are all that relevant now, but to go out and do those sort of things require you to be a pretty good salesmen, too, in order to get Congress and the people of the United States behind us. I wouldn't give up on any of this. If you fail one time, don't stop. We can't give up.

Mark: Let me separate aeronautics from space exploration. The vision for aeronautics goes back to NACA and was driven by the fact that in World War I, the United States did not have a single combat aircraft at the front. We were way behind. So for a hundred years now, we have been the leading nation in aeronautics in the world. Aeronautics today is not quite the largest, but almost the largest manufacturing industry that still has a very large balance of trade, roughly $75 billion a year give or take. So the vision for aeronautics is clear: the United States will continue to be the leading nation in aeronautics in the world. Period. The end.

Now, what about space exploration? Aeronautics is done because we have a social imperative to do it. We have victory in war, and we have the transportation system, and there are several million people who have jobs in the aeronautics industry. This is one area where NASA should stand up and say, "We know how to make jobs!"

The space industry alone doesn't employ that many people, but there are two issues. One is that the scientific work we've done in space has become very, very important. You know, I've heard political folks tell me we don't really need satellites; when you go home today and drive your car, have you got GPS in front of you? Most people don't know where it comes from. How many people know that two Nobel Prizes have been awarded for work done with NASA spacecraft? Riccardo Giacconi got the Nobel Prize for the work he did with the Chandrasekhar satellite [Chandra observatory] on X-ray astronomy. And John Mather got it for the Cosmic Background Explorer for showing that the cosmic background is not isotropic. With Earth-orbiting vehicles, we have done science that has new, genuinely important information about how the universe works. We haven't done that yet in the planetary area, but we should do both. And in the planetary area, I think the objective must be very simple; we're going to put people on Mars. You don't spread it around too much. Just say that is the objective.

Ames employee breakfast with Dr. Hans Mark.

Photo Credit: NASA/Ames Research Center

Audience: NASA is working on just a half a cent of the budget dollar. How and who do you recommend we send out to Congress to get the other half a cent?

Boyd: Engage the young people around the world and in this country. This summer we've had nine hundred students here at Ames, many of whom were foreign nationals. If we could somehow harness the power of these young folks who are really enthusiastic about what they see when they come to a place like Ames, I think that would help us tremendously.

Mark: The necessary foundation of this place has to be technical competence. If you bring a few technically competent people in, others will come. In addition to the salesmanship, there has to be technical competence. The position of a NASA center director is enormously powerful. It's powerful not because we're all that good at getting money from Washington. It is because we can choose people to do the jobs that we know they will do well.

Audience: Where do you see someone with less technical experience but with more management experience in NASA leadership?

Boyd: I think the management here at Ames recognized some time ago that technical excellence alone isn't going to hack it at a research technology center. In the mid-sixties, they said, "OK, you've done your technical things, now we're going to send you off to the Stanford Sloan Program because we need people who understand finance, procurement, what have you."

I said, "I don't want to go to the Stanford Sloan Program. That's got to be dull."

But I went, and it was probably one of the best experiences I had. It helped me understand where other people were coming from, too. I think that mix of the technical and engineering background, and a business background, is quite useful to me. So you need a mix, clearly.

Mark: I agree.

Hoffman: One of the things I wanted to get your thoughts on is recommendations for people starting their careers. I was mentioning a personal story I had to Hans and Jack. The first time I met both of these leaders was in 1983 as a graduate co-op student. I was doing research into leadership competencies, on how project teams perform, at Columbia University. Hans would have social events for the different co-ops, interns, and students. I had a friend coming up from Columbia, and I said, "Let's go to the deputy administrator of NASA's party."

He said, "No, no, let's not do that. That'll be boring."

To me, it met the number-one criteria for a graduate student: I knew it would provide free food. So I talked my friend into it. Leadership was there at the event, and there were about thirty of us students, so there was a lot of activity for the first half hour.

All of a sudden, Dr. Mark gets everyone around him at the center of the room. I'm stuffing my face and I hear Hans say, "I want to welcome all of you here to this event, particularly the students, because you're the future of us and it's critical that we bring on board the best. I see that we have twenty-nine of you who are aerospace engineers, and I know why you're here. One of you is a psychology guy from Columbia, and I have no idea what you're doing here."

At this point, I get this ball of sweat right on the back of my neck. I know where this is going. Hans says, "Can you identify yourself?"

I say, "I'm Ed Hoffman. I'm from Columbia University."

He says, "Well, why are you here?"

You realize how great of a question that is. You would think someone would know why they're at NASA, but that was the first time it really locked in. Why am I here? I said, "I'm here helping teams, how they work together, how leaders perform."

He says, "Well, I'm a leader. Can you help me become more effective?"

I throw the question back, and I said, "Well, can you give me

I THINK THAT MIX OF THE TECHNICAL AND ENGINEERING BACKGROUND, AND A BUSINESS BACKGROUND, IS QUITE USEFUL TO ME.

The development of the XV-15 tiltrotor research aircraft was initiated in 1973 with joint army–NASA funding as a "proof of concept," or "technology demonstrator" program, with two aircraft being built by Bell Helicopter Textron in 1977.

Photo Credit: NASA

… I LIKE THE TERM "MANAGEMENT BY EXCEPTION"—THAT IS, YOU MANAGE WHEN YOU THINK SOMETHING IS GOING WRONG AND SAY, "OKAY, WE HAVE TO DO SOMETHING." BUT, BY AND LARGE, YOU HIRE PEOPLE WHO ARE SMARTER THAN YOU ARE, AND THAT WORKS BY ITSELF.

an example of an effective leadership practice that you use?"

He said, "Well, one of the things I like to do is write down what are called 'Hans grams.' I write down notes on little stickies at the end of the day and leave them with my management team. Does that make me a good leader?"

Behind him, he can't see, but his management staff is giving all kinds of signals to tell him why it is not. So I said, "Why do you think that's a good practice; why do you do it?"

He said, "I communicate with my folks, they know it's a priority, and I know when they first get in in the morning they know what I'm expecting."

I said, "Well, based on what you're saying, that sounds like a good practice."

Thirty minutes later, he invites me to his office with a couple of other students, and he's showing me different awards and medals, and he said, "By the way, I'm still totally not sure why you're here, but I liked your answer. You handled that really well."

That was when I had an appreciation for being prepared and what a testing organization meant, which means you should know why you're at a place. There was a strong community then and you could go to these events and meet the leadership, and they would test you and ask questions, but mostly interact with you.

What do you recommend for folks who start at NASA, or what are your recommendations for young professionals in terms of being successful or having a career?

Boyd: First, find a mentor. Find one or more mentors.

Hoffman: How do you find a mentor?

Boyd: Most people are really happy to do it. Just talk to people. Most of them would be happy to deal with you. Be persistent if they're not. Otherwise, get to know your colleagues as best you can. Get to know them because you're going to work with them for the rest of your careers, for the rest of your life sometimes.

Mark: I teach a freshman course in the aerospace department, and at the end of the first and second years I always pick a group of people to send to NASA centers. NASA has this scholarship for summer jobs. I think that—and this is advice for, I might call it, "pre-professional"—the people who have had intern positions and co-op positions have no problem finding jobs even today in the current environment. So, get with it early, that's the short advice. Do it as soon as you can.

Hoffman: Who were your mentors?

Boyd: I had three that I remember. Harvey Allen, who was just a delightful man and brilliant. R.T. Jones was the one who told me when I got here, "Read everything that you can find out. We'll give you six months before we give you a real job to do."

Those two and Walter Vincente, who was another giant in the 1-by-3-foot supersonic wind tunnel. He was instrumental in teaching me how to write. Engineers are notoriously poor writers—and not too good at speaking for that matter—but the combination of those two, he helped me with.

Mark: Well, my father was a scientist, so obviously he was the number-one mentor. He had a student by the name of Edward Teller who became my second mentor. In the area of dealing with high-level politics and so on, I would have to say that Johnny Foster was my mentor there. We had an associate director here named John Foster, but I'm talking about the one who was in the nuclear weapons business and then went into the Pentagon. John Foster was a good physicist, and he also understood management. So I would say those three.

Hoffman: So the importance of finding a mentor is very clear, and also being able to answer the question of why you are here is one of the things that I would share. I've been here twenty-nine years, and this is one of those days I'll always cherish and remember.

In the grasp of the International Space Station's Canadarm-2, JAXA's Kounotori-2 H-II Transfer Vehicle is moved from the space-facing side of the Harmony node back to the Earth-facing port of Harmony.

Photo Credit: NASA

Understanding International Project Management

BY ANGELA MARSH

At the Marshall Space Flight Center Mission Operations Laboratory, we provide facilities, systems, and ground-systems services to other NASA centers, universities, and research centers and to international space agencies. International Space Station (ISS) payload operations are among the services we offer at our control center. The payload operations include command and control of science payloads aboard the ISS and communicating data from the experiments to organizations in the United States and to our international partners.

The International Space Station Payload Operations Center at Marshall Space Flight Center.

As mission operations systems manager and co-chair of the ISS Ground-Segment Control Board, I've become aware of some of the challenges and subtleties of working successfully with our colleagues at the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), the Canadian Space Agency, and the Russian Federal Space Agency. I took the Academy of Program/Project and Engineering Leadership's International Project Management (IPM) course in February 2012 in hopes of getting some tools and insights that would help us ensure that those international partnerships are as productive and effective as possible.

Crisis Response

Normal ISS payload operations are complex to begin with. An unforeseen crisis adds to the complexity, and not having a good understanding of how international partners operate can make a difficult situation even harder to evaluate and manage.

Around midnight on March 10, 2011—the morning of March 11 in Japan—our Huntsville Operations Support Center ground controller received a call from the ground controller at the Space Station Integration and Promotion Center (SSIPC), which monitors and commands Kibo, the Japanese experiment module, at JAXA's Tsukuba Space Center. Our log reports that the Japanese controller sounded "scared" as he relayed the news that the trans-Pacific circuit was down.

The source of the problem, of course, was the undersea earthquake and tsunami that caused such devastation in Japan. The ground systems for Kibo and Japan's H-II Transfer Vehicle (HTV) were damaged, and circuits between SSIPC and Johnson Space Center were lost. But the link between SSIPC and Marshall remained intact.

Nevertheless, we did not hear from JAXA for two full days after that log entry. The IPM course brought clarity to what was happening during that time. In a situation like the tsunami, people are worried and confused about what to do. Knowing the level of management decision required by the Japanese, those days were surely spent getting required approvals from line management for forward plans. After the course, I could have better explained to our ground controllers what was happening and told them not to worry as much—that JAXA was taking care of business the way they needed to and we would hear from them when decisions were approved.

Almost a year later, the IPM course identified the likely primary cause of that silence. In *Cultures and Organizations*, the main text for the course, Geert Hofstede discussed the relationship between bosses and subordinates and the process of making decisions in Japanese organizations. Those two days were almost certainly spent in methodical and detailed work and team reliance on leaders to make final decisions for the group.

On March 13th, the decision was made, and our Japanese colleagues requested a change in voice formats. On the 14th, voice was re-routed through Marshall. That remained the active link until the Johnson circuit was recovered on March 18th.

Learning About Our Partners

The IPM course covers cultural challenges, legal concerns, and teaming issues likely to be encountered when working with international partners. Some of the material is very straightforward. Things like being aware of time differences and foreign holidays when scheduling meetings and setting deadlines are simple but important, both as practical issues and as signs of respect and consideration.

There are many additional ways to show respect and begin to develop the trust that is essential to working well together, from learning greetings and common phrases in partners' native languages to trying local food and drink to subtler social issues like the meaning of particular gestures or ways of speaking in a given culture.

A lot of these elements are discussed in Hofstede's book. He explains how the cultural characteristics of various countries are likely to play out in business transactions and suggests the

Photo Credit: NASA/Marshall Space Flight Center

kinds of adjustments in communications, negotiating styles, and expectations that need to be made in various international work situations. Speakers at the course supplement his advice with information specific to international cooperation in space—for instance, how different space agencies manage their projects, and the influence of trade regulations on sharing aerospace technologies.

As useful as the information provided by readings and presentations is, the most valuable part of the course may be the opportunity it provides to meet and work with the foreign nationals who are taking it. Interacting with them informally and in class activities that involve playing out a multicultural project together bring the cultural issues to life and make our differences—and our similarities—vividly real. It also helps bring language issues to light.

English is the official language of the ISS, so our international partners are working in what for them is a foreign language. Helping out with translation and taking time to make sure that everyone has a common understanding of the subject under discussion are essential to avoiding problems. Remaining aware that our international colleagues are not native English speakers also contributes to our appreciation and admiration—they speak English so much better than most of us at NASA can speak any other language.

Bringing the Lessons Home

The IPM experience gave me the ability and courage to be a better mentor to my team and coworkers, making me more confident that I could give them useful guidance about working with different cultures and countries.

Sensitivity to cultural and organizational differences is essential to the success of all our ISS work with our partners. For example, the alpha magnetic spectrometer Asia Payload Operations Center in Taiwan will be responsible for the safe operation of the spectrometer for the next ten years. A high-level university professor who will lead some of that instrument's cosmic-ray research mentioned that he would like to visit or send someone to visit Marshall and the Huntsville Operations Support Center. This would give each of us insight into how the other works.

Business invitations between organizations in the United States require an understanding of business etiquette. Business invitations between a U.S. organization and a foreign agency involve additional layers of understanding and finesse. Thanks in part to the IPM course, I was aware of the importance of some of the details of this situation: whom the invitation should be addressed to, who should send it, what the expectations of the visit should be.

THINGS LIKE BEING AWARE OF TIME DIFFERENCES AND FOREIGN HOLIDAYS WHEN SCHEDULING MEETINGS AND SETTING DEADLINES ARE SIMPLE BUT IMPORTANT, BOTH AS PRACTICAL ISSUES AND AS SIGNS OF RESPECT AND CONSIDERATION.

Another example: I recently received an e-mail from one of our international partners informing me that he had received an e-mail from Marshall security officials requesting information about their control center assets. Of course, it didn't take participation in the IPM course for me to know that this was an error that had the potential to upset our partners. But the course

AS USEFUL AS THE INFORMATION PROVIDED BY READINGS AND PRESENTATIONS IS, THE MOST VALUABLE PART OF THE COURSE MAY BE THE OPPORTUNITY IT PROVIDES TO MEET AND WORK WITH THE FOREIGN NATIONALS WHO ARE TAKING IT.

Photo Credit: JAXA

JAXA's "Kibo" mission control room in Tsukuba Space Center.

did help me understand how important correcting it forcefully and quickly would be to maintaining our relationship of trust and cooperation. I immediately sent an e-mail to our partner, with copies to our other partner centers, explaining that he was not required to send that information and thanking him for bringing the request to my attention.

A more far-reaching security issue relates to compliance with Homeland Security Presidential Directive 12, a mandate that requires government agencies to know who is accessing government systems and whether they can be trusted not to compromise them. Our ISS international partners had a hard time understanding and accepting the idea that the U.S. government would not recognize their own governments' security credentials.

The IPM course taught that trust is the bottom line of the relationships with our international partners and here we were basically telling them we didn't trust their security processes and would require them to re-establish their identity using NASA credentials. Not wanting to compromise our relationships yet needing to comply with the security regulation, we decided to redesign our Huntsville Operations Support Center systems to authenticate foreign national users using their NASA user identities and RSA-token identification credentials. This approach still meant we had to convince our partners to load a user-identity verification system at their centers, but it would require no further effort on their part.

Convincing the international community that their systems would not be affected by the additional software took many hours of design review, consultation, and training (and a promise that there would be no cost to the partners)—and it required the trust we were working to preserve. ESA especially and understandably took exception to NASA's unwillingness to accept their identity and credential system, and it took all our relationship skills to win them over.

In the end, we gained access to our IT systems for the 365 foreign nationals we work with. Putting ourselves in their shoes and making the extra effort to design a system that would have as little impact on them as possible helped maintain the cooperative, trusting relations we have worked so hard to create.

Trust and Respect

As these examples suggest, trust and respect are key to successful international partnerships. That is the underlying lesson of the IPM course and of our experience working with our international ISS partners. The reliable service and support we have provided over the years have gained and kept our partners' trust and built a high level of mutual respect.

We continue to receive regular requests for new system designs and services. ESA has recently requested a new ISS delay-tolerant network. JAXA has asked us to provide Ku-band access to their ISS Japanese Experiment Module laboratory. Years ago, it would have been hard to carry out this request. The language barrier would have been part of the difficulty but so would the formality of documentation they required and the complexity of their management decision process. Over time, though, working together has become significantly easier as trust has developed among the personnel at each center. Sometimes decisions are made at a lower level than would have been possible in the past and with less need for extensive formal assurances. This progress makes us smile because we know we are being successful at a different level, an international level. ●

ANGELA MARSH serves as branch chief for the Marshall Space Flight Center Mission Operations Laboratory Mission Operations Systems Branch, managing day-to-day operations of the Huntsville Operations Support Center, which includes the ISS Payload Operations Center and the Fast Affordable Science and Technology Satellite Control Center. She also serves as the deputy chairman for the ISS Ground-Segment Control Board.

Building the Goddard Career-Path Tool

BY DAVID WILHELM, NANCY LINDSEY, MARIA SO, NICHOLE PINKNEY, AND NANCY RACKLEY

The ability to plan one's career path can be a strong force for morale and fulfillment in the workplace. The need for a clear career path has been recognized for many years at Goddard Space Flight Center. In fact, Goddard's Applied Engineering and Technology Directorate (AETD) began to plan a career-path tool approximately four years ago.

The idea was simple: build a career-path "map" that would be easy for employees to use. The design would be similar to the map used by the Washington, D.C., Metro subway system, since most people are familiar with metro or bus-mapping pamphlets. The various metro or bus routes would be career "ladders" that would give employees a way to lay out their future career development.

Due to other urgent demands, the AETD career-path project was temporarily set aside; but Goddard leader Maria So never abandoned the vision of an easy-to-use career-path tool.

Fast-forward several years. So was promoted to the position of deputy director of the Safety and Mission Assurance Directorate (SMA). With an eye toward building organizational strength for the SMA Directorate and considering morale and retention, as well as recruitment of engineers, scientists, and administrative support positions, she decided to revisit the idea of the career-path "Metro Map."

Building a new system is nothing new to an engineer like So, but her vision for success included a desire for strong collaboration and joint leadership with another important stakeholder, Verron "Ron" Brade, the director of Goddard's Office of Human Capital Management (OHCM). After obtaining support from her manager, Judy Bruner, director of Goddard's SMA Directorate, So asked Brade to collaborate in building a career path for the SMA Directorate. The project aligned with his strategy of transforming OHCM into a collaborative, valuable partner for its customers, so he readily agreed. They assembled a team that included Nichole Pinkney, chief of OHCM's Talent Cultivation Office; Nancy Lindsey, mission systems senior reliability manager; and David Wilhelm, senior human resources consultant.

From the outset, So's vision for the career-path tool included defined paths or "ladders" for each discipline. In addition, the application needed to be web accessible, allowing employees to view career-path information and see the different potential paths for their positions. Like other organizations at Goddard, the SMA Directorate is composed of several disciplines, and employees often did not know what training or experience they would need to be promoted, to move laterally into a new position, or to transition to another discipline.

Pinkney immediately saw the possibility of implementing a career-path system not only for SMA, but for all Goddard organizations. She realized that a centerwide career-path system could provide an overview of opportunities for growth and development, including discipline transition possibilities for center employees. It could also assist in identifying competencies and skills that are natural "feeders" to building the leadership team.

With this vision in mind, Pinkney agreed to a modest budget to hire a small business contractor to quickly build a prototype system for SMA. She realized that capturing the right data was vital to the usefulness of this system. She made sure that Wilhelm, as senior human resources consultant, would have sufficient involvement in this groundbreaking project, since he had tremendous insight into human-capital development. He drafted a set of insightful questions to ask SMA managers so the appropriate training data for all disciplines would be captured. He conducted all the interviews along with the SMA implementation team and guided the data-capture process. Once the initial data was validated by SMA management, Wilhelm conducted a review and validation with the other OHCM disciplines.

Understanding the goals defined by So and Pinkney, Lindsey took on the task of implementation management. With many years of experience in program management and requirement development, and a software development background, she had the knowledge needed to manage the project and to understand the expertise needed to ensure success. She built a team with the necessary diverse skills, including Wilhelm; B-Line Express, the small business contractor that has provided experienced design and Internet application development since 1995; and SMA managers, who provided raw career data and validated its incorporation in the SMA career-path web site.

Project sponsors provided guidance and offered suggestions during the design phase of the project and during debriefing meetings while giving the team the freedom to meet the challenge of developing a creative career-path tool. When confronted with a challenge, the development team frequently charted possible solutions in writing so they could collectively consider each other's ideas.

One such challenge was to show the user the option to transition between the ten unique SMA technical positions at seven grade levels without creating a visually confusing and intimidating "spaghetti" of transition lines. The team used the human-capital interview data-gathering process and storyboarding to resolve this issue.

Interviews showed and human-capital management verified that promotional transitions from level to level were consistent within disciplines and provided in the standard career paths within each discipline. So only information about transitions between disciplines was needed. The team then storyboarded and whiteboarded several concepts, walking through each user click. A textual list within the discipline description window and a graphical representation of transition options by grade/discipline proved to be the solution that supported the goal of transmitting consistent data to the user without creating a confusing image of many paths.

The same process was used to solve the similar challenge of showing the user how to transition from technical to supervisory responsibilities. Having a team that represented both the engineering side and the human-capital side of the business added efficiency and depth to the process of making design decisions.

B-Line Express was given the challenge of building an application that embodied the goals and objectives of the original vision. The company collaborated closely and frequently with Lindsey and Wilhelm to develop the web-based design concepts and ideas for how best to provide career-path guidance and strategic planning for the workforce. The team used storyboarding extensively to turn ideas discussed in their many team meetings into web-based application design. This iterative process was a fast and effective way to develop the application and keep it faithful to the vision that So and the team had formulated.

The B-Line development team, led by project manager Nancy Rackley, included a graphic designer, a web-application developer, and a database engineer—all essential skills. Because of B-Line's experience with comparable applications, the team was able to incorporate a variety of cutting-edge web technologies that ensured a robust user interface, and provided these capabilities quickly and at low cost. The B-Line team also took advantage of numerous collaboration tools to implement the application while maximizing autonomy for innovation, which was essential for the geographically distributed team. This helped greatly with software configuration management during development and with communication among team members.

The result of the collaborative effort is a fully functional career-path application that was designed, developed, and populated with data from four different people with varied skills and backgrounds in only six months. The benefits for Goddard employees that resulted from this collaboration include career planning, training and development planning, and a positive effect on morale. The response from Goddard employees who have accessed the tool has been extremely positive and mirrors the expectations of the development team.

"The career path is so easy to use and so helpful," noted an SMA employee.

"For the first time I can actually see in front of me how the SMA Directorate is structured by position, and more importantly, by the 'paths,'" noted another employee.

One employee from OHCM said, "I can see how the career path will help me build my IDP [individual development plan] and prepare me for my performance and development discussions with my supervisor."

According to *Diversity News and Views*, a recent survey indicated that roughly 54 percent of workers say knowing their career path is very important to their overall job satisfaction, nearly as important as compensation. The career path benefits Goddard management by providing a tool for succession planning (leadership development), assisting supervisors with employee career-development discussions, providing a positive effect on retention and recruitment, enhancing cross-organizational integration, and strengthening critical links between various center functions.

The career-path project is one in which all parties chose to cooperate to accomplish a shared outcome. So, Pinkney, Lindsey, and Wilhelm are all collaborative leaders in this project. Each of them accepted *ad hoc* responsibility for building an innovative career-path system that was developed in a cost-effective manner. Together they accomplished the shared purpose of providing career-building data to employees that will help them more easily take charge of their career. Along the way, the four of them established a process and a positive environment that supports the collaborative relationship between the SMA and OHCM organizations at Goddard. ●

DAVID WILHELM has spent more than twenty years in training and development, performing the full spectrum of instructional systems design activities for all levels of employment. He is currently a senior human resources development specialist in the Office of Human Capital Management (OHCM) at Goddard Space Flight Center.

NANCY LINDSEY has spent more than twenty-seven years in aviation and aerospace engineering performing a variety of engineering tasks across the gamut of space-vehicle life cycles and program types. She is currently a senior systems reliability manager at Goddard.

MARIA SO is the deputy director for planning and business management of the Science and Exploration Directorate at Goddard. Her previous roles include deputy director of the Safety and Mission Assurance Directorate, associate chief of the Mission Engineering and Systems Analysis Division in the Engineering Directorate, and branch chief of the Mission Systems Engineering Branch.

NICHOLE PINKNEY has been in training and development for more than fifteen years. She is currently chief of the Talent Cultivation Office in OHCM at Goddard, where she manages a team of expert human resource (HR) development practitioners in the field of career development and learning. She has worked on many HR development initiatives.

NANCY RACKLEY has worked for B-Line Express for more than ten years and has helped develop several applications for NASA centers. As B-Line's NASA program manager, she oversees various web-site/application design, development, and maintenance efforts at Goddard.

PROJECT KNOWLEDGE IN THE MOMENT

BY BARBARA FILLIP

NASA's current Spaceflight Program and Project Management Requirements document, NPR 7120.5E, requires projects to develop lessons-learned plans. To help projects and programs comply with this new requirement and with NPR 7120.6–Lessons Learned, Goddard's Office of the Chief Knowledge Officer (OCKO) created a framework that involves embedding existing knowledge management practices—such as Pause and Learn sessions, case studies, and workshops—within project plans. Carrying out these activities during projects—in the moment—helps ensure that memories of events are fresh and the lessons they provide can be put to use immediately. The first and primary beneficiary of any lessons-learned activity should be the project team itself, but these activities also support learning across projects.

Photo Credit: Ball Aerospace

The Suomi National Polar-orbiting Partnership (NPP) satellite at the Ball Aerospace facility. The Joint Polar Satellite System will be a near clone of NPP.

The Suomi National Polar-orbiting Partnership (NPP) and Joint Polar Satellite System (JPSS-1) missions are two Goddard projects currently trying to capture important lessons in the moment. JPSS-1 will be carrying the same instruments as Suomi NPP—and will be a near clone of NPP—so it has the potential to learn much from its predecessor satellite.

Capitalizing on an upcoming quarterly meeting of the JPSS-1 project in March 2012, Bryan Fafaul, the project manager for JPSS-1, proposed using the opportunity to engage the Suomi NPP and JPSS-1 teams in a knowledge-sharing exercise. The timing was perfect as Fafaul's team was moving forward with the JPSS-1 satellite development and the Suomi NPP team had recently completed a successful launch.

Pause and Learn

The foundational element of project learning is Pause and Learn, or PaL, which is a group-reflection activity to ensure that lessons are learned within the project. It is also an open conversation—an opportunity for anyone on the team to articulate insights about the work.

Participants can be a little anxious about how these open-discussion sessions will turn out, so it's important to have a facilitator who is aware of issues that need to be handled delicately and can deflect inappropriate comments that might derail the conversation. Once the conversation starts, getting participants to contribute their thoughts is never a problem. The key, however, is for a facilitator to guide participants to a productive conversation—one that allows everyone present to add value to the conversation and enhance the group's understanding of the issues at hand. Creating an open and trusting atmosphere in which team members can communicate freely is essential for capturing lessons learned and sharing knowledge effectively.

If participants walk into a meeting with divergent views of a particular event, they may not come out of a PaL session with a consensus, but they will at least understand that other team members, seeing the same event from another perspective, came up with different interpretations of the event and different conclusions regarding a lesson. When team members are focused on detailed technical lessons, the facilitator's role can be to connect that detail to a broader lesson or theme, such as proper planning or effective communication.

By conducting PaL sessions systematically after key project milestones, a project ensures it is taking the time during the project to reflect on what has happened—and perhaps even make mid-course adjustments—and is keeping track of insights gained at different stages of the project life cycle. There are multiple benefits to keeping track of insights as they occur. Trying to cover all the lessons of a project's entire life cycle would likely be unmanageable. Focusing on a reasonably short period of time (a phase, for example) makes more sense. Also, our memories are fallible. A project team's analysis at the end of a project would most likely neglect or misremember important events and learnings from early phases of the project.

Learning from a Sister Mission

The sessions that gave the Suomi NPP team an opportunity to reflect on what they had learned were a tremendous boon to JPSS-1.

"We were very lucky to have had Suomi NPP just complete a successful launch, commissioning, and hand-over to the JPSS program," Fafaul said. "As such, I really wanted to capture as much of their experience as possible for my team as we move forward with JPSS-1 satellite development. With that said, we leveraged three critical areas: satellite integration and test; the launch campaign; and commissioning for the JPSS flight-project Pause and Learn sessions."

Fafaul sought the assistance of the OCKO to help plan and implement the sessions. Ed Rogers, Goddard's chief knowledge officer, facilitated the sessions. To make the PaL sessions manageable, participants were divided between Suomi NPP staff (inner table) and JPSS-1 staff (outer ring). NPP participants were asked to prepare talking points before the session about what went well on their project and what could be improved. The JPSS-1 project management team gathered all the input and shared it with the OCKO team in advance of the PaL. This helped ensure the PaL was tailored to JPSS-1's knowledge needs and offered opportunities for targeted knowledge-sharing activities.

"JPSS is a unique project in that we are currently building a near clone of Suomi NPP for JPSS-1 that includes the same instrument suite as Suomi NPP, and we are responsible for developing the JPSS-2 satellite," said Fafaul. "It is critical that

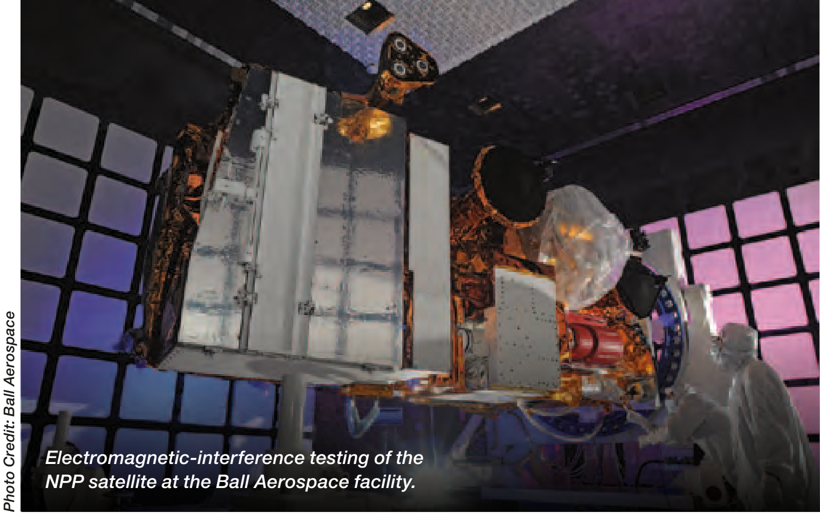


Photo Credit: Ball Aerospace

Electromagnetic-interference testing of the NPP satellite at the Ball Aerospace facility.

we glean as much from the on-orbit performance of the Suomi NPP satellite as possible to ensure we do the right things for JPSS-1 and JPSS-2. Our lessons learned demand us to look back (NPP); look down (JPSS-1); and look forward (JPSS-2) so that we can effectively communicate. And there is no better way to do that than through regular Pause and Learn sessions."

When discussing the launch campaign, the NPP team noted how the countdown simulations had proven very valuable in preparing for the actual countdown. This was an example of something the JPSS-1 team should try to emulate. In the same conversation about the launch campaign, the NPP team noted that the work environment at the launch site was very different from what the team members were used to, and they weren't necessarily ready for it. Launch-site activities require very precise execution of a well-thought-out plan. The lesson, in simple terms, was "don't wait to get there to figure out what needs to be done. Figure out who will be doing what and when ahead of time." This also implies developing a good understanding of roles and responsibilities during the launch campaign and building relationships with launch-site partners ahead of time. Knowing this, the JPSS-1 team will be more likely to give more attention to preparations for launch activities.

Another issue was contamination, which affected NPP both in the integration and testing phase and at the launch site. The existence of multiple contamination-mitigation plans led to confusion, last-minute changes, and some instances of contamination that could have been avoided. Based on the PaL conversation around this issue, the JPSS-1 team is developing a strong contamination-mitigation plan owned by government contamination control that will leverage specific lessons learned by NPP.

Aggregating Knowledge

PaL sessions are just the initial steps of the JPSS-1 lessons-learned plan. Beyond the immediate needs of the JPSS program, relevant lessons will be shared within the Flight Project Directorate's Knowledge Exchange. The Knowledge Exchange is a knowledge-sharing hub based on SharePoint that now includes a collection of conversation maps,[1] which are a key output of every PaL session. A conversation map is a graphic representation of the conversation that took place during a PaL, highlighting key insights that emerged from the conversation. They serve as a visual reminder of past conversations and are always available to the project team and can be used to identify actions to be taken in the future.

The Knowledge Exchange is not simply a collection of individual project-specific maps. Insights emerging from conversation maps can be aggregated across projects. Looking at multiple conversation maps from multiple projects often reveals patterns that suggest broadly applicable lessons.

Not surprisingly, most PaLs will come across team communication issues. Aggregating insights related to a specific topic (in this case, team communication) in a separate map allows for valuable knowledge to emerge and provides a means for sharing insights across projects. The process generates a knowledge web made up of conversation maps based on project-specific information, and topic maps based on insights aggregated across projects. When a team conducts a second or third PaL, it can use conversation maps created from previous sessions as a starting point. The maps can also facilitate writing official lessons learned at the end of the project to meet NASA requirements. When appropriate, key lessons are submitted for formal inclusion in the agency's Lessons Learned Information System in compliance with NPR 7120.6.

During the subsequent quarterly meeting of the JPSS-1 project, Fafaul allocated an hour of the agenda to talking about ongoing project-learning activities and Rogers facilitated a short scenario-based discussion focused on organizational silence. Now the JPSS program is adopting the PaL process as well, and conducted its first PaL on September 12, 2012. As more projects adopt the PaL process as the core project-learning activity of their lessons-learned plan, more conversation maps will be generated, enabling the creation of a rich web of knowledge within the Flight Project Directorate's Knowledge Exchange. ●

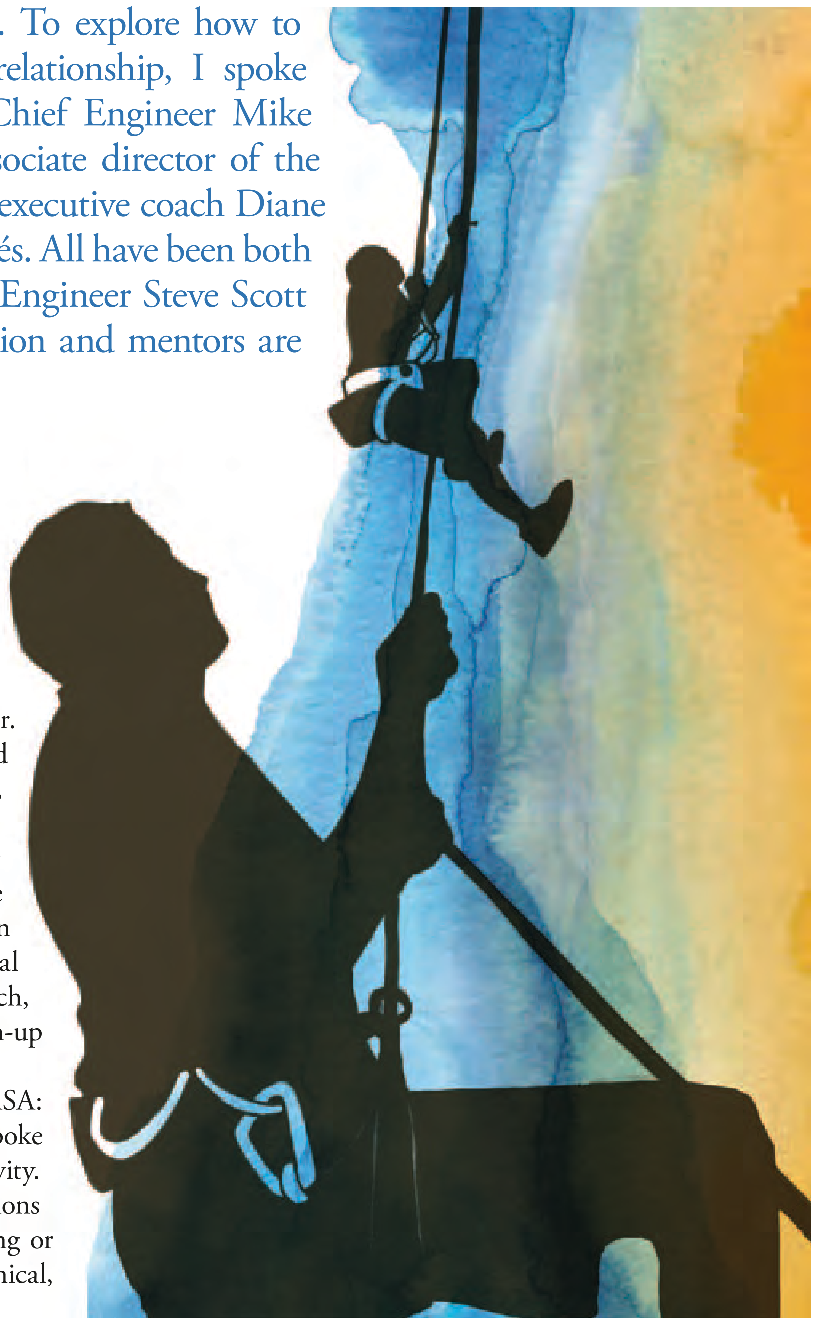
BARBARA FILLIP is a knowledge management specialist in the Office of the Chief Knowledge Officer at Goddard Space Flight Center. She came to Goddard as a contractor with Library Associates Companies in May 2008 after spending more than ten years working in the field of international development, occupying functions encompassing program and project evaluation, information and communication technologies for knowledge sharing, as well as capacity building and training.

1. Most of the current maps (100+) were developed based on case studies and other existing lessons-learned materials rather than Pause and Learn sessions. Most future maps will be created based on Pause and Learn sessions.

Getting the Most from Your Mentor

BY RICHARD McDERMOTT

Mentoring has a long tradition at NASA. To explore how to get the most out of a mentor–protégé relationship, I spoke with several NASA veterans, including Chief Engineer Mike Ryschkewitsch and Liz Citrin, deputy associate director of the Joint Polar Satellite System program, with executive coach Diane Brennan and with a handful of their protégés. All have been both mentors and protégés. As Goddard Chief Engineer Steve Scott said, "NASA is really a learning organization and mentors are the key that unlocks the door."



Mentoring at NASA takes various forms. Technical and management development programs, such as the Systems Engineering Leadership Development Program (SELDP), encourage mentoring as part of the program. Terry Nienaber's supervisor, Pete Spidaliere (mission systems engineer for the Magnetospheric Multiscale mission), was also his formal SELDP mentor. The relationship was very close, as Spidaliere guided Nienaber, of Langley's Mechanical Systems Branch, during the transition to a new role, a new project, and an unfamiliar NASA center—Goddard—for the yearlong program. Nienaber recounts that Spidaliere even gave him a "good-natured shove into paying more attention to my health, nearly dragging me to the gym." But formal programs account for only a portion of mentoring. Much, perhaps most, mentoring at NASA is an informal match-up between a protégé and a manager or expert.

Mentoring spans three dimensions of work at NASA: technical, managerial, and career. All the mentors I spoke with understand that mentoring is a whole-person activity. Whatever their specific focus, mentor and protégé discussions touched all three dimensions. So when you are choosing or working with a mentor, consider the implications for technical, managerial, and career issues.

Given NASA's wide diversity of disciplines, capabilities, centers, and personnel, you'll need to develop a work style that can accommodate differences and build collaboration. Citrin had a protégé who thought his position gave him the authority to do what he wanted. She guided him to a more inclusive and collaborative work style.

To develop this combination of very different skills, NASA staff frequently have numerous mentors during their career, and sometimes two or three at once, each focusing on different aspects of skill building and career development.

Finding a Mentor

You can take the initiative to find a mentor. Ask your supervisor, current or previous mentors, managers, or colleagues who have experience in the kind of challenges you are facing. Nienaber said he looks for "people that impress me with how they handle things in which I'm weak."

Making the Mentor Relationship Work

Define Your Intent

This is simple but important and easy to forget. Find mentors who either address your weak spots or deepen a strength, and focus the discussion on those cutting edges. In the NASA environment, depth and breadth are both critical to develop technical and managerial expertise. As your relationship evolves, keep an eye on your intent, shift it as appropriate, but don't just let the conversations drift.

Find the Right Mentor

As in any relationship, mentor and protégé need to click. There is no reason to believe that someone with the right technical skills will be the right mentor for you. Citrin pointed out that many different personal or management styles work in NASA. You don't need to and may not be able to change your core management style. So find a mentor who can give you good, frank feedback but still work with you as you are, rather than try to turn you into someone else. As you discuss your intent, listen for how they can help you. If their advice isn't helpful, you're free to end the relationship without any negative reflection on you or the mentor.

Keep Mentors That Work

Getting a new mentor does not mean you need to end current mentor relationships. Despite the fact that Goddard's Richard Barney has had numerous technical and management mentors during his career, he still turns to Tom Magner, the mentor he was assigned on his first day more than thirty years ago. At a given time, you may have several mentor relationships.

Take the Lead

Bring questions to discuss, manage your meeting time, ask to shadow your mentor to meetings, draw insights from your mentor, and follow up. One of Felicia Jones-Selden's protégés e-mails her topics the day before a meeting and Jones-Selden, deputy director of the Applied Engineering and Technology Directorate, routinely brings protégés to meetings so they can talk about the issues afterward. Taking the lead makes the mentor–protégé relationship more of a partnership. As she notes, it should bring out the best in both of you. Brennan notes, "Mentors are people we respect and aspire to emulate. This can create feelings of intimidation and fear. It's important to recognize this dynamic and to shift it to a mind-set of curiosity and learning."

Make It Easy for the Mentor

Mentors, like everyone else at NASA, have more to do than they can fit into the day. It's tempting to meet in the mentor's office, but that often means disruptions that make deep discussion impossible. Find a time and place that are conducive to open dialogue and the least disruptive for your mentor; morning coffee, lunch, and Friday afternoon are likely possibilities. Since Jones-Selden has several protégés, she routinely establishes regular monthly lunch mentoring sessions.

Find Impromptu Mentoring Opportunities

When following up on complex subjects, Nienaber prefers "walk-arounds" rather than writing an e-mail because it increases opportunities for deeper discussions. Additionally, when he sees someone handle an issue particularly effectively, he talks with them afterward about what they were considering during a potentially difficult conversation.

Meet Regularly

Project demands can easily supersede mentoring meetings. But wide gaps between meetings will kill momentum and the depth of connection. Brennan notes that making time for mentoring meetings is a challenge and needs to be a priority. One of her

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protégés likened the experience to taking your car in for a tune-up. "It's an hour 'time-out' where you get to be open, honest, and unguarded; to think strategically, consider questions, listen, learn, and re-energize."

Learning with Your Mentor

Create a Purposeful, Open Discussion

Start by discussing your intent and expectations. Barney said, "You have to have some hutzpah in asking your mentor what he or she wants to get out of the relationship." Scott feels that meeting in his division chief's office makes it too formal, so he takes his mentor to Starbucks where they can talk more as equals. When Nienaber asked Ryschkewitsch to be his mentor, Ryschkewitsch set a condition: "Only if you coach me, too. You have to give me feedback on at least one thing you think I could do better." Making the mentoring relationship two-way shifts the power structure of the relationship to a more collaborative one.

Focus on How You Think

Expertise is a combination of knowledge and thinking skills—skill in diagnosing issues, understanding their causes, and making difficult judgment calls. One of Ryschkewitsch's mentors taught him the skill of thinking down a path when diagnosing and understanding technical problems and recognizing when to shift paths. Now he passes on that lesson by teaching his protégés this skill of thinking down multiple paths.

Practice Thinking with Your Mentor

You can only develop a skill through practice. We understand the importance of practice in the arts and sports. Pianists learn by playing for their teacher; the teacher guides and directs them based on hearing them play. Developing good thinking skills is much the same. When Nienaber turned to Rosemary Baize at Langley to help with a difficult career decision, she asked probing questions that helped him sort out emotions, facts, and outcomes rather than giving him suggestions. By helping him shift the way he thought about the decision, she steered him away from some poor choices.

Ask Your Mentor to Help You Think

Don't ask your mentor what to do. Instead think aloud, as Nienaber did, about a judgment call and ask your mentor to question and guide you with questions like, "What am I missing? What considerations should I have? Help me understand the science or principles that are working here." Then ask your mentor to guide you in making a decision in the same questioning way. Your mentor is likely to ask you about the options, the assumptions you are making about them, if they really address the issue, the science behind them, potential consequences, or other dramatically different approaches to the resolution. Sometimes it may feel that your mentor is driving you down unnecessary routes, but remember: the purpose of the discussion is not to solve the problem but expand your thinking.

Explore How Your Mentor Thinks

Pay attention to where your mentor directs you, the hidden clues he or she uses to correctly diagnose the situation; her analysis of the assumptions you are making; the science, research, or principles he draws on to understand the situation; the issues he or she is concerned about as you consider right courses of action together. Paying attention to how your mentor thinks as you discuss a technical, managerial, or career issue is a great way to learn. Because you are discussing a real issue that matters to you, the relevance, depth, and consequences of your mentor's attention and concerns will have much more impact than if you simply hear a story about one of his or her projects.

Learn to Think Aloud

Being a good protégé will make you a better mentor and vice versa. Protégés often think they should get the "right answer" from their mentor, but if you learn to explore your own and your mentor's thinking openly, you'll develop the skills you need to guide protégés when you start mentoring yourself.

Building the Future

The NASA staff I interviewed said their mentors' guidance was critical to their success. Hopefully these tips will help you carry on that success. As Ryschkewitsch said, "Mentoring is more than just helping the individual. It is bringing up the next generation." ●

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The Knowledge Notebook

Where Is the Knowledge in NASA?

BY LAURENCE PRUSAK

Imagine if the Curiosity rover found evidence of life on Mars—not fossil microorganisms, but a live, English-speaking Martian. Suppose he (or it) started asking us questions like, "What does NASA do?" Well, that's easy enough to answer. For the sake of simplicity, we might say, "Space exploration." But then suppose our Martian asks, "How do you know how to do that? Where do you keep the knowledge you need?"

Well, that is one interesting question.

Where do you think this knowledge is? You would think it should be pretty easy to answer such a question, since knowledge is so important, but in the many years I have asked people in organizations this question, I have received very diverse answers and almost no consistency of responses. That lack of agreement certainly leads me to wonder how we can ever hope to work effectively with knowledge and learning if we can not even tell where it is.

There are several reasons for this uncertainty. Knowledge is by its nature intangible. It has no physical form that we locate and describe. That uncomfortable fact leads many to conflate knowledge with information or data, or sometimes even IT systems, which *are* concrete and can be pointed to and measured. In fact, those are the answers I most frequently get when I ask the question. But the answers are wrong. Knowledge is not data or information. It is not an IT system (or its content).

Another reason for this odd failure to answer what seems like a basic question is that knowledge is rarely, if ever, considered in any class or graduate program. Take a look at the index in the back of any text on economics or organizational behavior. Not a word about knowledge. Most strategy books ignore it, too. That is remarkable given that knowledge is, in many ways, our most important source of wealth. It is surely the basis of NASA's capabilities and capacities. (I will write about why this is the case in another column.) But if something is rarely taught or even mentioned in the literature, it is a good bet it will be pretty hard to arrive at a common and meaningful definition or description of it.

OK, so let's try to answer the question. Where is NASA's knowledge?

There are generally three main places to "look" for knowledge in any large and complex organization. The first one—often mentioned—is in the people of the organization. This is the most obvious response, and an important one. We can call such knowledge "embodied" as it is literally in the bodies of individuals. Research and reflection can show, however, that thinking only about the knowledge worker—the individual—is not a very useful approach to knowledge.

Knowledge is very social. It is found in organizational practices, networks, communities, and other aggregated units. People come and go in organizations, yet the organizations continue to "know" things and have capabilities. IBM is more than one hundred years old. None of its original employees are still alive and yet the company retains its technical know-how, no matter how many individual employees leave over time. Procter and Gamble is even older and preserves its original DNA—knowledge about household goods and how to sell them. This is because the knowledge is retained primarily in practices that are sustained over time in spite of employee turnover.

A second and less apparent place to find knowledge is in the organizational routines and processes in which organizational knowledge is embedded. All organizations more or less do the same things day after day. These established routines, which apply knowledge in an organized series of activities, allow knowledge to be retained for as long as it is needed. It represents an organization's best take on the best way to accomplish some aspect of its work. NASA procedural requirements, like NPR 7120.5, incorporate a lot of the agency's knowledge about carrying out projects. These patterns, of course, change over time, when new or better knowledge is recognized and agreed upon and new processes are developed and embedded.

And the third place to find knowledge is in systems and documents. Although we can make the case that it is really information that is found there, we can reasonably state that the information is a kind of frozen or represented form of knowledge. It is less dynamic and far less contextual than the other forms, but it is still a vital component of effective capabilities.

So here is a partial but I hope useful answer to our Martian's query. It's a start, at least. Until we can have some consensus around these issues and have given serious thought and time to them, we will be fated to under-optimize the most valuable thing we have. And the most expensive, too! ●

KNOWLEDGE IS VERY SOCIAL. IT IS FOUND IN ORGANIZATIONAL PRACTICES, NETWORKS, COMMUNITIES, AND OTHER AGGREGATED UNITS.

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NASA in the News

On August 25, 2012, Neil Armstrong, America's first man on the moon, passed away at the age of 82. NASA joined the nation in celebrating Armstrong's life and achievements. Friends and family, including fellow astronauts, scientists, and engineers who worked with Armstrong throughout his career, held several memorials to remember the man who took that first small step and giant leap for human space exploration. Many of those astronauts and former colleagues sat down to speak with NASA Television about the Apollo 11 commander: www.nasa.gov/multimedia/videogallery/index.html?media_id=152143701. The agency also curated a photo gallery that captures Armstrong's life throughout his career at NASA: www.nasa.gov/topics/people/galleries/armstrong.html. Armstrong's full biography can be found at www.nasa.gov/topics/people/features/armstrong_obit.html.

Sounds of Space

University of Iowa researchers for the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) aboard the Radiation Belt Storm Probe released a recording of the phenomenon known as "chorus" radio waves. The radio waves, which are at frequencies audible to the human ear, are emitted by energetic particles in Earth's magnetosphere. "People have known about chorus for decades," said EMFISIS principal investigator Craig Kletzing. "Radio receivers are used to picking it up, and it sounds a lot like birds chirping. It was often more easily picked up in the mornings, which along with the chirping sound is why it's sometimes referred to as 'dawn chorus.'" Listen to the chorus of space at www.nasa.gov/mission_pages/rbsp/news/emfisis-chorus.html.

Destination Station

As the International Space Station transitions from construction to full-time research lab, NASA reflects on what it took to make an orbiting space station a reality and what it stands to offer going forward. From partnership to operations to scientific research, the past ten years and next ten years have been captured in a series of videos, photos, and interactive features in "Destination Station," available at www.nasa.gov/externalflash/destination_station.

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