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# ASK

INTERVIEW

Dr. Charles Pellerin

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ON THE COVER Engineers test a prototype of airbags used for landing on Mars.

# Table of Contents



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

*ASK Magazine* grew out of APPL's Knowledge Sharing Initiative. The stories that appear in *ASK* are written by the 'best of the best' project managers, primarily from NASA, but also from other government agencies and industry. These stories contain genuine nuggets of knowledge and wisdom that are transferable across projects. Who better than a project manager to help another project manager address a critical issue on a project? Big projects, small projects—they're all here in *ASK*.

Please direct all inquiries about *ASK Magazine* editorial policy to Todd Post, EduTech Ltd., 8455 Colesville Rd., Suite 930, Silver Spring, MD 20910, (301) 585-1030; or email to tpost@edutechltd.com.

# Learning About *ASK*

*The* ASK Magazine *prototype appeared in January 2001, and was released to a small group of readers, less than a hundred of some of the most reflective project managers we knew at the time*

The format we chose—stories—was boldly different than any other project management publication we were aware of. This was truly an innovation, and so a prototype seemed like a good way of testing this new concept to see if it was legitimate. We wanted our readers to tell us if we were on the right track, and by producing a prototype we could gain that knowledge quickly in case we needed to rethink our approach.

All I had to start was a stack of transcribed presentations from the APPL Masters Forum of Project Managers from September 2000. It was my job to pull out the best stories and contact the authors to fill in some areas that the editorial team (Ed Hoffman and Alex Laufer and myself) thought deserved more attention.

Let me tell you a little story within this story. I learned a tremendous amount about project management at NASA while working on this prototype issue—for instance, when I conducted my first interview with a NASA project manager, Elizabeth Citrin of Goddard Space Flight Center. I began the interview by asking her some generic questions about scheduling and budgets. As an interviewer, you know when you've got good material by the excitement you get back from the interviewee. It felt like a stiff interview, until I tossed aside my prepared questions and simply asked her, "So what is it that gets you excited about a project?"

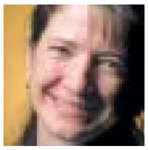
And there the interviewed tipped. Liz told me that it was the science, so I asked her to tell me more about the science on the mission she was project manager on then. Her eyes lit up even brighter, and suddenly we were having a wonderful time talking about the project and its science objectives and how those intersected with her management.

Whenever I do an interview with a NASA project manager, I'm always looking for that tipping point. NASA project managers will speak passionately with me about the work they do and why they love it, but the onus is primarily on me to get them to open up.

Back now to the *ASK* prototype. We came out with the prototype in January '01 as intended, and the advice we got from our audience was critical in helping us think through what we wanted to accomplish with *ASK*. We continue to learn from our readers and adapt the magazine with their help. In that way, the *ASK* project still feels a bit like a prototype.

In this issue of *ASK*, you'll find examples of how prototyping has been used to benefit a range of projects. We reach a much larger audience now than we did when we released the *ASK* prototype, but we still look forward to hearing from our readers as to how to do a better job. As always, we invite you to share your thoughts with us. •

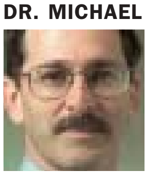
**JOHN BRUNSON** of the Marshall Space Flight Center is a member of the NASA Program Management Council Working Group. He served as project manager for three separate microgravity payloads that flew on various Spacelab missions. His career in the space industry began in 1980 as a technician working on the first Space Shuttle.



**DR. MICHELLE COLLINS** works in the Spaceport Engineering & Technology Research Group at Kennedy Space Center. She has over 20 years experience in aerospace spanning engineering, R&D and project management. She is on the Florida Tech Engineering Accreditation Board, the National Fire Protection Association's Technical Committee for Halon Alternatives, and the United Nations Environmental Programme Halon Technical Options Committee.

**HECTOR DELGADO** is Division Chief of Process Tools and Techniques in the Safety, Health and Independent Assessment Directorate at the Kennedy Space Center. In 1995, he served as Senior Technical Staff to the NASA Chief Engineer at NASA Headquarters in Washington, D.C. He has received many honors and awards including the Exceptional Service Medal, Silver Snoopy Award, and various achievement awards.

**DR. OWEN GADEKEN** is a Professor of Engineering Management at the Defense Acquisition University where he has taught Department of Defense program and project managers for over 20 years. He retired last year from the Air Force Reserve as a Colonel and Senior Reservist at the Air Force Office of Scientific Research. He is a frequent speaker at project management conferences and symposia.



**DR. MICHAEL HECHT** has been with NASA since 1982 at the Jet Propulsion Laboratory (JPL). He is project manager and a co-investigator for the Mars Environmental Compatibility Assessment (MECA). In his previous assignment with NASA's New Millennium Program, he was instrumental in defining the "microlander" that was adopted as NASA's New Millennium Program Deep Space 2.

**JODY ZALL KUSEK** is a Senior Evaluation Officer at the World Bank. She is currently involved in supporting the efforts of seven governments to move to a focus of performance-based management. She has spent many years in the area of public sector reform, serving the Vice President of the United States, the U.S. Secretary of the Interior, and the U.S. Secretary of Energy in the areas of Strategic Planning and Performance Management.

**DONALD MARGOLIES** of the Goddard Space Flight Center was Project Manager for the Advanced Composition Explorer (ACE) mission, launched in 1997 and still operating successfully. He received the NASA Medal for Outstanding Leadership for his work on ACE and a NASA Exceptional Service Medal for the Active Magnetospheric Particle Tracer Explorers (AMPTE) mission.

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**JOAN SALUTE** is the Associate Director of Aerospace at Ames Research Center. She has managed many NASA projects including those involving flight testing of thermal protection materials, commercial technology, commercial applications of remote sensing, and remote sensing science projects. She has been at Ames for 20 years, and was awarded the Sloan Fellowship to attend Stanford Graduate School of Business.

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**CHARLIE STEGEMOELLER** is Manager of the Johnson Space Center (JSC) Human Space Life Sciences Programs Office. He is responsible for the programmatic and tactical implementation of the lead center assignments for Space Medicine, Biomedical Research and Countermeasures, and Advanced Human Support Technology. He began his career at NASA in 1985 with JSC Comptroller's Office as a technical program analyst.

**HUGH WOODWARD** is a Program Manager for Global Business Services with the Procter & Gamble Company. He served as the Chairman of the Project Management Institute (PMI) for consecutive terms in 2000 and 2001. He was elected to the Board of Directors in 1996, and before being elected as the chair, served terms as vice chair and in several other key leadership roles.

FROM THE DIRECTOR'S DESK *Dr. Edward Hoffman*

# Playing with Prototypes

*On a recent trip to the Jet Propulsion Laboratory, I brought home some toys for my children*

I FREQUENTLY RETURN HOME FROM MY TRIPS TO NASA Centers with fun little things for them. The urge is irresistible, and the truth is the stuff is as much for me as it is for the kids.

One of the toys I brought home on this trip was a gyroscope. When I showed it to my daughter Amanda, she was as smitten with it as I was when I spotted it in the JPL gift shop.

> *"...It's not enough to have brilliant ideas; you have to be able to demonstrate them. You have to get people to want to play with them."*
>
> —*Michael Schrage,* Serious Play

For the next hour we laughed and played. We placed it on its side, right side up, upside down, on different surfaces and changed speeds. We discussed ways to improve the gyroscope. We talked about the science. It was just plain fun.

I have always liked gyroscopes. I'm not exactly sure why, but I know it has something to do with how they feel in my hands. The whole time Amanda and I were playing, I couldn't stop thinking of the power of letting people touch and play with something, and the learning experience that provides.

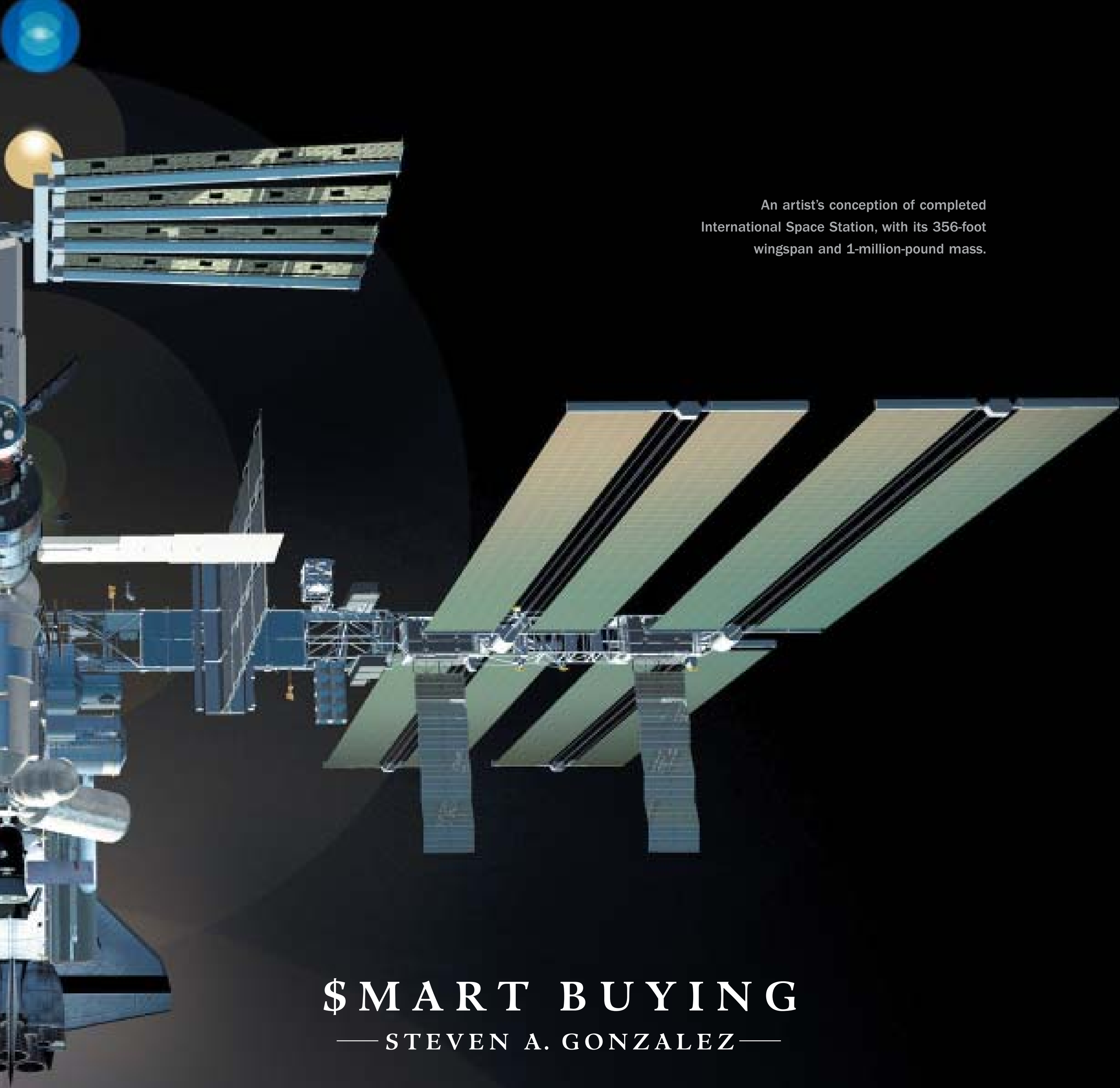
In his outstanding book, *Serious Play*, Michael Schrage suggests that play should be a critical core competency of any modern organization. Coupled with the serious nature of work is the joy that comes from playing with a prototype or model. A fascinating premise of the book is that prototypes and models have their power in allowing people to play with difficult concepts. If this is not proof, after an hour or so Amanda announced, "I'd like to make my own gyroscope."

The power of models and prototypes has always been a part of my life. I remember as a kid, not much older than Amanda, playing football on East 9th Street in Brooklyn. We used primitive forms of prototypes by drawing pictures and plays on the street with chalk. If it was raining or we were concerned about the other side stealing our plays, we would gather the team around someone's back and draw the play with an index finger.

Here again, I am reminded of *Serious Play* and the notion that a prototype, model, or simulation is important because it creates interactions between people involved with the outcome. Our drawings opened up a space to discuss and explore the execution of the play. Sometimes our discussions were so lively and went on so long that the other side would start counting down aloud to make a point of their impatience.

Back at the scrimmage line, we'd run our play and see what happened. Sometimes it worked, sometimes not. Incomplete passes, sweeps that ran out of bounds—afterwards we'd regroup in the huddle and attempt to figure out what went wrong, drawing the play again and learning from our mistakes. A couple of downs later, we'd try again and see if we could muster better yardage. Each time, we learned to read the defense a little better.

That, too, is the nature of playing with prototypes: They are a constant source of learning. This issue of ASK is devoted to prototyping, and I hope you will find plenty to learn from inside...



An artist's conception of completed International Space Station, with its 356-foot wingspan and 1-million-pound mass.

# $MART BUYING

STEVEN A. GONZALEZ

**When it came time to buy the next-generation data storage system for the Mission Control Center at Johnson Space Center, we asked our contractor who provides Control Center support to come up with a solution that would consolidate three current storage systems, as well as provide additional capability and functionality—all without spending vast amounts of money.**

EVENTUALLY, THE CONTRACTOR'S REPORT ARRIVED AT MY office. To my great disappointment, the proposed system came along with a multi-million dollar price tag. And, even more disappointing, the system relied on the same technology we already had in place and wouldn't deliver much additional functionality. It was clear that we needed to come up with a better solution—the best we could buy. But how do you buy the best technology, when you don't even know what technology is out there?

INSTEAD OF SPENDING ABOUT $3 MILLION, WE SPENT $750,000 ON A STATE-OF-THE-ART SYSTEM IDEALLY SUITED TO MEET OUR CONFIGURATION REQUIREMENTS.

Technology changes often and staying aware of the latest technological developments is always a challenge. In this case, we needed to invest in an in-depth evaluation of potential solutions.

I realized that we had to learn first-hand to be better buyers, so I came up with the idea of inviting storage area network vendors to come on site and show us their capabilities and products. I hoped that by "test driving" the latest, greatest technology, our civil servants would be smarter buyers when it came time to choose a system.

I HOPED THAT BY 'TEST DRIVING' THE LATEST, GREATEST TECHNOLOGY, OUR CIVIL SERVANTS WOULD BE SMARTER BUYERS WHEN IT CAME TIME TO CHOOSE A SYSTEM.

We cleared out two rooms, reached agreements with several companies, and then, one-by-one, put their storage systems through the paces that would enable them to be installed at Mission Control—in essence, testing out a series of prototypes of the system we hoped to acquire.

Why would a company expend their own resources to temporarily install more than a million dollars of equipment at our technology lab? It allowed them to say that they had helped create a Mission Control Center prototype, and to tell potential clients that NASA was evaluating their equipment.

Our prototype project allowed us to better understand our requirements, before investing in a system. One of the things we learned about was clustering capabilities that would enable us to better support the Space Station's 24-hour operation. We had to have a storage system that could be reconfigured to a reduced environment so that the rest of the Control Center could be updated. We needed to be able to quickly move from one configuration to another, but didn't know how we could reduce the four hours required to do this. We discovered a clustering capability associated with some of the systems we tested that provided that capability and reduced the time dramatically.

While our people were brought up to speed on the latest technologies available, the companies got a heads-up on our requirements. We used the prototypes to learn, and we told the companies that NASA and its contractor support would create the RFP that would go out for the new storage system based on what we had learned. We couldn't promise them anything, but it would give them a chance to see how their systems could be adapted to work in our particular environment. As it turned out, one of them did get work from the Mission Control Center contractor using the prototype concept they presented to us.

In the end, NASA got a better system for less money than had been thought possible. Instead of spending about $3 million, we spent $750,000 on a state-of-the-art system ideally suited to meet our configuration requirements. And in the process, we became smarter customers and smarter buyers of new technology. •

## LESSONS

• Prototyping can be a key management and communication tool. Prototypes can increase the active participation of users in project definition.

• Using the products of different vendors allows the user to refine his or her objectives.

## QUESTION

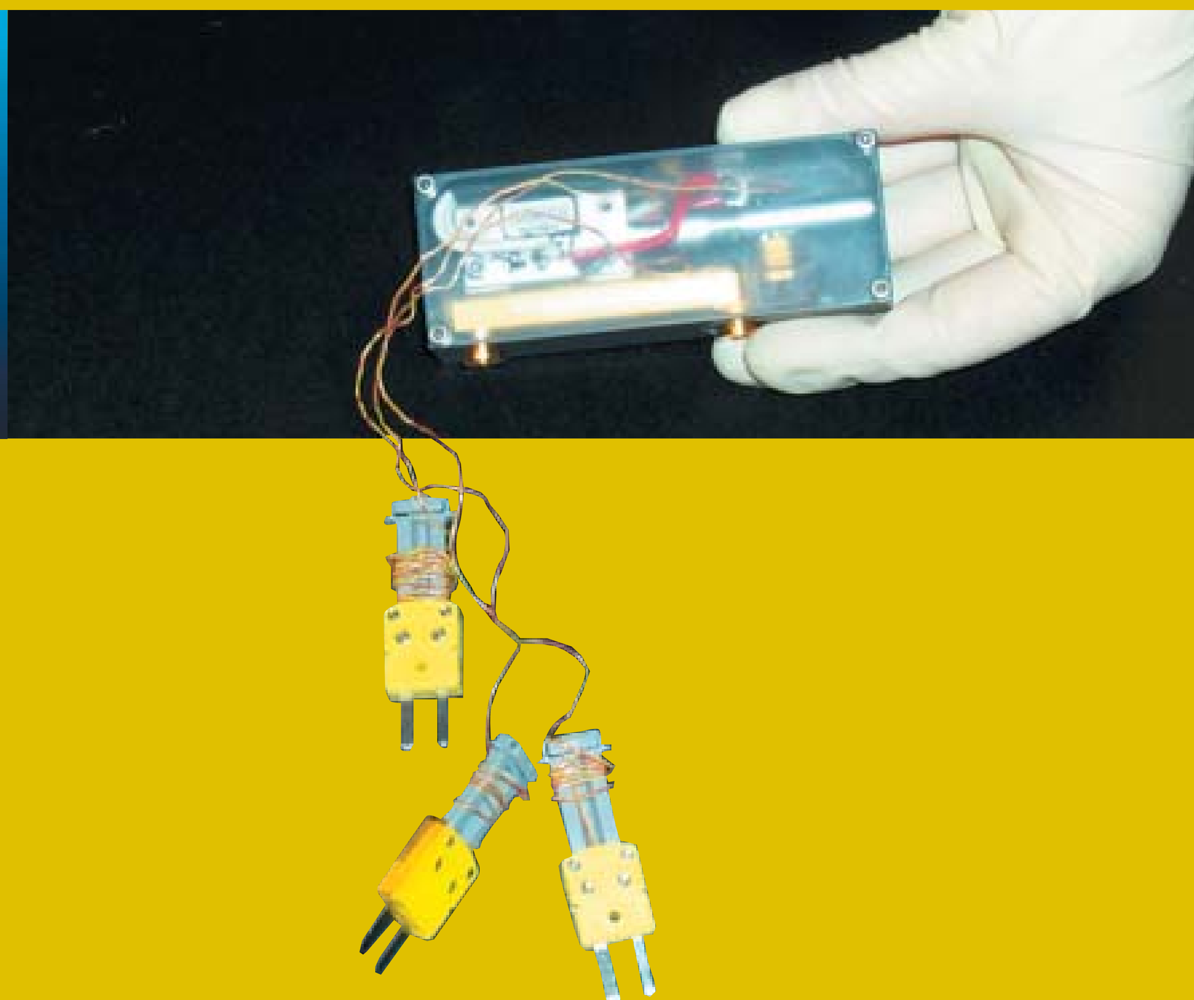
*What would it take on your projects to be a smarter buyer?*

**Clouds form the backdrop for the connected Zarya and Unity modules after their 1998 release from the Space Shuttle Endeavour's cargo bay.**

Two years ago, **STEVEN A. GONZALEZ**'s story, "It's All About Passion" (*ASK 2*), described founding the Qualification and Utilization for Electronics Systems Technology (QUEST) lab with his fellow engineers at Johnson Space Center. The QUEST group sought to reinvigorate their passion for work by mapping out a path to NASA's future. About the lab's founding ideals, Gonzalez wrote, "The farthest reaches of the galaxy would forever be expanding as long as we had the imagination to see a way there.... Our mission, as we saw it, was to come up with a plan to achieve the infrastructure and technology that would make this vision a reality."

Today, Gonzalez serves as Chief of the Operations Research & Strategic Development Branch at Johnson, and his team continues to support the QUEST vision. Now called the Quest Innovations Lab and under the leadership of Tony Bruins, the group partners with private industry to bring cutting-edge technology to NASA at low cost.

# AS SMALL AS POSSIBLE



BY SCOTT TIBBITTS

This story begins with a bit of serendipity: I was on a trip to see a Shuttle launch and I happened to sit next to a guy who was in charge of batteries for Space Systems/Loral. He told me that they needed to create a new battery bypass switch, the device that takes a battery out of commission if it goes bad.

After discussing the conversation back at my company, we decided that we could create the switch. We contacted the folks at Loral and they said, "Okay, let's see what you can come up with. We need it as small as possible." We asked, "How small?" They said, "We need it as small as you can possibly make it."

I called in my lead design engineer and said, "Dave, I need you to make this switch as small as humanly possible."

Dave went to work and he created a prototype for the bypass switch that we were pleased with. We showed the prototype to the customer and we said, "This is the smallest bypass switch we can make." And they asked, "Are you sure?" And we said, "Yes, that's it." They told us that they weren't too happy about the size, but if that was as small as we could make it, they would consider it.

"The people who run small technology companies are bold and fearless," says Dr. Michael Hecht of the Jet Propulsion Laboratory. When Hecht started up his $5-million project to fly an instrument to Mars, he looked to small business and found his way to **SCOTT TIBBITTS**, President of Starsys Research in Boulder, Colorado. "I remember very well a spring morning when I first came and sat opposite Scott at a conference table and I told him about my project. He listened patiently, and then he told me, 'If we mess up your project, we might as well take the shingle down from in front of the door.' That was my first introduction to the Starsys philosophy. I learned far more from them than they ever could have learned from me," says Hecht. Since 1988, Tibbitts's company has grown from a garage-based, two-person business building thermal actuators, to a 90-person firm with a world-class reputation for producing more than 2,000 mechanisms flown on more than 200 spacecraft.

***A WEEK LATER, DAVE CAME TO ME WITH A NEW PROTOTYPE – THIS ONE WAS LESS THAN HALF THE SIZE OF THE FIRST PROTOTYPE.***

A month later, we went to a trade show and saw a prototype for the same switch that a competitor had created. It was half the size of ours. I brought Dave over to take a look. We looked and looked at it. A week later, Dave came to me with a new prototype—this one was less than half the size of his first prototype.

Now, I can't tell you how many times I harped on Dave before he designed the first prototype that it had to be "as small as possible." But it wasn't until he saw the dimensions of what someone else had come up with that he created his second, smaller design. One thing going on was personal pride: If another designer could do something, then, by God, Dave could do it.

I've come to call this "harnessing the power of the sun." You don't want to use this in a manipulative way, but if you have the opportunity to take someone who has a self-righteous pride that they can do something, couple it with talent and point them in the right direction, magic can come from that.

Another lesson that I've learned is that—whether you're talking to a designer about a prototype or to a team about an entire project, good managers don't say, "I need it as small as possible," or "I need it as inexpensive as possible," or "I need it as soon as possible." They set an ambitious but realistic goal, and they drive their team to it by saying, "Hey, I need this. How can we do it?" That's when the creativity kicks in and people start thinking outside the box.

When you've agreed on such a goal, it's amazing sometimes how clever people can get. •

## Lessons

• Setting ambitious but realistic goals for a project is a key to succeeding in today's competitive environment.

• Competition is a powerful motivator—as is personal pride—which project managers may use to elicit creative contributions from individuals.

## Question

*When setting a goal for a project, how do you know whether it is ambitious enough?*

# Right-

RIGHT

RAPID

ROUGH

# - Rapid - Rough

IDEO (pronounced "eye-dee-oh") is an international design, engineering, and innovation firm that has developed thousands of products and services for clients across a wide range of industries. Its process and culture have attracted the attention of academics, businesses, and journalists around the world, and are the subject of a bestselling book, *The Art of Innovation* by Tom Kelley (reviewed on page 39). One of the keys to IDEO's success is its use of prototyping as a tool for rapid innovation.

**BY DR. CRAIG LAWRENCE**

## RIGHT

A LEADING MANUFACTURER OF PERSONAL COMPUTERS came to IDEO to design a new laptop. One of the many areas they wanted us to improve was the design of the door that covers and protects the connectors on the back of the product. Why were they so interested in this door? It turns out that one of the most common failures in a laptop is the connector door. This little feature is constantly used and abused, and inevitably breaks or falls off, causing great annoyance to the user. Our customer wanted an innovative solution that was reliable and easy to use.

The team brainstormed hundreds of alternate solutions, and quickly narrowed down the field to several that seemed promising. How to select the best concept? Analysis was not enough; we needed to know how the doors functioned when used, and this clearly called for prototyping. At this point in the program, the overall design of the laptop had not yet been developed. Regardless, the team pressed ahead and built a series of prototypes that focused exclusively on the connector door.

Models of the door concepts were machined from plastic that would simulate the actual performance and feel of a real production solution. These models were then attached to blocks of wood that roughly approximated the size and weight of the final laptop design. Great attention to detail was placed on the areas around the door and hinge, while no effort was made to simulate any other aspect of the laptop.

Some of the concepts were complex. For example, one concept used a clever geared hinge to open a set of double doors, revealing the hidden connectors in an appealing way. Others were simple; one even "borrowed" from the common metal tape measure to create a sliding door. In fact, the team literally used a tape measure in the prototype—a quick method of testing the concept. These prototypes were taken to potential users and tested. They were pulled, pushed, squeezed, dropped, and cycled until the flaws in the concepts were revealed and a clear winner could be selected.

This example illustrates an important concept in prototyping. A prototype should be designed to answer a specific question. The key is to ask the right question (the right question is the one you really need answered), and target your prototypes to answer it.

We find that if we try to answer too many questions with a single prototype, the prototypes become more expensive, take longer to create, and often provide less value than a series of quicker, cheaper prototypes targeted at individual questions. Prototyping in this manner keeps the cost of failure low.

## RAPID

Prototyping does not have to be painful. Prototypes don't have to break your project budget and devour all of your project resources. A prototype can (and should) be built in a few minutes.

> By limiting the time, energy, blood, sweat, and tears you put into a prototype, you reduce your bias towards the concept.

IDEO developed a small digital camera that plugs into the expansion port of a PDA (Personal Digital Assistant). While this product provided serious engineering challenges, one of the toughest challenges was developing the software interface that the user encounters when operating the product. A poorly designed interface can ruin a user's experience with a technically perfect product.

Before any software code was written, IDEO's interaction designers prototyped the user interface using the quickest method they could think of: Post-It® notes. They created a series of handwritten Post-Its that represented the on-screen menus and windows the user might encounter while using the product. The team could quickly simulate and test different interface screens and menu logic by simply peeling away successive layers of Post-Its as a user navigated through the "software." If something did not make sense, they could toss the Post-It and quickly create another.

Again, this prototype was taken to users and tested, refined, and iterated. By the end of the prototyping process, the team had a solid structure they could use to develop the actual software. All without ever turning on a computer.

The main value of this sort of rapid prototyping is the ability to quickly evaluate your concept, and refine it through a series of iterative prototypes. Instead of spending your time and resources speculating solutions and analyzing the problem, spend your time solving it. Fail early in order to succeed sooner.

One of my favorite tools for rapid prototyping is Lego®. These ubiquitous children's toys are a great way to prototype fairly complex mechanisms. During the development of a medical instrument, an IDEO team used Legos to prototype several concepts for a mechanism to convert continuous rotary motion into reciprocating linear motion. These prototypes clearly could not be used for surgery, but they are great for allowing an engineer to visualize a concept and work through some of the complex details rapidly.

There are many great materials and tools available for rapid prototyping. Often, these are things you can find laying around: wood, plastic, tape, hot glue, coat hangers, boxes, plastic tubes, and toys. For more complex problems, tools like fused deposition modeling (FDM) and stereo lithography (SLA) are often useful. Feel free to mix high-tech and low-tech components and techniques. Use your prototype to get feedback, and then move on.

### ROUGH

A prototype does not have to be pretty.

Sleep apnea is a significant problem facing millions of people. While a sufferer of this condition sleeps, the muscles at the base of the throat relax and obstruct the airway. This results in a drastic slowdown or even stoppage of breathing that can cause hypoxia or even death. One solution to this problem is to provide positive pressure to the person's airway to keep it open. The user wears a mask over the nose connected by a tube to a pump to provide the needed pressure.

IDEO worked closely with a medical device manufacturer to develop a product designed to help people with sleep apnea. Several products existed on the market, but all shared a common flaw: They were uncomfortable to wear while sleeping, and many sufferers refused to use them. IDEO set out to develop a product that exceeded the performance of existing products on the market, and that would let a user sleep comfortably.

> Fail early in order to succeed sooner.

After earning a Ph.D. at Stanford University, **CRAIG LAWRENCE** joined IDEO in 1999 as a mechanical engineer and project manager in the Smart Products studio. Focusing his efforts on developing electromechanical products, Lawrence has been a technical contributor and manager on such projects as a portable fuel cell battery for consumer electronics and a handheld medical instrument to measure human metabolism.

Lawrence is a frequent instructor at IDEO workshops, helping clients understand how to work with innovation tools. In addition, he is a regular instructor at APPL's Advanced Project Management course, and he has participated in other NASA forums for the knowledge sharing community.

One concept that quickly emerged was to mount the air tube over the user's head. This idea seemed attractive since it addressed a number of complaints from users. It could locate the tube in a predictable place, keep it from moving around as the user shifted during sleep, and it relieved the weight of the tube, preventing it from pulling at the mask.

A series of head-mounted concepts were generated and quickly prototyped at the engineers' desks using commonly found objects and a little creativity. Engineers put prototypes together using the lining of a bicycle helmet, stereo headphones, and pieces of hand-cut plastic in order to try out different ideas. They took them home and slept with them on, waking up to modify them as they encountered problems.

These prototypes weren't attractive; however, they did the job and allowed the team to focus in on a winning solution. The final product incorporated a number of concepts from the various prototypes, including a unique cantilever design allowing it to accommodate various head sizes and shapes. The final product was beautiful, but it was a beauty that came from humble beginnings.

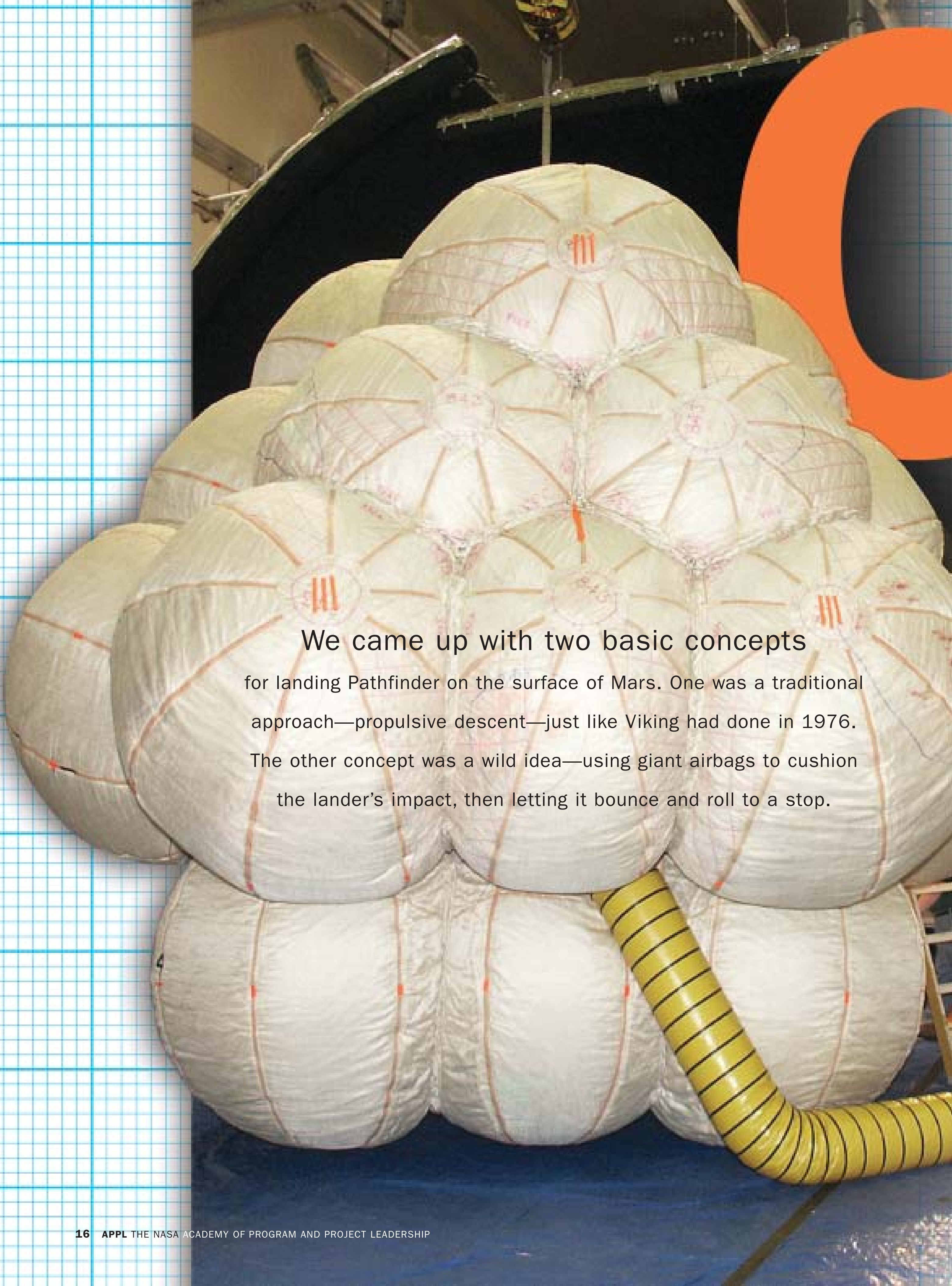
One of the benefits of creating rough prototypes is that you reduce your emotional attachment to a concept. By limiting the time, energy, blood, sweat, and tears you put into a prototype, you reduce your bias towards the concept, and are more likely to make objective conclusions and decisions about its value. •

### Lessons

- Prototyping is a technique that embraces failure as a means to ultimate success.
- The Right-Rapid-Rough approach fosters innovation by forcing you to use all of your senses to attack a problem.

### Question

- *How do you learn from small failures on a project?*

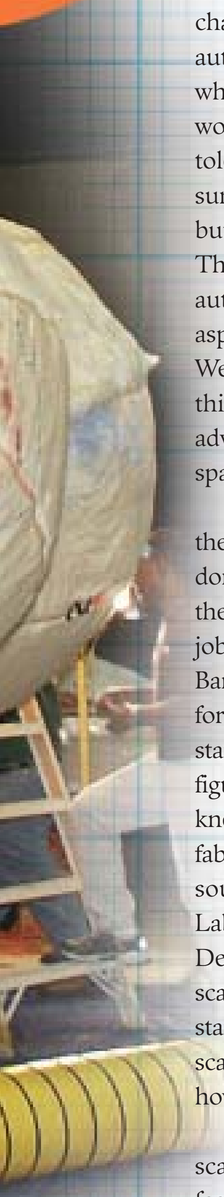


We came up with two basic concepts

for landing Pathfinder on the surface of Mars. One was a traditional approach—propulsive descent—just like Viking had done in 1976. The other concept was a wild idea—using giant airbags to cushion the lander's impact, then letting it bounce and roll to a stop.

# OFF THE CHARTS

by Brian K. Muirhead



NASA BASICALLY LOOKED AT THE TWO OPTIONS AND SAID, "Well, propulsion…that's the old way of doing business. You guys will never get this job done if you do it that way. It's too expensive." And so we said, "Okay, let's go make this airbag thing work."

The airbags idea was clearly eccentric. Off the charts. When you think of an airbag, you think of the automobile design, about twice the size of a pillow, which took many years to develop. But what we needed would have to be about 19 feet in diameter, designed to tolerate a head-on collision with a very rocky Mars surface at 60 miles per hour or more. And not just once, but multiple times, as it bounced and rolled to a stop. The only thing in common between our design and an automobile airbag was the name. Another very eccentric aspect of this was the idea of using fabrics in outer space. We were used to dealing in aluminum and titanium, but this needed to be the stuff of bulletproof vests… advanced polymer cloth. We'd worked with software in space, but not "softgoods."

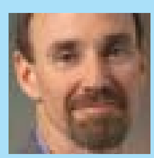
The young man who had come up with the kernel of the airbag concept was Tomasso Rivellini. Tom had never done a flight hardware engineering job before, but he had the right energy and creative instincts. So we gave him the job. Of course, he knew he needed help. He went to Bob Bamford and Bill Layman, two of JPL's intellectual giants, for help in developing the basic design. But once Tom started working the details, he alone was responsible for figuring out a way to build and test this behemoth. Tom knew that JPL didn't have the expertise in working with fabrics and sewing—with so-called "softgoods." So he sought out and found people at Sandia National Laboratory in Albuquerque and ILC Dover in Dover, Delaware, to help build a scale model followed by full-scale prototypes. This job took a lot of trial and error. Tom started with a 1/20th scale model, and worked up to full scale. It turned out that the only way to really understand how an airbag works is to test it full scale.

Every time we showed the video of the first full-scale test, in which the airbags were dropped about 120 feet onto a flat surface, people laughed. It did look comical seeing a giant beachball bounce like a superball.

But our early attempts were discouraging. Our first drops on a rocky surface simulating expected Martian terrain were complete failures. We weren't sure if this thing was going to work. But we kept working the details, improving the design, and going back into test. It was a very iterative process. We tried an analytical approach, but we spent over a week of Cray computer time to get only a few seconds of data on the impact. The problem was just too complex for state-of-the-art analysis tools at that time. So we had to rely on Tom and his team's ability to design, build, and test their way to a design that would work. And they did.

The manager of NASA's Viking mission to Mars—the legendary Jim Martin—was, at best, skeptical that the airbag idea would work. He chaired the formal review boards that oversaw the project's progress throughout its three-year development. He knew about all the trials and tribulations of the airbag development, and that the proof would only come on landing day. On July 4th, 1997, Jim and I were standing next to each other shortly after the landing. Jim turned to me and said, "You know, Brian, I think these airbags ought to be the required technology, the technology of choice, for any mission that is going to land where the terrain is unknown." Our eccentric idea had just become mainstream. •

EXCERPTED FROM *THE MARS PATHFINDER APPROACH TO "FASTER-BETTER-CHEAPER,"* BY PRICE PRITCHETT AND BRIAN MUIRHEAD. USED WITH PERMISSION OF PRITCHETT, LP.

"I like to do things that people consider impossible missions," says **BRIAN K. MUIRHEAD**, who led the design, development, and launch of the flight system for the Pathfinder Mission to Mars. "There were many people who thought we would not be able to land on Mars. [This mission] attracted innovators and some renegades. It was a major challenge, so it hooked the risk-takers and people with a competitive spirit." For his achievements on Pathfinder, Muirhead was awarded NASA's Outstanding Leadership medal. He was also named Engineer of the Year for 1997 by *Design News* and 1997 Laureate for Space by *Aviation Week & Space Technology*. In 1998, he achieved another milestone of sorts, when he was awarded his very own "star" in the sky. Asteroid Muirhead is a Mars-crossing asteroid, between 5 and 9 kilometers (about 3 to 6 miles) in diameter, and reported to be traveling in a highly inclined, eccentric orbit.

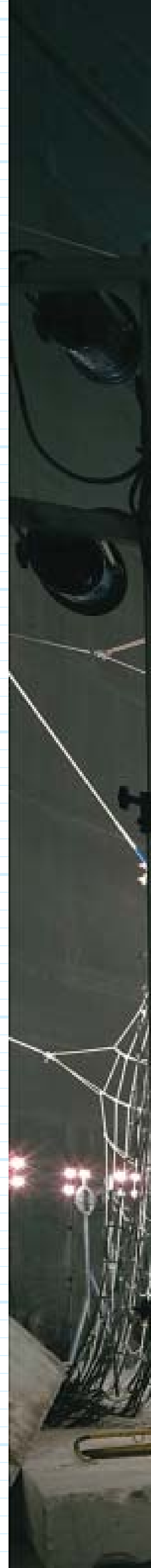
# DROPPING IN ON MARS

by Tommaso Rivellini

Here I was: 26 years old, I had never worked on a flight project before, and all eyes were on me. Every time I walked by the Pathfinder project office, Tony Spear, the project manager, would throw his arm around me and announce, “Hey everybody, the whole mission is riding on this guy right here.”

Our task was to design and build airbags for Pathfinder’s landing on Mars—an approach that had never been used on any mission. Airbags may seem like a simple, low-tech product, but it was eye-opening to discover just how little we knew about them. We knew that the only way to find out what we needed to learn was to build prototypes and test them. We just didn’t know how ignorant we were going to be.

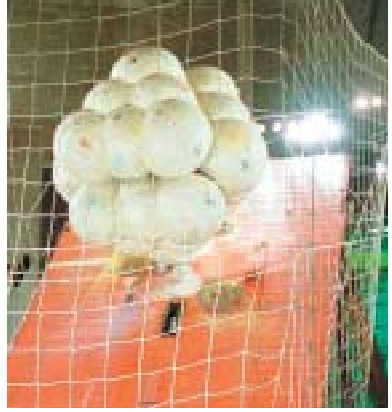
Airbags seemed like a crazy idea to a lot of people. Nobody ever said that, mind you, but there seemed to be a widespread feeling that the airbags weren’t going to work. “We’ll let you guys go off and fool around until you fall flat on your faces.” That was the unspoken message I received day after day.



**We knew that the only way to find out what we needed to learn was to build prototypes and test them. We just didn't know how ignorant we were going to be.**

Everyone's main fear about using these giant airbags was that the lander would be buried in an ocean of fabric when the airbags deflated. I began the search for a solution by building scale models of the airbags and lander, and I played with them in my office for a couple of months.

I built the models out of cardboard and plastic, and taped them up with packing tape I got from the hardware store and ribbon from the fabric store. I used a small raft inflator that I had at home to pump up my model airbags. Over and over again, I filled the miniature airbags and then let them deflate, watching what happened.



**I fooled around with a dozen or more approaches before I finally came up with something that I thought worked.**

I fooled around with a dozen or more approaches before I finally came up with something that I thought worked. Slowly but surely, I came up with the idea of using cords that zigzag through belt loops inside the airbags. Pull the cords a certain way, and the cords would draw in all of the fabric and contain it. Wait to open the lander until after all of the airbags had retracted, and the fabric would be tucked neatly underneath.

## Testing on another scale

Once we built large-scale models to conduct drop tests, we started by doing simple vertical drops, first at 30 feet, and then up to 70 feet. The bags performed well, although the way they bounced like a giant ball was interesting to observe. People began to realize that the concept might just be reasonably sound. But we still had our doubters. Even after we had the mechanics figured out for the airbags, a big question remained: What about the rocky Martian terrain?

Landing on Mars, we had to accept whatever Mother Nature gave us. The Pathfinder wouldn't have a landing strip. To simulate conditions on Mars, we brought in large lava rocks the size of a small office desk. They were real lava rocks that our geologists had gone out and picked; if you tried to handle one of them, you would cut up your hands.

The more landscape simulations we tested, the more we started tearing up the airbags. Things were not looking good. Once again, we realized that this was an area that we just didn't understand. The challenge was to protect the bladder layer, essentially the inner tube of the airbag system, with as little fabric as possible because the project could not afford to just throw mass at the problem. We tried material after material—heavy duty Kevlars and Vectrans among them—applying them in dozens of different configurations to the outside of the airbag.

Ultimately, we knew that we could just throw on more and more material and come up with a reasonably performing airbag system, but the weight of that solution would have come at the expense of something else—another component of Pathfinder would have to be sacrificed. We weren't, however, going to Mars just to land there and take a few pictures. We wanted to go there and do science—and we needed instruments to do that science. So there was a lot of motivation to come up with the lowest-mass, highest-performance airbag system that we could.

## 5, 4, 3, 2, 1

Each test became like a ritual, because it took between eight and ten hours to prepare the system—including transporting the airbags into the vacuum chamber, getting all of the instrumentation wired up, raising the airbags up to the top of the chamber, making sure all the rocks were in the right place, and preparing the nets.

The vacuum chamber where we did the drop tests used so much power that we were only able to test in the middle of the night. Once the doors of the vacuum chamber were closed, it took three or four hours just to pump down the chamber. At that point, everybody either broke for dinner or went to relax for a while, before coming back at midnight or whatever the appointed hour was. Then we had another 45 minutes of going over all of the instrumentation, going through checklists, and then ultimately the countdown.

The last 30 seconds of the countdown were excruciating. All of that anticipation, and then the whole impact lasted less than one second.

When we finished a drop test, we knew right away whether it was a success or failure. Brian Muirhead, the flight systems manager, was always insistent that I call him immediately—no matter how late it was. At 4 a.m., I would call him at his home and have to give him the news, "Brian, we failed another test."

Each test was followed by a high-pressure rush to figure out what went wrong, what test to run next, how to fix the extensively damaged bags, and how to simultaneously incorporate whatever new "experimental fix" we came up with. As a team, we agreed upon a course of action, usually in a surly, sleep-deprived mood over a greasy breakfast at a local diner. Then the ILC Dover folks would figure out any new patterns that needed to be generated as well as the detailed engineering to ensure the seams and stitch designs could handle the test loads. Our hero was our lead sewer, who incidentally sewed Neil Armstrong and Buz Aldren's moon suits. She worked under less-than-ideal conditions while we slept and turned our sometimes unusual ideas into reality. Usually by the next day we were ready to do it all over again.

Tony Spear and Brian understood the challenges we were facing. They knew we had a solid team working on this, and I always kept them informed on the technical progress. They were always understanding, but that's not to say they were always happy.

## Back to the drawing board

We said, "Okay, let's start doing analysis, computer modeling of the airbags and the impact against the rocks." At the same time, we expanded our test program to understand how to optimize this airbag abrasion layer.

It turned out that the time, money, and effort we expended on the computer modeling didn't pay off. Though we ran the most sophisticated programs available back in 1993 and 1994, the results didn't help us design the abrasion layer. We had to rely on our prototypes.

After doing dozens of drop tests, looking at the data, and studying what was happening, we started to realize that a single layer of heavy material wasn't the solution. Multiple layers of lightweight material might prove stronger.

We were forced to decide on the final abrasion layer design in order to meet our scheduled Qualification drop tests. In spacecraft terms, this is supposed to be the last test that you run in order to qualify your final design. By the time you get to that point, there is supposed to be no question whatsoever that you have a fully functioning system that meets all of the mission requirements. It is supposed to be a check-the-box process that the system is ready for flight. The problem was that at that point we had still only experienced partial success; we'd never had that A+, 100% grade on any of our drop tests.

Flying in to watch that last drop test, my plane was delayed. One of my colleagues at the test facility called and asked me, "Do you want us to wait for you?" I told him, "No, go ahead."

When I got to the facility, the test crew wasn't there. I went into the control room and ran into the guy who processes the videotapes. "So what happened?" I asked him. "Did you guys do the test?" He pointed at a VCR and said, "The video is in there. Just go ahead and press play."

So, I hit play. Down comes the airbag in the video—it hits the platform and explodes catastrophically. My heart sank. We weren't going to make it. But then I realized that there was something strangely familiar about the video I had just watched. In an instant it came to me; they had put in the videotape from our worst drop test. The practical joke could mean only one thing: We had had a successful drop test, and were finally good to go. •

### Lessons

• Prototypes focus attention on the most essential characteristics of a problem.

• To develop innovative products, you must be tenacious in the face of failures.

### Question

*How do you know whom to assign innovative tasks on a project?*

### DROPPING IN ON MARS, AGAIN

Much like his role as Systems Engineer on the 1997 Mars Pathfinder mission, **TOMMASO (TOM) P. RIVELLINI** led the Entry, Descent and Landing System team that worked on the 2003 Mars Exploration Rover (MER) missions. Scheduled to arrive on Mars in early 2004, the landing of each of the two MER spacecraft will resemble that of Pathfinder, including deployment of inflatable airbags.

But it was by no means a straightforward effort adapting Pathfinder technology to MER. "To try to squeeze out more performance, we had a lot of problems. It was like Pathfinder all over again," explains Rivilleni. "On Pathfinder, we never had a chance to explore in-depth the physics of why things behaved the way they did. We came to realize that we made mistakes on Pathfinder that we needed to fix. All aspects of the system required rework compared to what we expected. Slowly but surely, our team pushed through it all."

# SUPPLYING THE GIANT

BY LARRY LAWSON

**When I was program manager for Lockheed Martin on the Joint Air Surface Standoff Missile (JASSM), the government-stated objective for this stealthy high-performance cruise missile was a unit price of $400,000. The predecessor program, which was cancelled, had cost four times more.**

It was critical for our team to find a radically different way of doing business. Deciding to build the airframe out of composites was the first step, refining processes from the boat building industry was second, and the final step was choosing a supplier.

Lockheed Martin built the first prototypes at our Skunk Works facility in Palmdale, California. These units were hand-built and used early prototypical tooling. They looked great but were not affordable. We had to focus on minimizing touch labor and cycle time and reducing material costs. We needed a company to produce the composite quilts we would use to avoid hand lay-ups.

WE BROUGHT THIS SMALL HOUSE FROM BEING A BASEBALL BAT PROVIDER TO AN AEROSPACE HOUSE, AND IT HAS BEEN A REMARKABLE TRANSFORMATION.

The company we found surprised a lot of people. We partnered with a small company outside of Boston whose primary business was making baseball bats and golf club shafts. They had never built a military product but they knew how to weave carbon fiber and build basic composite parts. Their experience in the commercial market had forced them to learn to build these parts to final shapes with little labor, and they could control material price because they bought fiber as a commodity.

We began our efforts with them by building prototypes and eventually came up with fuselages that were usable with some rework. We began testing these bodies for material and structural properties and then using them in flight test articles. Once we qualified the integrity of processes we could focus solely on first-pass quality. Lockheed Martin, the Air Force Mantech office, and the vendor continued to refine the process to meet or exceed all our objectives. We brought this small house from being a baseball bat provider to an aerospace house, and it has been a remarkable transformation.

Along these same lines, my favorite JASSM story is the supplier we chose for the wings of the missile. One really creative individual in our organization knew about a company that built surfboards and had ventured into building the blades for windmills. We went down to their factory in a disadvantaged part of Los Angeles, saw what we liked and gave them a chance. Today, this technique is used not only on JASSM but on another missile in our portfolio, as well.

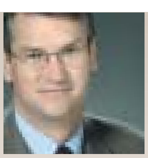
We had no choice but to operate this way. Our customer, DoD, told us point blank: “We want a missile in half the time for half the cost of what we used to be willing to pay.” We had entered the era of acquisition reform. Acquisition reform gave us the freedom to become highly creative in developing solutions that best met the customer objectives. “Faster, Better, Cheaper” wasn’t just a NASA concept. The government charter of quick turnaround at low cost forced us to demonstrate we could build this thing right and do it for what we said it would cost. Prototyping was a key component of our strategy. •

## Lesson

• To achieve remarkable results from a contractor, you must demand it unequivocally. However, you must also release the contactor from beaurocratic constraints. Most important of all, you must select a contractor who is willing to take on such risk.

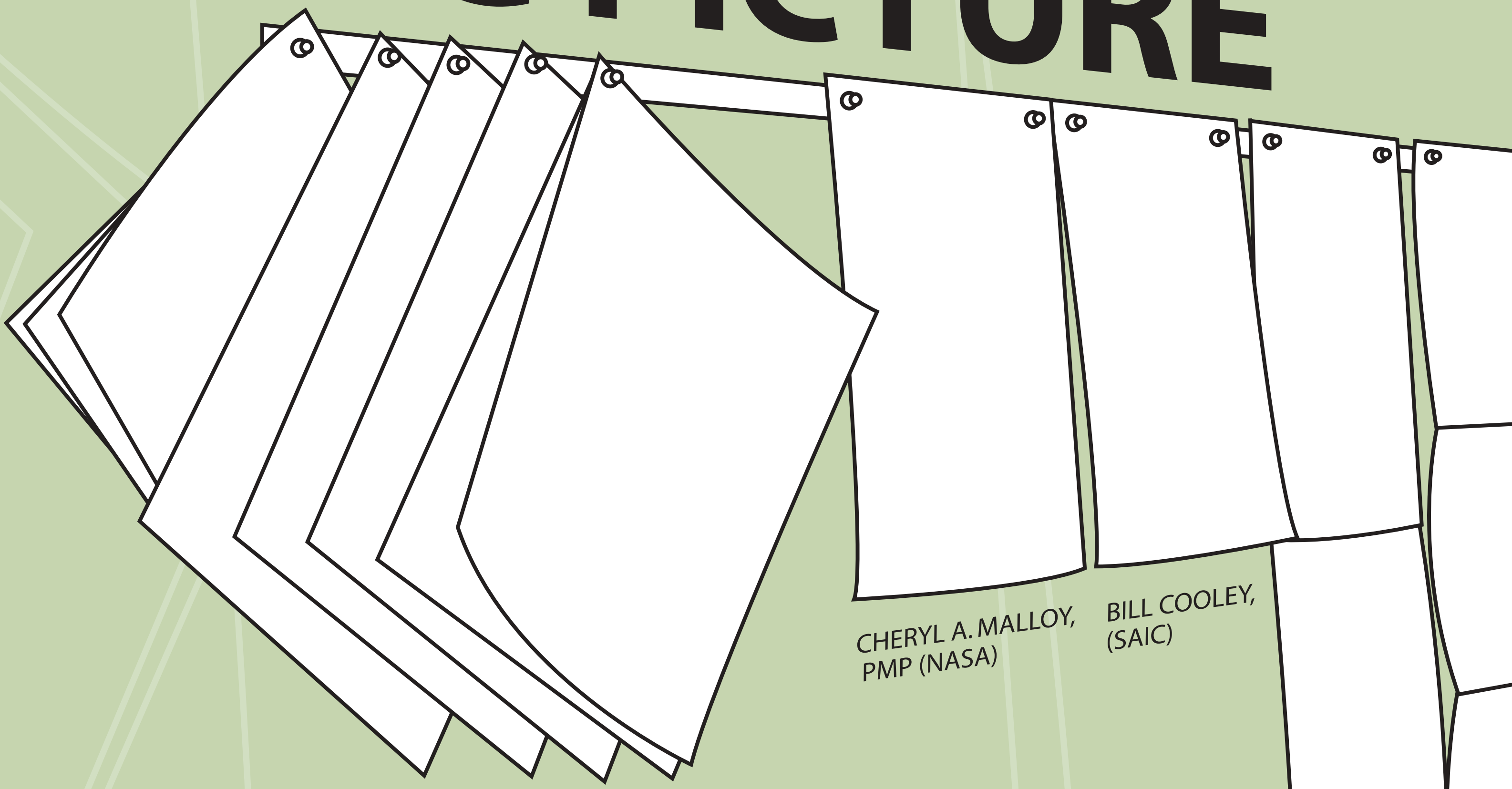
## Question

*Have you ever considered creating an environment where you required your contractor or subcontractor to be more innovative?*



“Before acquisition reform, the government said to its contractors, ‘Follow these military standards and everything will be okay,’” remarks **LARRY LAWSON**, Vice President of Systems Integration and Business Development for Lockheed Martin Corporation. “From a contractor’s point of view, that was a comfortable place to be. You knew that if you followed the handbook you were in good shape. Suddenly, we found ourselves in a position where our customer was saying, ‘Throw out all the standards. You don’t have to follow them. I don’t want you to reference a single military standard.’” At the time, Lawson served Lockheed Martin as Vice President of Strike Weapons, which included the Joint Air-to-Surface Standoff Missile (JASSM). The Office of the Secretary of Defense honored JASSM with the David Packard Award for acquisition excellence. Mr. Lawson has received the Inventor and Manager of the Year awards from Lockheed Martin and holds patents in Advanced Discrimination Technology.

# THE STORYBOARD'S BIG PICTURE



CHERYL A. MALLOY, PMP (NASA)

BILL COOLEY, (SAIC)

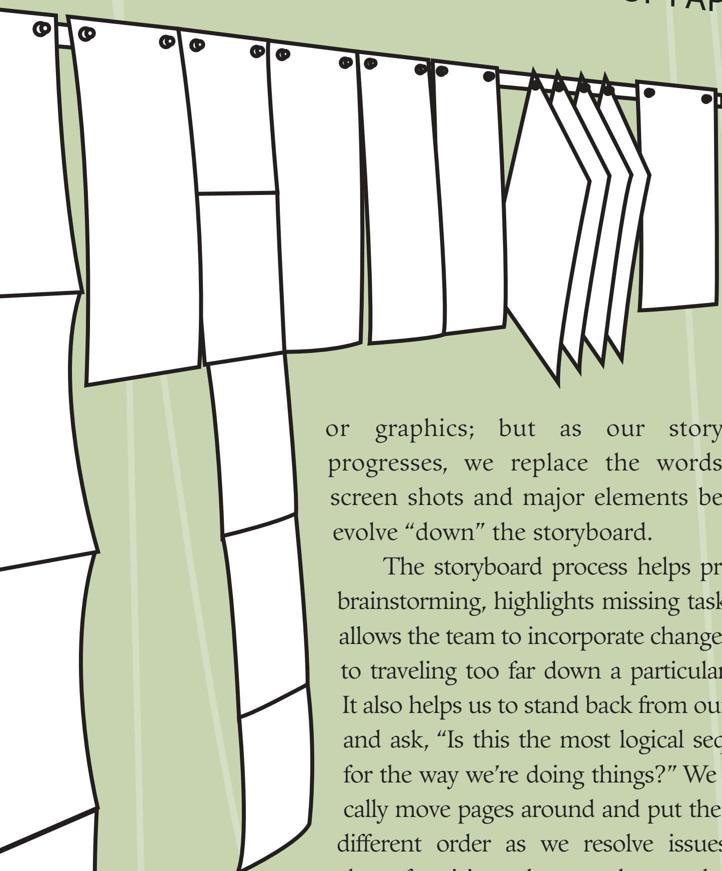
AT SCIENCE APPLICATIONS INTERNATIONAL CORPORATION (SAIC), CAPE CANAVERAL OFFICE, WE'RE USING A PROJECT MANAGEMENT TOOL THAT FACILITATES TEAM COMMUNICATION, KEEPS OUR PROJECT TEAM FOCUSED, STREAMLINES WORK AND IDENTIFIES POTENTIAL ISSUES. WHAT DID IT COST US TO INSTALL THE TOOL? ALMOST NOTHING.

Our tool is a storyboard. The basic ingredients include a 12-foot-long tack board strip on the wall, a pack of thumbtacks, paper, and a writing instrument. We use our storyboard to create a paper prototype of our product. Graphic, sequential depictions give a quick project overview while breaking down the product into its major components.

Though it could be applied to any type of project, we have found that the storyboard concept is ideally suited for software development. For example, many members of a software development team are specialists at coding and can get caught up in a particular function or aspect of the project. The storyboard helps them conceptualize the relationships between project tasks and the bigger picture. Seeing the big picture was a particular problem for us on our current project, so we posted a copy of a story by Dr. Michelle Collins, "Lessons From the Great Masters" (*ASK 3*), to try to help the team think at a higher level and ask the right questions: What is the operational concept of this product? What do we really need to do first?

Most of the board, however, reflects the major elements of the project. We tack sheets of paper on the wall in the sequence that users will likely perform their tasks. At first, we sketch out ideas with a few words

"ANYONE IN THE ORGANIZATION CAN LEARN ABOUT OUR ENTIRE PROJECT BY WALKING DOWN THE LINE OF PAPERS."



or graphics; but as our storyboard progresses, we replace the words with screen shots and major elements begin to evolve "down" the storyboard.

The storyboard process helps promote brainstorming, highlights missing tasks, and allows the team to incorporate changes prior to traveling too far down a particular path. It also helps us to stand back from our work and ask, "Is this the most logical sequence for the way we're doing things?" We physically move pages around and put them in a different order as we resolve issues. The number of revisions done to the storyboard is based on a project's schedule and budget constraints.

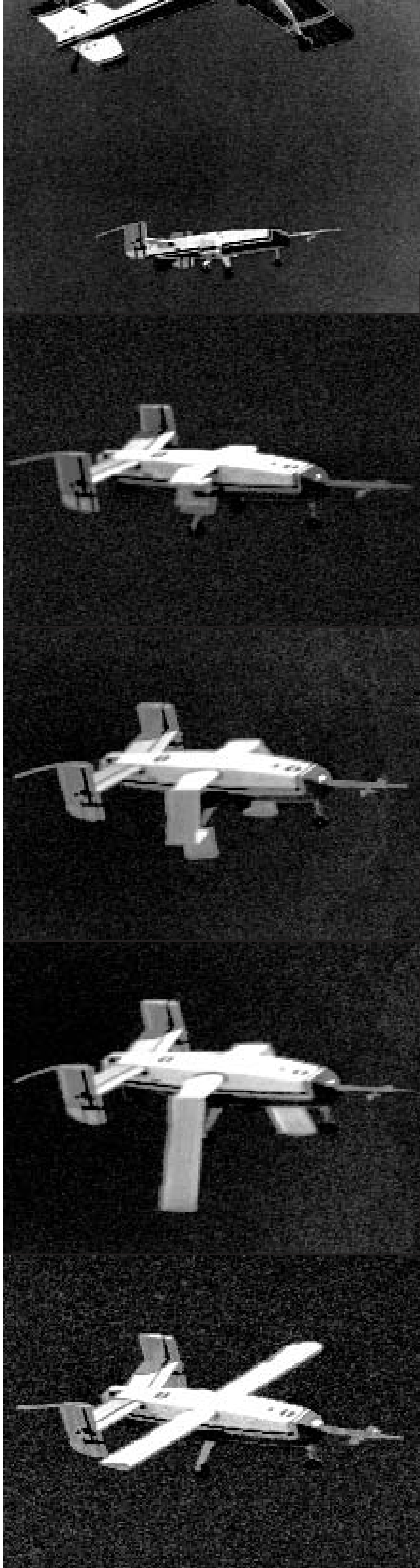
The storyboard also gives us maximum exposure. During our "graffiti phase," anyone in the organization (potential users, customers, and team members alike) can learn about our entire project by walking down the line of papers conveniently located in the office hallway. When they see something that doesn't make sense to them or they think of a feature that might be added, they write down their comments directly on the sheet of paper on the wall. For example, one person wrote on the storyboard, "When a procedure is executed where are the results stored?" Thanks to this comment, we realized we were so focused on the procedure itself that we hadn't thought about where the documentation of the procedure would be stored. How could we track and display the information without cluttering the screen? Would our repository be on individual hard drives or a shared network? The comment helped us to step back from our work and look at it from a user's perspective.

We have a designated keeper of the storyboard whose job it is to evaluate those comments and meet with the team to see which ideas should be implemented into our planning. If we decide to use an idea, it becomes part of our evolving storyboard. When we recognize good ideas that are outside our current scope, they are consolidated and tacked at the end of the storyboard on a separate page called "Future Features."

By using the storyboard, we get many people involved in providing constructive feedback and, most importantly, we make certain that team members aren't going off in different directions. The storyboard keeps us all working toward the same goal. •

## TRADING PLACES

As part of NASA's newly established Industry Exchange Program (IEP), **CHERYL A. MALLOY** began a nine-month assignment with SAIC in December 2002. IEP promotes the exchange of ideas, best practices, and operational insights between NASA and its industry partners by arranging temporary assignment exchanges. During her tenure at SAIC, Malloy had the opportunity to work with several program and project managers at SAIC, including **WILLIAM COOLEY**, a technical analyst who specializes in merging software with physics. Malloy, a 15-year NASA veteran, previously served as Expendable Launch Vehicle Mission Integration Manager.



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# PROOF OF CONCEPT

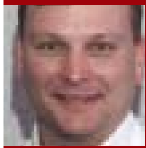
[ By Jeffrey Bauer ]

Back in 2000, one of the potential Mars projects involved delivering and then flying an observation plane over the planet. Among the challenges of the project was the small size of the capsule that was going to be used in order to get the plane to Mars. With the planet's thin atmosphere, a plane would need to have large wings in order to fly efficiently. How could you package a large-winged plane in a small capsule?

WINGS THAT INFLATE WHEN NEEDED SEEMED LIKE AN IDEAL solution to the problem. I knew that people had been working on the concept of inflatable wings for other applications, but the technology was immature and unproven. Before anyone would consider a design incorporating inflatable wings, you had to know the concept was sound. And that's where prototyping enters this story.

I got together a small team. We learned that a set of small-scale inflatable wings had been created for a Navy munitions application through a Small Business Innovative Research (SBIR) program. At the conclusion of that SBIR, the prototype wings became the property of the government, and the Navy program offered to transfer the hardware over to us. With the wings in hand, we secured discretionary funding to test our design concept.

In a sense, this prototype we were going to build was the product. We were just trying to answer some fundamental questions before we went out and tried to advocate for significant funding to do anything real. And therein lay the beauty of prototyping: it allows you to try a lot of things in a short period of time, without having to spend a lot of money to try them. There were lots of doubters about whether or not this idea had practical merit, and we didn't know for sure ourselves whether any of our ideas would pan out.



## NASA AND ITS PARTNERS

"In my project world, there is typically a good deal of cross-pollination of projects between NASA and the military, if not outright collaboration," says **JEFFREY BAUER** of NASA's Dryden Flight Research Center in Edwards, California. Currently, Bauer serves as the NASA project lead for an activity that will eventually grant routine national airspace access to high-altitude, long-endurance unpiloted aircraft. NASA, DoD and FAA will collaborate with seven Unmanned Aerial Vehicle (UAV) manufacturers on the program. Bauer also serves as manager of NASA's Environmental Research Aircraft and Sensor Technology (ERAST) program. ERAST is developing high-altitude long-endurance UAVs for science and commercial applications.

Once he had our video as proof of concept, he successfully sold a $50-million program based on our low-cost (roughly $100,000) prototype.

We had our model shop design a small airplane around the set of wings. All the testing that had been done under the SBIR had used pre-inflated wings; because we needed wings that could be inflated in flight, we also needed to design an in-flight inflation system. We came up with a system that used compressed nitrogen gas to inflate the wings.

Our prototype flew with stable enough dynamics that it could be controlled and land successfully. We had proven the principle that, yes, you could inflate wings in flight that wouldn't fold back on themselves or fail in any other mechanics. We had proven the concept to be a viable option for vehicles with volume constraints.

We shot a video as we ran several drop tests where we inflated the wings in flight under varying conditions, and then put together a demo to prove to others that this concept does seem to have some merit.

At the time we did this demonstration, the interest for a Mars aircraft program faded, and it wasn't among the missions selected to fly. To our great satisfaction, however, that wasn't the final word on our prototype project.

We sent the test flight video off to anyone we thought might be interested in the concept. One of those people was an associate in the military. At the time, he was trying to sell a program that relied on the use of inflatable wings. Whenever he briefed people about the program, they all told him that it was unproven and too risky a concept to consider.

View graphs and a lot of conjecture don't inspire people to invest in projects. Proof of concept does. Once he had our video as proof of concept, he successfully sold a $50-million program based on our low-cost (roughly $100,000) prototype.

Why use a prototype? If you can validate basic principles early in the life of a project, you mitigate risks substantially before you embark on a full-scale development effort. We answered a fundamental question before we went out and tried to advocate for significant project funding. Things might not have turned out exactly as we had wished, but another part of the government was able to benefit from our work, and we are proud of that. •

### Lessons

• Prototyping is one of the most crucial tools for innovation. Ideas can be tested and verified quickly by prototyping, before an extensive commitment of resources.

• One prototype is worth a thousand words. A good prototype has the power to communicate more convincingly than any analysis.

### Question

*How do you develop a knowledge database for prototypes?*

CAUTION

# PROTOTYPING "ROPE-A-DOPES"
## And Other Pitfalls

**By Terry Little**

My experience, both first-and second-hand, has been that people have misused prototyping almost as often as they have used it wisely. I will try and cite some of the ways I have seen people abuse the concept.

BEWARE

DANGER

The legitimate use of prototyping is to find out something you don't know—not to demonstrate something you do know.

**"Rope-a-dope"** I had a boss once who gave me some advice about how to get support for a new program. He said that you label some obscure aspect of the program as "high risk" when, in fact, you know that it is eminently low risk. Then, he continued, you get someone to give you limited money to support a risk-reduction prototype and, voilà, the prototype demonstration is successful! You then use the prototype's success, ideally with videotape and loads of "data," to secure funding for a major new program or project.

The sad part about his strategy is that it often works. Technologists use it all the time as a way of getting funding that they could not get otherwise. I call the strategy prototype "rope-a-dope" because it is deliberately misleading. The legitimate use of prototyping is to find out something you don't know—not to demonstrate something you do know. Others may differ with me, but I fail to see marketing as a legitimate use of prototyping—at least not when the government is paying the bill.

**"Kluging"** Another pitfall is a belief that basic system engineering principles can go out-the-window when you design and build prototypes. There may be rare instances where "kluging" together a prototype (like my high school science fair projects) makes sense, but usually one should build a prototype with an eye toward making a smooth transition to beyond the prototype stage. There is nothing worse than having a successful prototype demonstration and then having to start again from scratch to build something that's affordable and serves some useful purpose.

Some years ago an Air Force program spent several hundred million dollars to build missile prototypes for a competitive "fly-off." The prototypes worked just fine, but the designers had to completely redesign the missile to make it into something that anyone would want to buy. That redesign had some major cost and technical problems that almost led to the program's demise. I am quite sure that had the prototype design been more thoughtful and systematic, the transition would have been much less painful.

**Risk-averse Beware** It's OK for a prototype to fail. In fact, if there isn't a non-trivial likelihood of a failure, then why build a prototype at all? The purpose of building prototypes is to reduce risk and, sometimes, to find problems that you can only find from a prototype. "Try-fail-fix-try-fail-fix…" is a legitimate and sound prototyping strategy, but hasn't always been acceptable where I have worked. Perhaps NASA is different, but my experience is that "higher-ups" tend to be fine with risky ventures so long as the ventures succeed. It reminds me of people who are happy making high-risk investments so long as they don't lose any money.

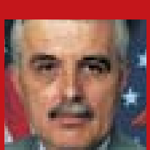
There isn't much that we can do about others' attitudes except to make sure that all the higher-ups understand the risks and to regularly remind them as the effort unfolds. It is easy to get so mesmerized by a prototyping project that we lose our objectivity and become less-than-sober about assessing risk. It's always a critical mistake to take a path and underestimate the number of opportunities to stumble along the way.

**Seeing Forests Instead of Trees** Finally, I have seen plenty of instances where someone built a prototype of the wrong thing—for example, producing a system prototype when only a subsystem prototype was necessary. Building a prototype when a model or simulation would have yielded a similar result is also common.

The missile program I mentioned earlier should have built seeker prototypes and tested them in hardware-in-the-loop simulations and captive carry. There was no real need to go to the expense and time to prototype the entire system, because 90% of the risk was in the seeker. However, the program succumbed to external pressures to shoot down an aircraft. The money and time required to do that stunt would have better gone to packaging the seeker prototype in a more production-representative configuration. It was that packaging challenge that later threatened the program.

The lesson here is to carefully craft any prototyping effort to address the most salient risks or unknowns. Spending 90% of the money to address a 10% risk area is just not good use of taxpayer money.

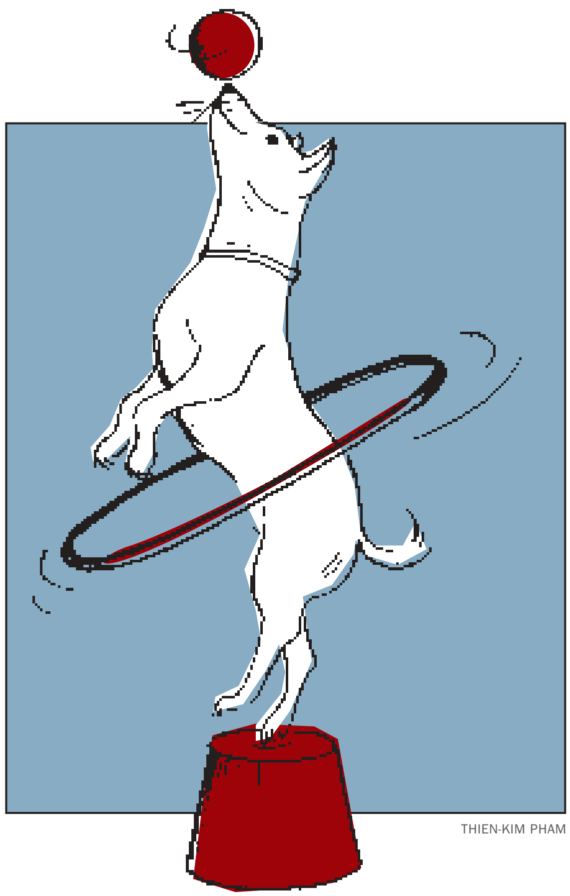
**Knowing Your Tools** Overall, I love prototyping as a tool. As with any tool, it's important to use it wisely. (You don't want to hammer a nail with a screwdriver.) When prototyping is the right tool, it can be a powerful means to identify challenges, reduce risk or prove a hypothesis. It is a superb way to learn what we don't know. Prototyping can give us the confidence that there is a way ahead, or the knowledge that there isn't—either way, it's a worthwhile investment. •



**TERRY LITTLE** is the Director of the Kinetic Energy Boost Office at the Missile Defense Agency. One of the most seasoned program managers in DoD, he is also a regular contributor to *ASK* Magazine.

# An Old Dog and New Tricks

BY W. SCOTT CAMERON



THIEN-KIM PHAM

## As I approach my 55th birthday, the old adage

"you can't teach an old dog new tricks" keeps coming to mind. I'm not sure why, because I don't feel old and I'm still interested in taking on new challenges and learning new tricks. However, as I mentor new project managers, I am also aware that others may consider me an old dog unable to learn new tricks. To the contrary, the people I mentor continue to teach me new tricks and challenge my assumptions about project management.

For example, I was mentoring a new project manager and we were looking for ways to reduce our engineering and overall project costs. One option we considered was offshore (non-U.S.-based) design engineering. The young project manager was eager to experiment, but I had never tried this concept before and knew other project managers who had with bad results. Nevertheless, the concept still intrigued me.

There was a nine-hour time difference between our office and the offshore engineering office we were considering—as well as a language difference. I could just imagine the nightmare of being that far apart and trying to clean up a project gone awry. The schedule and cost implications to the business proposal would be horrific. Since neither of us wanted to risk the entire project design, we agreed to prototype this concept on a specific portion of the project.

We worked with our engineering contractor to select one element of our design for execution in their offshore office. Someone on the contractor's staff had previously worked in this office and understood their capabilities. His familiarity with their strengths and weaknesses was integral to our prototype strategy.

The potential risks of our strategy should not be understated. The offshore option generally isn't considered unless the potential savings are high for either the contractor or client. Working offshore, in this case, wasn't going to yield a huge savings for the project or for the engineering contractor. But we saw its value as a learning experience. And since we weren't putting the entire project at risk and we had a person in place with strategic knowledge, we could present our idea as a prototype execution strategy with manageable risk. In the end, upper management accepted our plan.

We defined the work we wanted designed and transmitted it electronically. We also had two of the offshore office's lead engineers visit our site to understand how we worked and what we needed. They stayed for three weeks, and this face-to-face time was invaluable. With these personal relationships created and a better understanding of how each other worked, the design was completed on schedule and with no increases in construction costs.

I understand now the key fundamentals of what it takes to make an offshore project successful, as does the project manager I was mentoring. Now that I'm a bit wiser on this subject, I would certainly consider going offshore again. Though we didn't save money on this project, the potential for that is certainly there on bigger projects.

**Since neither of us wanted**
**to risk the entire project design, we agreed to prototype this concept on a specific portion of the project.**

Here is what I learned: It worked because we were able to mitigate the perceived/real "offshore risk." We worked through someone who already knew their offshore engineering culture and how to get work done there, plus we took the time to meet with their engineers. Good communication is the key to success on any project. If you're separated by nine time zones, you must figure out a way to bridge that gap, same as you do when you're separated by nine cities, nine floors of an office building, or nine doors on the same floor.

I doubt I would have chosen this option had I not been mentoring someone who was as curious to learn "something new" as I am. Because I was working with someone in a learning situation, he stimulated my curiosity and excitement to learn a new trick. The mentoring arrangement was a stimulus to experiment with the prototype.

Mentoring, at its richest, is a two-way street. •

**W. SCOTT CAMERON** is the Capital Systems Manager for the Food & Beverage Global Business Unit of Proctor & Gamble. He is also a regular contributor to *ASK* Magazine.

ASK Talks with

# Dr. Charles Pellerin

*Starting out as a bench engineer and later serving for a decade as Director of Astrophysics, Dr. Charles (Charlie) Pellerin's NASA career spanned nearly 30 years*

In 1975, Pellerin left his position as a principal investigator at Goddard Space Flight Center and transferred to NASA Headquarters. Eight years later, he was named Director of Astrophysics. During his tenure, he conceived of the "Great Observatories" strategy—four large contemporaneous telescopes spanning the observable electromagnetic spectrum.

Pellerin oversaw the launch of a dozen scientific satellites, including the Hubble Space Telescope. When a flawed mirror on Hubble prevented the telescope from performing, he launched a successful space repair mission for which he was awarded a NASA Outstanding Leadership Medal. Before retiring from the Agency in 1995, he also received NASA's highest honor, the Distinguished Service Medal.

Since the time that the Hubble review board identified failed leadership as the root cause of the telescope's failure, Pellerin began an intensive inquiry into the effects of social factors on project success. As a consultant to NASA, accounting firms, and aerospace companies, he has developed a "four-dimensional" approach to measuring and improving the effectiveness of project leadership, project culture, and organization interfaces.

***Would it be fair to say that since leaving NASA you have focused your career on trying to understand why projects fail?***

Yes, why projects fail around social issues and around leadership—because I saw this same thing coming up again and again.

***Can you explain what you mean by "social issues," and how they relate to leadership?***

I was the Director of Astrophysics at NASA between 1983 and '92. I had a lot of flight projects going on, perhaps as many as 20 at any one time, and I would try to watch and pay attention to them all. That was my primary job, I thought.

I began to see a pattern repeated far too often when a successful project manager would get promoted or leave a project for some reason. I would replace him with someone who looked just as good on paper, but three months later, all of a sudden, the project started to fall apart. Milestones got missed. Reserves depleted too fast.

I was frustrated that I couldn't anticipate and recognize the difference between project managers who were going to succeed and project managers who were doomed to fail. We could predict things like sensor performance. We could understand the detectors. We

could understand the power systems. But we couldn't understand this one critical, invisible piece: What makes a good manager?

So, I pondered this. I read books and thought about it a lot, but I got very little insight.

***Was it the magnitude of the Hubble telescope problems, launching it with a flawed mirror, which brought this all to a head?***

Yes, exactly. If you go back to what was happening at the time, we launched Hubble in 1990 and very soon thereafter we found that a technical person had made an error. At first we thought, "Now at least we know what the error was. We can figure out how to fix it." And that's just what we did—we fixed it. This would appear to be a very happy story for me; I got a NASA medal for the repair mission.

That's all well and good, but then I said, "Wait a minute. We should have had systems in place to find this kind of thing." The procedures are written. The engineers sign them. Safety & Quality Assurance stamps it all to verify that this is being done properly along the way.

Hubble was the final straw for me. I needed to understand what had happened, because when I looked around me I realized it was commonplace. I mean, take a look at *Challenger*. It was not, in a sense, a technical failure. It was another human communications failure. I knew a bunch of those people. They were damn good managers and engineers, but they got caught in a story. They created an environment where it wasn't safe to tell the truth.

***That's interesting how you describe it as people who got "caught in a story." How do stories figure into this leadership quotient?***

The stories that you carry affect how you make decisions in your life. That's why I'm very interested in the stories we tell. We all perceive reality through the filter of the "stories" we believe. We create stories to make sense of our experience. And, we act within this context as if it were truth, because to each of us it feels like truth.

I collect and study the impact of organizational and personal stories. Here's an example: An entire American industry clung to their long-held story that "Improving quality means higher cost" until they had lost over 60% of domestic market share to a foreign industry. I am speaking, of course, about the automotive industry.

Similarly, it's fascinating to help projects discover some of the stories they carry with them. They tell stories about their contractors, managers tell stories about scientists and vice-versa.

***What kind of story did you tell when you were Director of Astrophysics?***

The primary story that drove me, for good or bad, when I was Director of Astrophysics was that "We have a perishable opportunity here." Never in the history of man had anyone invested what we were investing in astronomy.

If you added up all of the ancillary support, like the Shuttle launches and the civil service manpower I didn't have to pay for, I probably had \$2 to \$3 billion per year to look at stars. I told people, "This is never going to happen again in our lifetime, and we're going to make the best of it. If you're not dedicated to giving your very best to it every day, go to work someplace else because this is a privilege and opportunity we have." That was the story I told at that time.

I WAS FRUSTRATED THAT I COULDN'T ANTICIPATE AND RECOGNIZE THE DIFFERENCE BETWEEN PROJECT MANAGERS WHO WERE GOING TO SUCCEED AND PROJECT MANAGERS WHO WERE DOOMED TO FAIL—

***What was it like to work for you?***

You'd have to ask the people who worked for me, I suppose. I tried to be fair and not to confuse "toughness" for "meanness," but there were certainly people who were uncomfortable in my division. I had a reputation for being tough. I remember that during one performance appraisal, a boss said to me that I would do better if I could "suffer fools gladly."

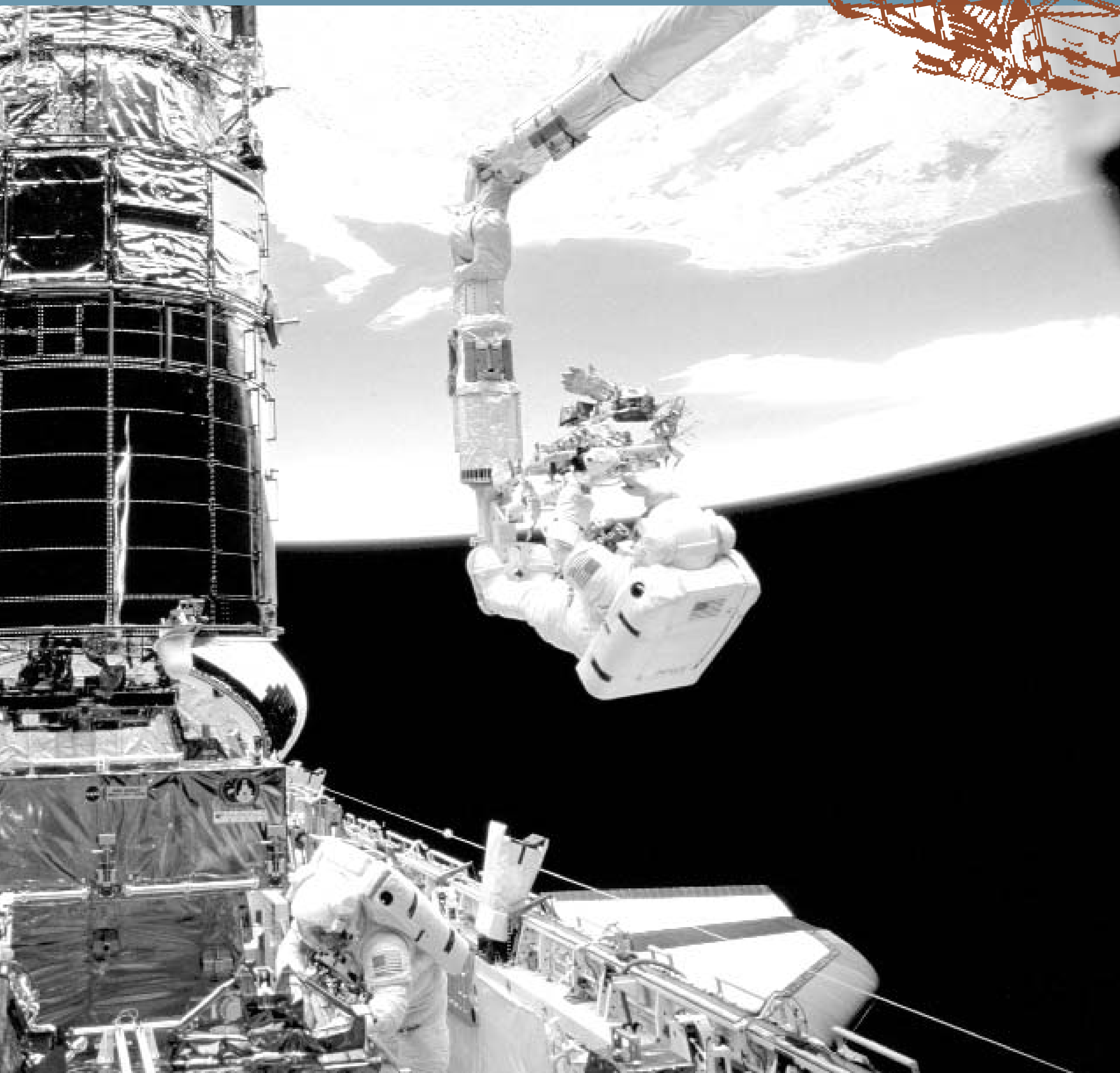
I can recall people who joined the division who said, "You're not the son of a bitch that people say you are. You are actually a great guy to work for." I said to them, "Well, don't ever tell anybody. I want people who like to work for SOBs to come here."

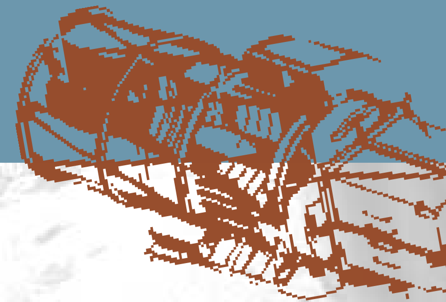
It was this simple. If you shared my story, you would be comfortable. If not, you wouldn't. I recall one hire who believed "Headquarters would be a nice place to ease into retirement." He didn't last long in the Astrophysics Division.

***What are some of the other stories that you've told?***

I have lots of them. As Howard Gardner says, "Leaders achieve their effectiveness chiefly through the stories they relate." Here's one: A day's work for a day's pay. This was often said to civil servants during Lyndon Johnson's Presidency. The variation I used with my staff went something like this: At the end of the day, I want you to stop at some small house outside the Capital Beltway, preferably one with a car in front that's worth

F. Story Musgrave and Jeffrey A. Hoffman (below) prepare to install protective covers for magnetometers on the Hubble Space Telescope in December 1993.





Mission Specialist James H. Newman tests the Portable Foot Restraint used on the first Hubble Space Telescope servicing mission.

less than my titanium bicycle. Go inside and tell the people what you did during the day and what you were paid. If they agree that they got good value for their tax dollars, then you're doing good work. If you can't imagine passing that test, you should work elsewhere.

Here's another one: When I was in college and running out of money, my roommate and I started a monogrammed sweatshirt business. We made a ton of money in four months. That was what mattered at the time. But the story I learned over the years is that making money is easy. What we need to focus on is making a contribution, and that's a lot harder.

Closely related is another story I carry with me: Those who love you deserve a life of service in return. And, you know, I tell my wife every day that I live in service to her, but I don't think she fully buys it.

***What kind of stories are you telling now?***

My main story (now) is that "unknown and unnamed" social undercurrents are at the root of many, if not most, project difficulties. These can be defined, measured, and remedied. Helping NASA projects do this is the most important contribution I can make with my life now.

***You said that leadership was at the core of the Hubble mishap. Do you find evidence of this in other projects?***

Sure. Diane Vaughn in her book, *The Challenger Launch Decision*, said she was a year into her study before she realized that then-accepted accounts of what happened were wrong. Vaughn concluded that the disaster was caused by an "incremental descent into poor judgment." And she went on to say that the technical risks grew out of social issues. Notice the word "social" again. She realized that signals of potential danger had been repeatedly "normalized." That was okay in the context of the stories their culture supported.

And that's not the only example. Administrator O'Keefe cited similar language during recent testimony on the *Columbia* disaster. Art Stephenson, following the back-to-back Mars failures, said that success begins with leadership and forming a culture where people are permitted to succeed.

***How are you trying to address these issues in your work with APPL today?***

We have been developing a leadership/culture assessment and learning system called "Four-Dimensional (4-D) Leadership" since 1995. We began with workshops, and then added coaching, and now have Web-based diagnostics customized for NASA projects. Simply put, we make three measurements in each of the social dimensions—directing, visioning, relating and valuing—that we believe are fundamental to effective leadership and efficient cultures.

MY MAIN STORY (NOW) IS THAT "UNKNOWN AND UNNAMED" SOCIAL UNDERCURRENTS ARE AT THE ROOT OF MANY, IF NOT MOST, PROJECT DIFFICULTIES

In a Web-based survey that only takes about 10 to 15 minutes to fill out, we ask respondents about observed behaviors such as mutual respect, trustworthiness, clear roles, and responsibilities. We review the data with the project manager (our "customer") and the leads for each of the project teams. If the numbers for leadership or culture effectiveness are too low, we use a combination of workshops, telephone coaching, and consulting to improve performance. Then we re-measure and track progress.

***Does it work?***

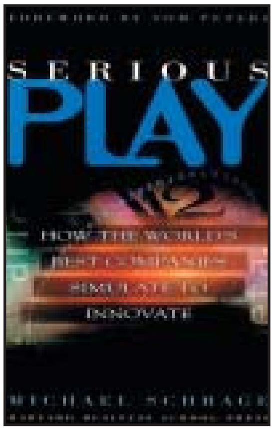
Project managers tell us it does. We're in the process now of working with projects at Goddard, JPL, and Ames, and our database of validated metrics is growing by the day.

We believe that we're not far from having conclusive data that these systems work and that dramatic reduction in project failures, minor and major, are within our grasp. I'm talking about preventing high-profile failures like the Hubble mirror—but just as important are the less-visible performance shortfalls, budget overruns, and project terminations that managers and teams experience every day.

I truly believe that we can identify and address the root cause of most project difficulties. That's my story. And many of the projects I'm working with are choosing to run that story, as well—because they see results.

You know, no story is "good" or "bad." Some just get you the results you want and some don't. •

# Books about Prototyping




**Serious Play**

Michael Schrage, 2000. Boston MA: Harvard Business School Press

*Reviewed by Dr. Gerald Mulenburg*

*Serious Play* by Michael Schrage will probably be of more help to you as a project manager than many of the other books on your bookshelf. It's about something that all NASA project managers do to ensure the success of their projects. We innovate by creating models, simulations, and prototypes. But these creations, as Schrage makes clear, are not the project, which project managers and team members sometimes forget, and our management never seems to understand.

The main point of the book is that developing prototypes (models, simulations, etc.) enhances collaboration because the prototypes act as catalysts to increase learning and understanding. Schrage points out that the process of developing a plan (read prototype) leads to innovation because of the behavioral changes that occur among the participants. The prototyping process inspires "clever interactions between people."

This, therefore, is not a how-to book about prototyping; it is a why-to book about using prototyping as the means of innovating, and it provides a framework for understanding the value of prototyping. In Schrage's words, "Serious play is not an oxymoron; it is the essence of innovation, less the product of how innovators think than a by-product of how they behave." The book argues that this approach to prototyping fundamentally transforms how organizations approach innovation challenges.

The debris left on the wayside that results from prototyping Schrage calls "productive waste" that "shrinks risk." He claims that, "The real value of a model or simulation may stem less from its ability to test a hypothesis than from its power to generate useful surprise." He cautions, however, to beware of relying too heavily on prototypes to predict the future, but instead to use the results as "projections" to gain insight into the future.

The book consists of three parts: Part I sets the stage with two chapters describing the relationship between innovation and prototyping. Part II covers the language of prototypes, models, simulations, and other activities including computer-aided design and computer-aided engineering. Part III measures the paybacks of serious play and how to turn innovation into a way of doing business in an organization.

In the end, Schrage makes a strong case for the value of prototyping as the backbone of an organizational approach to innovation. In his forward, author Tom Peters writes, "*Serious Play* is simply the best book on innovation I've ever read." Peters goes on to say that Schrage's approach to prototyping as process "is possibly the most insightful, counterintuitive twist in a generally insightful book." •

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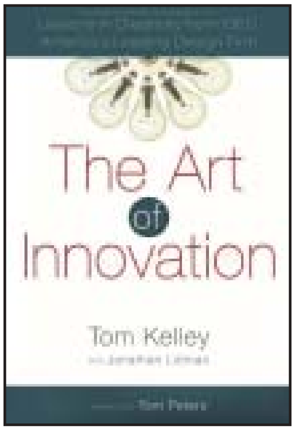
*Dr. Mulenburg reviews books regularly for* ASK Magazine. *His last review appeared in* ASK 10 *on* The Attention Economy. *He is also a member of the* ASK *Review Board.*




**The Art of Innovation:**
**Lessons in Creativity from IDEO, America's Leading Design Firm**

Tom Kelley with Jonathan Littman, 2001. New York: Doubleday

*Reviewed by Jody Lannen Brady*

In its quest to develop innovative products, California-based IDEO has designed a shopping cart inspired by diapers, ridden exercise bikes in a meat locker, and prototyped a computer mouse using a butter dish. With plenty more stories like these, IDEO general manager Tom Kelley and co-author Jonathan Littman flesh out the philosophy behind the cutting-edge work done by America's self-described leading design firm.

Indeed, the stories included in *Art of Innovation* make it a good read, but what if your next project won't involve building a better toothpaste tube or a finned football? Is there something in this book for the typical NASA project manager?

There is. Chapters on brainstorming, team dynamics, dealing with uncertainty, and creating prototypes transcend project specifics. The chapter on prototyping alone makes the book worth picking up. Kelley gets to the heart of what a prototype should and shouldn't be. "What counts," he explains, "is moving the ball forward, achieving some part of your goal. Not wasting time." With examples from science, hardware design, and movie making, Kelley outlines the use of prototyping to solve problems, speed progress, and minimize risk.

Throughout, Kelly addresses building and sustaining creative, motivated teams. His "hot teams" approach considers everything from selecting team members to rewarding performance. "Great projects are achieved by great teams," writes Kelley. "Though [projects] are naturally about groups and teamwork, too often these groups are simply the result of inertia….That sort of staid, unfocused group bears little or no resemblance to the hot groups we're talking about."

Yes, the *Art of Innovation* reads at times like an infomercial for the publicity-happy design firm, but that doesn't detract from the book's usefulness as a stimulus for re-envisioning project work and thinking outside the box. •

*Jody Lannen Brady is the Associate Editor of* ASK Magazine.

LETTER FROM THE EDITOR-IN-CHIEF *Dr. Alexander Laufer*

# Letting Go of "Once and for All"

*Research is about discovery. Sometimes, if we let it, research can shake our core beliefs*

THAT WAS THE CASE FOR ME IN 1988, WHEN I WAS INVITED to do some work for the Construction Industry Institute (CII), a research consortium of top American companies and universities.

I had come to CII's attention because of my work regarding project planning. To continue my research, CII made it possible for me to interview 39 project managers at 11 companies. I asked each manager a series of questions about planning at the early phase of a project. Rather than confirming what I expected to hear, out of this process came something I didn't understand. Again and again, the managers I spoke with told me that they searched for potential solutions, i.e. they started engineering designs, before they finalized their project objectives.

"Objectives first, means second." Define the problem, then solve it. That is what I had been taught as a student, and that is what I had subsequently taught to my students. But top-notch managers at well-respected companies were telling me that they didn't work that way. In almost all my interviews, I observed the same discrepancy. The objective formation process is not an isolated activity, and it is not completed before searching for alternatives begins.

This astonished me or, to be honest, it shocked me. For a couple of months, I wrestled with what I had heard. My wife and children have told me that it was clear to everyone around me that something was bothering me. We lived in a duplex, and after my neighbor heard me pacing back and forth, night after night, he asked if there was something wrong with me.

Because I had conducted my research accepting the prevailing assumption (objectives before means), I hadn't phrased my questions in a way that could directly disprove the assumption. Instead, my conclusions had to be derived indirectly from my data, and this added to my feeling of unease about the validity of my findings.

It took me a long time before I fully understood what I had observed, and it required a lot of reinforcement. As I went back through the literature and re-read pioneering works by highly respected researchers like James March, Donald Schon and James Thompson, I found support for my new understanding of project planning. As March wrote, "The argument that goal development and choice are independent behaviorally seems clearly false. It seems to me perfectly obvious that a description that assumes goals come first and action comes later is frequently radically wrong."

*It took me a long time before I fully understood what I had observed, and it required a lot of reinforcement.*

The old paradigm assumed implicitly that a manager first reduces all uncertainty of objectives, and only then begins to develop the plans or means to accomplish those objectives. But experienced project managers were telling me that they simultaneously reduced the uncertainty of both objectives and means. My findings showed that in most capital projects, not only is "means uncertainty" (how to do it) resolved late in project life, but so is "end uncertainty" (what to do).

So, my research led me to formulate a new paradigm. Under conditions of uncertainty, it is impossible to finalize project objectives at the outset once and for all. Rather, in order to set stable project objectives, one must sometimes first explore the means. That is what I learned.

We can learn much from research—but very often we need to be willing to engage in a little unlearning first. •