National Aeronautics and Space Administration

ASK the Academy
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About *ASK the Academy*

The challenges that NASA projects tackle are novel in nature—they are often "firsts" or "onlies" that demand innovation, knowledge, and learning. Mission success depends on the free flow of ideas across the agency as well as with partners in industry, academia, other government agencies, research and professional organizations, and international space agencies. To address this, the Academy of Program/Project & Engineering Leadership has invested in knowledge sharing strategies that emphasize the power of telling stories in order to help create a community of practitioners who are reflective and geared toward sharing.

With its field centers across the country, NASA is a decentralized organization in which experts have few opportunities to learn about each other's work. *ASK the Academy*, a monthly e-newsletter, serves as a means of regular communication with the agency's technical workforce about best practices, lessons learned, and new developments at NASA and throughout the world. It is intended to serve as a way to build connections and share knowledge across the agency.

ASK the Academy began in December 2005 as *ASK OCE*, a biweekly publication of the NASA Office of the Chief Engineer. In January 2008, it became the monthly *ASK the Academy*.

Messages from the Academy Director

The Power of a Vision

January 29, 2010 — Vol. 3, Issue 1

When you close your eyes and think of NASA, what comes to mind? Your answer, whatever it is, says a lot about the strength of NASA's vision.

Many people think that an organization's statement of its vision is simply words on a page. That couldn't be further from the truth. The exercise of closing your eyes leads you to conjure up images. If an organization has articulated a powerful vision that is consistent with its actions, chances are that the images you'll see will reflect the vision in some way.

An organization's vision is its fuel for action. It excites people and lets them know where they're going. Studies have shown that the greatest organizational motivator for employees is challenging and meaningful work. There's a well-known parable in business circles that illustrates this. Long ago in medieval Europe, three men were breaking up a massive pile of rocks with sledgehammers. A passerby stopped and asked each man what he was doing. The first man replied, "Breaking rocks." The second man said, "Working so I can feed my family." The third man said, "Building a cathedral." It's clear from their responses which man connected his work to the larger vision.

A vision is critical for getting things done in the present, but it's also important for defining the reality you want to create in the future. There's no greater example in American history than the leadership of Dr. Martin Luther King, Jr. during the civil rights movement. When he delivered the "I Have a Dream" speech during the March on Washington in August 1963, he articulated a vision that was so far-reaching and inspiring that it became part of our civil discourse. The connection between the words "dream" and "vision" is no coincidence. King used the commonplace metaphor of a dream, which everyone can understand, to convey his vision.

NASA is virtually unique among government organizations in its focus on exploration, which is an intrinsically visionary pursuit. The earliest space visionaries were storytellers, not scientists or engineers. The very idea of space exploration was outside the realm of the possible until the dawn of flight in the early twentieth century. In 1930, three science fiction writers founded the American Rocket Society, a predecessor of today's American Institute of Aeronautics and Astronautics (AIAA). It's hard to think of another technical profession where one generation's fantastic story becomes the next generation's reality. Stories are powerful tools for sharing a vision with others.

As Dr. King's example reminds us, a vision is a dream of a better future. Nothing could be more important.

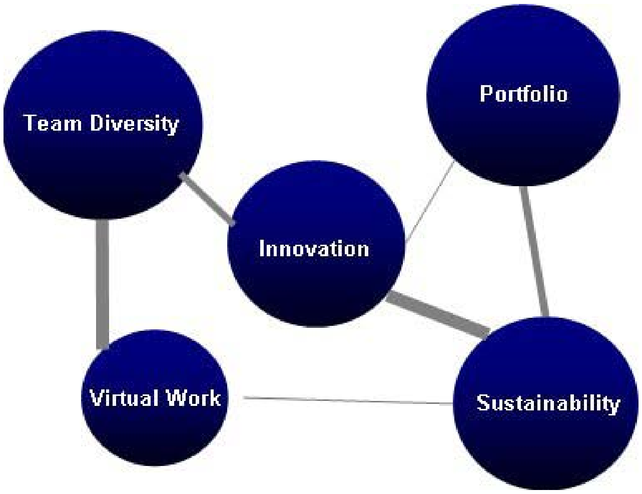
Trends in Project Management

February 26, 2010 — Vol. 3, Issue 2

Five trends are reshaping the practice of project management.

Over the past year, as I met with colleagues at NASA and around the world and reviewed current research about project management, five key themes kept surfacing: team diversity, sustainability, virtual work, innovation, and portfolio management.

Team diversity has increased as projects have become more complex, technically challenging, and global. In broad terms, there are three dimensions of team diversity: cultural, cognitive, and geographic. Project organizations like NASA recognize the value that cognitive and cultural diversity adds to projects, and geographic diversity has always been a feature of NASA's project teams. Cognitive diversity refers to teams with varying levels of expertise, education, experience, age, training, and professional backgrounds. Cultural diversity manifests itself through different languages and communications styles as well as less obvious aspects such as goals, resources,



Connectivity of the 2009 PM trends

politics, budgets, and national security concerns. Geographic diversity continues to intensify as projects involve multiple partners from government, industry, academia, and nonprofit organizations.

Virtual work facilitates and enhances geographic team diversity. It also attracts talent and facilitates relationships that would otherwise be more difficult to acquire. Companies like IBM, Proctor & Gamble, and AT&T have either partially or fully eliminated traditional offices. NASA and IBM both host conferences and meetings on "islands" in Second Life. Virtual work is not without its difficulties. Even though virtual communities and workplaces offer a new way of working that attracts talent and cuts costs, project managers are still trying to understand ways to remedy problems like isolation, insufficient support and oversight, and the increasingly blurry line between work and personal life.

Sustainability has arrived as a permanent feature of the landscape for project-based organizations. In 2009 NASA held its first Green Engineering Masters Forum and the Jet Propulsion Laboratory completed construction of its Flight Projects Center, NASA's "greenest" building to date. As I wrote in October 2009, while some use sustainability as a synonym for "environmentally friendly," I interpret it more broadly to refer to principles and practices that enable long-term societal progress. Sustainability is above all a systems thinking challenge. Project management has taught us to think about life-cycle costs. Sustainability tackles questions of life-cycle impact, which can extend far beyond the duration of a project.

Innovation is a constant in the world of complex projects, both in terms of products and processes. The nature of projects demands adaptive thinking to adjust to ever-changing requirements, budgets, and resources. Technology development is also an essential element of project success. The innovation challenge in the aerospace sector is closely tied to shifting workforce demographics, new models for public-private collaboration, and the need for more sustainable practices.

Portfolio management reflects the strategic context in which project-based organizations operate today. Organizational success is not a matter of managing a single project successfully. The larger challenge is managing a portfolio of programs and projects in order to execute the organization's strategy. NASA's four mission directorates function as its portfolio management organizations. As project-based organizations continue to grow around the world, portfolio management will increase in importance.

In a time of tight resources and strong competition for top talent, the organizations best prepared for the project management environment ahead will be the ones to thrive. In 2010, I believe these trends will continue in tandem with increased interest in organizational transparency and risk management.

Knowledge Explosion

May 28, 2010 — Vol. 3, Issue 5

NASA is undergoing a knowledge explosion—and not a moment too late.

When the Academy first began sponsoring knowledge sharing forums and publications in the late 1990s, there was a degree of skepticism in some corners of NASA about the purpose of these activities. In an engineering organization, how could stories enhance the probability of mission success?

The twin failures of the Mars Polar Lander and the Mars Climate Orbiter were a watershed moment that drove home the criticality of knowledge sharing for NASA. In the aftermath of these failures, the General Accounting Office (now the General Accountability Office) released a report in January 2002 recommending, among other things, that NASA develop ways to broaden and implement mentoring and storytelling as means of conveying lessons learned.

Since then there has been a veritable explosion of knowledge sharing efforts across the agency. The Academy just completed a comprehensive survey of technical workforce development across the agency, which found that all 10 centers use informal sharing and lessons learned sessions (e.g., Pause and Learn activities, after-action reviews, brown bag lunches, and "lunch'n'learn" sessions). Nine of ten centers have academic or research portals, and eight employ discipline or specialty network videos or case studies. Other knowledge sharing practices include: project team lessons learned workshops, comprehensive "knowledge capture" activities (e.g., Space Shuttle Main Engine and Ares I-X), the Office of the Chief Engineer's Joint Engineering Board, and the Academy's forums, publications, videos, and case studies. Technology is also a big part of knowledge sharing. All 10 centers use portals, wikis, social networks, or team micro-sites. Most also use discipline or specialty networking technology, blogging, YouTube, and social bookmarking sites.

In short, knowledge sharing has taken root broadly across the agency. This is how it should be. To paraphrase former House Speaker Tip O'Neill, all knowledge is local. At NASA, experts in specific disciplines are the keepers of a great deal of local knowledge. The role of the Academy is to help build an agency-wide community of reflective practitioners who establish a culture in which sharing is the norm. The Academy also plays the part of a facilitator, providing channels through its forums and publications to ensure that local knowledge can reach the broader community.

Knowledge sharing will only be more important in the years ahead as NASA pursues an aggressive research and technology agenda. One of the keys to innovation is finding new uses for technologies and processes that were originally developed for other purposes. Knowledge flows across the agency will be critical to those kinds of connections. The community that has grown across NASA in the past decade has its work cut out for it.

Lessons From Torino

June 30, 2010 — Vol. 3, Issue 6

The demands of excellence are the same the world over.

Last spring I had the opportunity to visit three project-based organizations in the Piedmont region of Italy. What I saw was a commitment to three elements that might seem like an unlikely combination: craftsmanship, standards and processes, and cutting-edge technology.

My first visit was with Comau, a subsidiary of the Fiat Group that specializes in robotics and automation systems. My conversations with Valerio Crovasce, who leads Comau's project academy, served as a reminder that in an extremely competitive sector like the automotive industry, having a workforce that's highly skilled in project management is a competitive advantage. On the shop floor you see robots doing work that is highly routine, standardized, precise, and sometimes dangerous. There is a drive to develop standards and processes that optimize efficiency for repeatable tasks. At the same time, as a supplier producing components and subsystems for others, there is a clear understanding that the customer is at the center of any project. Stakeholder management is a top concern. Even in an organization focused on robotics, relationships are paramount.

I also visited Thales Alenia, a major European aerospace manufacturer. Thales has a strong program to develop top young engineers from universities, and it emphasizes learning how to think from a systems perspective. Thales also gave me a tour of an immersive learning and working environment it has developed that is a three-dimensional representation of everything we know about the solar system. This simulation, which is based on data from ESA, NASA, and other space agencies, is a powerful learning tool. It gives individuals the opportunity to communicate in real time and form relationships based on learning.

My final visit was to the Ferrari plant. The company was originally founded as a local entrepreneurial venture, and there is still a strong sense of connection to the community. The importance of story is immediately clear. As you enter the facility, there are historical cars on display with small placards that tell their stories. An executive told me that those cars are intended to remind employees of the big picture as they walk by them every day on the way to their workstations. I was also struck by the strength of the craftsman culture, which coexists with precision robotics. The men and women working in specific production areas are empowered as experts with a great deal of autonomy, and they exude a sense of pride. When you look out on the factory floor, you see something utterly unexpected: plants and trees that refresh the air. At the end of the line, the cars themselves bear a closer resemblance to works of art than mass-produced automobiles.

The bottom line is that it takes all three elements—high technology, standards and processes, and people—working in concert to achieve world-class excellence. Technology is critical for innovation. Standards and processes are means of leveraging knowledge, lessons learned, and best practices in pursuit of quality and continuous improvement. Neither technology nor standards and processes are useful in the absence of highly skilled, educated, and motivated people who have a sense of dignity and purpose about their work. When all three come together, the results are *senza paragone*.

Change Management and Adaptive Challenges

July 30, 2010 — Vol. 3, Issue 7

What do we mean when we talk about change management?

Change is an inevitable part of the life of an organization. Regardless of why it happens, it is always difficult and painful for many people.

One metaphor that's helpful for understanding change in an organizational context comes from evolutionary biology. In *The Practice of Adaptive Leadership*, Ron Heifetz, Marty Linsky, and Alex Grashow recall that humans have been practicing adaptation for millennia:

"Our early ancestors' process of adaptation to new possibilities and challenges has continued over the course of written history with the growth and variation in scope, structure, governance, strategy, and coordination of political and commercial enterprise. So has the evolution in understanding the practice of managing those processes, including in our lifetimes what we call adaptive leadership."

They go on to define adaptive leadership as "the practice of mobilizing people to tackle tough challenges and thrive," noting that they use the term "thrive" as an evolutionary biologist would when describing the three characteristics of a successful adaptation: "1) it preserves the DNA essential for the species' continued survival; 2) it discards (re-regulates or rearranges) the DNA that no longer serves the species' current needs; and 3) it creates new DNA arrangements that give species the ability to flourish in new ways and in more challenging environments."

This concept of thriving is the essence of change management. Core values and practices remain intact, while the organization modifies or closes out activities that no longer match current needs, and develops new ones to meet current and anticipated future needs.

Heifetz, Linsky, and Grashow suggest that organizations typically encounter one of two types of issues: technical problems and adaptive challenges. With a technical problem, the problem definition is clear, the solution is clear, and process takes place through established lines of authority. Adaptive challenges are altogether different. Both the problem definition and the solution require learning, and the primary decision-making takes place at the stakeholder level.

NASA currently faces an adaptive challenge. It has faced them before, and it has thrived. Doing so again will require learning across the enterprise.

When NASA has gone through periods of transformation and rigorous self-examination in the past, the Academy has served as a change agent by facilitating learning through professional development activities. The precursor to today's NASA Academy of Program/Project & Engineering Leadership, the Program and Project Management Initiative, was established in 1988 as part of NASA's response to the Challenger accident. The focus was on ensuring that the workforce retained fundamental knowledge about NASA's project management practices.

A decade later, in the aftermath of the back-to-back failures of the Mars Climate Orbiter and the Mars Polar Lander, NASA Administrator Dan Goldin made it clear that he expected the Academy to find a way to support teams, not just individuals. It was a wake-up call that helped set the Academy on its present course. Similarly, a report by the Government Accountability Office (GAO) in January 2002 that looked at the Mars failures found "fundamental weaknesses in the collection and sharing of lessons learned agency-wide." This spurred us to expand the scope of our knowledge sharing efforts.

After the Columbia accident in 2003, the Columbia Accident Investigation Board concluded that "NASA's current organization...has not demonstrated the characteristics of a learning organization." The Academy increased its support to project and engineering teams and looked for new ways to address communications, organizational learning, and technical excellence.

In short, all of the Academy's core initiatives came about in response to change initiatives that demanded learning.

Unlike some of the examples above, the adaptive challenge NASA faces today is not driven by failure. Like the transition from Apollo to Shuttle, it is the result of changes in the political, social, economic, and technological context in which the agency operates. As a government organization, the agency's mission has always been shaped by stakeholders in the White House and Congress in response to the world around us. This is as true today as it was in the age of the "Space Race" between the Soviet Union and the United States. As the new national space policy notes, the space age began as a race between two superpowers for security and prestige. Today, the benefits of space activities are ubiquitous in everyday life, and the space community includes increasing numbers of nations and organizations around the globe.

A new challenge is here. It's time to thrive.

Virtual Project Teams and Learning

September 30, 2010 — Vol. 3, Issue 9

Virtual teams are a permanent part of the landscape for complex projects. How do we learn to thrive in this environment?

Virtual teams are nothing new at NASA. Early projects like Apollo and Viking featured vast teams distributed around the country at the agency's field centers and partners in industry and academia. The difference today is that many teams are global, spanning oceans and continents. Teams are also more fragmented than in the past. Thirty years ago, a complex project might have included teams in California, Virginia, Florida, and Massachusetts. Now projects include teams and individuals connected by the Internet and cell phones working from any number of locations. International teams pose additional cultural, institutional and legal challenges (e.g., ITAR restrictions on information sharing). The majority of NASA's missions now include some sort of international partnership or involvement.

There's no doubt that virtual teams pose challenges. Just scheduling teleconferences can be difficult when a team spans 10 time zones. Cultural differences add another level of complexity to the mix. I once heard from a European colleague that Americans like to engage in small talk first before getting down to business, whereas in his culture people take care of business first and save the small talk for last. It's an anecdotal example, but one that hints at the kinds of subtle differences that international teams deal with every day.

Microsoft's research group has been studying virtual teams for years and identified some common difficulties that they confront. One of the difficulties that remote team members face is maintaining awareness of what their colleagues are doing. Without the benefit of informal communications such as "water cooler conversations," remote team members miss out on the continuous flow of updates that become part of the shared experience and knowledge base of collocated team members.

At the same time, virtual work enables teams to gather expertise that is untethered from geography. This promotes cognitive diversity, which researchers such as Scott Page have shown is critical to outstanding team performance. Virtual teaming arrangements also offer flexibilities for workers, making it easier to attract talented performers.

Given that this is the context of projects today, how can we enhance our ability to connect to one another when face-to-face encounters are limited by geography and travel budgets?

One technical solution that Microsoft's research unit has recently employed is an "embodied social proxy," also jokingly referred to as "crazy webcam remote cart thing." The principle is simple: a two-way webcam device provides continuous videoconferencing availability to connect remote team members with a hub of colleagues in a home base location. The Microsoft pilot project relies on sturdy, reliable technologies in an effort to make virtual contact through the webcam as common as phone calls or email. It is not far-fetched to expect that proxies of one sort or another will become increasingly common in our work environments.

A key to adapting to this new way of working is to learn in the same modality in which we work. When the Academy first started, nearly all of our courses took participants away from their home centers to Wallops Island, where training took place in an isolated classroom environment. While traditional training is still an important part of how we convey essential knowledge and skills, we are also developing new offerings in technology-enabled learning that will bring the experience of training closer into line with the experience of working at NASA. Since we already work virtually, our training strategies need to include learning in a virtual environment as well.

I will be writing more in the months ahead about the Academy's technology-enabled learning as we roll out virtual courses and learning opportunities. In the meantime, I'd love to hear from you if you've had a positive virtual learning experience. With so many virtual learning tools and methods available today, it seems clear that the future will allow for increasing customization rather than one-size-fits-all solutions.

The Good Idea Paradox

November 30, 2010 — Vol. 3, Issue 11

Organizational support for good ideas can be a mixed blessing.

Do what you want as long as I don't know about it, a manager once told me. I could run with any idea I wanted, but if something went wrong, it was my neck on the line. I found this both freeing and discouraging. While I had the freedom to experiment, it bothered me that if a good idea did fail, I was left to deal with the consequences.

I believed then (and still do) that if something went wrong, the responsibility for dealing with it rested with me. I also believed (and still do) that a good manager would acknowledge the situation and ask, "What do you need from me?" He or she should provide the tools or support to solve the problem.

Years later I visited one of NASA's centers, and during a discussion with some engineers, I learned about a unique tiger team activity that could potentially save money and streamline operations in its business area. This activity was supported by the organization but had almost complete autonomy.

When I recommended to one engineer that the Academy might highlight some of the good innovative practices of his team, he seemed hesitant. I later learned that this reluctance stemmed from my "management" status. From this experience and others like it, I have come to find that the survival of good ideas, particularly "quiet innovations," depends on the ability to fly under the radar. If good ideas are exposed, there seem to be two outcomes: 1) the organization looks for ways to "control" the innovative approach, or, 2) management wants to help.

At first glance, the second outcome does not sound problematic, but it introduces the challenge of fully realizing a good idea with "too many cooks in the kitchen." Good ideas tend to address an existing problem and germinate among a very small number of people until they're ready to be introduced to the organization at large.

I don't think organizations intentionally suppress good ideas. They live and die by them. Good ideas need support to be fully realized, but they also dread support to avoid unintended consequences.

So what is the solution? Money is the knee-jerk answer, but I'm reluctant to agree. Most good ideas are risky at the outset, whereas most organizations tend to fund safe ideas. The challenge organizations face is to find ways to cultivate good ideas by asking, "What do you need from me?" One widely touted solution to this is the approach taken by Google, among other organizations, which is to give employees autonomy and dedicated time to pursue their own ideas. This poses challenges for a public organization like NASA, but it's worth noting that some highly innovative firms are finding ways to help give life to good ideas.

The trick is to avoid interfering too much and be willing to accept the possibility that an idea might flop. For now, "infant" good ideas are rare and generally hidden, but they don't have to stay that way.

Academy Briefs

PM Challenge Leadership Roundup

February 26, 2010 — Vol. 3, Issue 2

"We are about risk and innovation and taking chances," NASA Administrator Charlie Bolden told a packed auditorium at PM Challenge 2010.

Bolden talked extensively about the changes NASA faces based on the White House's recently announced FY 2011 budget. Responding to concerns about the new direction of NASA's human spaceflight program, he said, "To think that...NASA is getting out of the business of human space exploration is folly." He noted the growing role that international partnerships will play in the future of human space exploration. "One of the things we're going to do differently is we're going to really involve the international partners," he said. He encouraged NASA employees to engage with the challenges ahead. "Talk to each other. Listen to each other. Be open to new ideas."

Johnson Space Center (JSC) Director Mike Coats welcomed attendees to the conference and spoke about the changes ahead for JSC in 2010. "This is a very emotional and dramatic year for many of us at the JSC," he said, referring to the conclusion of the Space Shuttle program and the cancellation of the Constellation program. He said that NASA's new human spaceflight program has the same goal but takes a very different direction. "Integrated project management will be more important than ever."

Glenn Research Center Director Whitlow Wilson, who was recently named Associate Administrator for Mission Support, spoke about the challenges of project management in a research environment. "Is good enough better than perfect?" he asked rhetorically. Noting the tendency of researchers to seek "perfect" solutions, he cited cases at Glenn in which project managers led by defining success in project terms (including tight deadlines for deliverables), which helped researchers to understand the context of their efforts as project team members.

NASA Chief Engineer Mike Ryschkewitsch, speaking for Associate Administrator Chris Scolese, addressed the subject of risk in space exploration. In addition to cost, schedule, and technical risks, he highlighted the importance of political, social, and talent risks, which are typically driven by events outside the agency. He noted the difficulty that most people have assessing everyday risks (for example, misinterpreting the relative safety risks of flying versus driving), and said that NASA has to do a better job of communicating with the public about the risks of space exploration.

Keynote speakers from other organizations included European Space Agency (ESA) Director General Jean-Jacques Dordain and Project Management Institute President and CEO Greg Balestrero.

Dordain spoke about space exploration and the need for a global approach to it. "Space exploration is a process. It is not a destination," he said. "It is an open-ended process." Cooperation, he said, makes progress in exploration slower but more focused. "Cooperation is never easy," he said, "but we have no alternative." He applauded the recent U.S. decision to extend the life the International Space Station (ISS) until 2020, noting that ESA has received 45 proposals from scientists to conduct Earth observations from the station. Looking beyond the ISS, he identified a need for space-faring nations to set up a political forum to develop a global accord for space exploration. He asked, "Which partner will lead?" and then answered his own question: "I hope that partner will be the United States."

Balestrero spoke about the increasing complexity of global projects. Referring to a recent trip to Masdar City, Abu Dhabi, the world's first "carbon-neutral zero waste" city, he said that projects are now bound by four constraints rather than three: time, cost, scope and sustainability. Regarding spaceflight projects, he said that a primary challenge is making complexity routine. "There are 'complicators' and simplifiers," he said. "I'm with the simplifiers."

PM Challenge International Forum Roundup

February 26, 2010 — Vol. 3, Issue 2

PM Challenge's first-ever international forum featured representatives from over a half dozen space agencies as well as industry, academia, and nonprofit organizations.

With international cooperation and collaboration poised to play an increasing role in NASA's future, the international forum at PM Challenge 2010 provided an opportunity for NASA to bring together partners from around the world to share perspectives, challenges, and opportunities.

Greg Balestrero, President and CEO of the Project Management Institute (PMI), kicked off the forum with an overview of the context for global projects. Challenges such as space exploration require an enabling environment, he said. "The enabling environment is here, and we have to talk about in terms of a global solution."

Michael O'Brien, NASA Assistant Administrator for External Affairs, set the stage by describing the extent of NASA's international partnerships. Historically, the agency has had over 3,000 international agreements with over 100 countries. It currently has 458 active international agreements with 118 countries, with just 10 partners accounting for half of those agreements. He emphasized that the successful implementation of existing agreements is critical for NASA's credibility. "Do what you say you're going to do," he said.

Representatives from three partner agencies provided their perspectives on working with NASA. Andreas Diekmann of the European Space Agency (ESA) suggested that a new trend might be toward more integrated cooperation, with missions that are jointly planned and developed. He contrasted this with past and current international missions that have emphasized discrete contributions from partners. Yoshinori Yoshimura of the Japanese Space Agency (JAXA) noted that changes at NASA can have a dramatic impact on JAXA, and he said that when difficulties arise, partners should try to indicate a common path and build consensus. "The best agreements are difficult to negotiate but don't have to be referred to later," said Benoit Marcotte of the Canadian Space Agency (CSA). "They have to be fair for both or all parties."

Looking at the current framework for international collaboration, Kathy Laurini of NASA's Space Operations Mission Directorate provided a brief overview of the Global Exploration Strategy, written by 14 countries in 2006, and the associated International Space Exploration Group, composed primarily of active participants in the ISS. She said that that partner interdependencies and full utilization of the ISS are two of the greatest challenges that need to be addressed in the future. "It's up to all of us to make sure we take advantage of that," she said of the ISS.

Representatives from some of the active ISS partner agencies, including Benoit Marcotte, CSA, Kuniaki Shiraki, JAXA; Alexi Krasnov, Russian Space Agency (RSA); and Bill Gerstenmaier, NASA Associate Administrator for Space Operations; shared their lessons learned from the station. Gerstenmaier prefaced remarks by NASA's international partners by referring to the lessons learned document that the ISS partnership released in the summer of 2009. Noting that Japan's Kibo module for ISS was in development for 20 years, Shiraki mentioned the need for sustainable support from partners as well as the public. Marcotte said it was important to be prepared to "seek and work compromises." Krasnov echoed a similar theme. "We can do better together," he said.

The forum also considered new opportunities for international collaboration in space exploration. European Space Agency (ESA) Director General Jean-Jacques Dordain emphasized the longstanding close relationship that ESA enjoys with NASA. "We don't know what it means not collaborating with NASA," he said. At the same time, he held up ESA's success in running a space agency with 18 stakeholder nations as an example others could learn from. "If there is one field ESA can teach the world, it is international cooperation." Dordain spelled out the reasons for international collaboration in space exploration and constructed three plausible future scenarios, concluding that the future should be based on the partnership of the International Space Station (ISS). "The most important asset of the station is the partnership," he said. "We should not take any risk to weaken that partnership."

One of the key areas for international collaboration in the future is Earth observation. Michael Freilich, Director of the NASA Earth Science Division in the Science Mission Directorate, said, "The problem of understanding and predicting climate change is far too large for any single agency or even any single nation, and therefore we must have good collaborations." Jean-Louis Fellous, Executive Director of the Committee on Space Research (COSPAR), explained that climate change is hard to monitor because of the long-term, precise measurements required to make meaningful predictions. Fellous identified four challenges posed by Earth observation — financial and geographical; compatibility among measurements; modeling and forecasting; and knowledge and innovation — and encouraged the idea of developing virtual constellations that would image the land surface, and measure ocean surface topography and global precipitation. The next challenge, said Freilich, is in understanding how these individual pieces interact in the larger system. To do this data must be rapidly collected, reliable, and available to all. Project managers in Earth observation must identify partners early to sort out overlapping political and scientific interests as well as to determine commonalities among agency operations and visions.

Space science also holds high potential for continued international collaborations. Bob Mitchell, program manager of the Cassini mission, pointed out that difficulties in multinational missions do not necessarily stem from cultural or geographic differences. "Where we have had issues on Cassini, it has not been along national lines," he said. Rather, there were often disagreements among scientists about the mission's priorities. (For instance, those involved with the Huygens probe had different interests than those working on the Cassini orbiter.) Peter Michelson, Principal Investigator of Fermi (also know as the Gamma-Ray Large Area Telescope, or GLAST), said that Fermi handled one of its management challenges by forming an international finance committee so that finance committees from different partner nations could meet to review the status of their commitments to the project. "They developed a working relationship in which they could talk frankly," Michelson said.

The forum made clear that there is significant variation in international approaches to spaceflight project management. Himilcon de Castro Carvalho, Brazilian Space Agency (AEB), said that project management in his organization is under severe budget and human resources restrictions, and that as a result, the focus is on work breakdown structure (WBS) planning, activity definition and sequencing, quality and verification planning, and risk planning. B.N. Suresh of the Indian Institute of Space Science and Technology described the overall management processes, milestone reviews, and quality management processes, which bear some similarities to those of NASA. Dr. Paul Spudis of the Lunar and Planetary Institute provided an overview of his involvement with the Chandrayan-1 lunar mission launched by the Indian Space Research Organization (ISRO) in 2008. Spudis was the Principal Investigator for the Mini-SAR imaging radar experiment on Chandrayan-1, one of 11 instruments on the spacecraft. He spoke of the challenges of dealing with a foreign press environment on an international mission. "Follow your partner's lead with the press," he counseled. "Keep quiet and let them set the tone."

The commercial space sector will clearly play a key role in future international collaborations. Andy Aldrin of United Launch Alliance (ULA) noted that the United States government spending currently accounts for the majority of global spending on space, but that flat U.S. budgets and growing expenditures abroad will lead to changes in that balance in the coming years. Bo Behmuk, former General Manager of Sea Launch for Boeing, said, "The international way of doing business is our future." Greg Pech of ULA emphasized the importance of maintaining close contact with partners and suppliers around the world. "There are times when you just have to get off the phone, get on the plane, and go visit them, sit across the table and face to face, and really connect. There's just no substitute for that."

Increased collaboration in space exploration will also place greater demands on the international program/project management community. Edwin Andrews of PMI said that PMI forecasts a 31% increase in the global number of project-oriented employees in project industries between 2006 and 2016, which translates as 1.2 million new project-oriented jobs annually. The international space agencies represented at the forum varied widely in their approaches to the development of their project workforces. Takashi Hamazaki of JAXA said that on-the-job training accounts for most of JAXA's professional development efforts. Bettina Bohm of ESA explained that her agency focuses on ensuring that there is a qualified applicant pool, providing training courses for project managers, selecting individuals for key assignments, and extending lessons learned across the agency. Dr. Ed Hoffman, Director of the NASA Academy of Program/Project & Engineering Leadership, offered an overview of the Academy's framework to promote individual, team, and organizational learning.

The NASA Academy of Program/Project & Engineering Leadership organized the international forum in collaboration with the PM Challenge organizing team. The Academy received significant assistance from James Zimmerman of International Space Services.

Jean-Jacques Dordain on Global Opportunities and Challenges

March 31, 2010 — Vol. 3, Issue 3

Exploration makes us human, according to Jean-Jacques Dordain, Director General of the European Space Agency.

(Editor's note: The following is an except of Mr. Dordain's keynote address at PM Challenge, which he delivered on February 9, 2010, in Galveston, Texas.)

Today, I have been invited to share with you my views about space exploration. It is always amazing for me to be asked to give my views to those in an agency that landed a man on the moon, but I'll do my best.

Exploration is an open-ended process. This means that exploration is a process, not a destination. It started a long time ago along with the origin of humankind. Human experience with exploration is much longer than human experience with space! All continents have contributed to that process, starting from Africa with the first humans who spread to the rest of the world. People from around the Mediterranean, the Chinese, the Vikings, the Europeans, and the Americans have all explored and ventured outside their habitats, never all at the same time but in successive and different steps.

And it will continue, nobody can stop this process; but, as in the past, the process will experience accelerations and pauses.

Accelerations are generated by technology breakthroughs such as the wheel, the ship, the submarine, the plane, the rocket. They are also generated by economic growth and by competition. Pauses are generated by budget constraints and they may also seem to be generated by cooperation, partly because cooperation is forced upon actors by budget constraints and also because building up cooperation takes time. But the succession of accelerations and pauses has never stopped the process of exploration, and will never stop it.

Exploration is inherent to humankind; exploration makes us human and it must involve human presence. However, the question of how best to explore space with humans or robots has never been settled. At the present time, humans are more efficient explorers than robots. But the gap has closed considerably, as robots are becoming increasingly sophisticated partners to precede and support humans in their quest. Consequently, although the debate between the two approaches is still raging, it is a false debate: the right approach is that of a balanced mix of both robots and humans.

Exploration aims at expanding knowledge and at extending the range of human actions. Exploration is not science, even if exploration leads to interesting scientific outcome. Exploration is about discovering the unknown, going where we have never been with a view to exploiting its resources, with a return for our planet.

The benefits must be measured down on Earth: economic growth, technological innovation, scientific information, international cooperation, education. These are all aspects that can contribute to solving problems on planet Earth.

Whether or not you include exploration of planet Earth within exploration is not so important. What matters is that exploration of space should not be conducted to the detriment of exploration of planet Earth since the goals are consistent and complementary.

With exploration, we are therefore addressing the future of planet Earth. It is interesting to see that 40 years after the first landing on the moon by two American astronauts, the significance of that historical step of human exploration is today very different than 40 years ago. At that time, it was a clear demonstration of the supremacy of U.S. technology over the world, and a symbol of the U.S. identity. 40 years later, it is not any more a matter of the moon and the United States, but rather of planet Earth and humankind: there are 27 astronauts who have seen planet Earth as a small and fragile golf ball floating in the universe and, as a result, helped develop the understanding that our future can only be global.

Thanks to that first landing on the moon, we have witnessed two paradigm shifts: the first about the objective, which has shifted from space to planet Earth; and the second about the process, which has shifted from competition to cooperation. We have started with one flag on the moon, then two 2 flags for the Apollo-Soyuz mission, then four with Space Station Freedom, and now five flags for the International Space Station. The cooperative process may be much slower than the competitive race, but it is also much more robust and sustainable.

Future space exploration can indeed only be global, and it will require us to assemble the nations who explored individually in the past so as to explore collectively in the future. This is not easy, not easy at all. This will even be the most difficult part of exploration, much more difficult than any required technological development, but it is necessary. There is no alternative. We shall have to invent the future together.

Make ISS utilization a success

These next ten years are necessary to make ISS utilization a success, to demonstrate to the public and governments that they were right to invest in the ISS. Also, we need time to reap the benefits, be it for science, for technologies, for new partnerships, etc. As I said to the Augustine Committee, we shall not build exploration on the failure of the ISS. So our first priority shall be to ensure the success of the ISS.

These next ten years provide the perspective to improve the ISS and to make it a concrete step towards exploration. The two questions that we should now ask ourselves are how to increase the benefits of the ISS, and how to decrease the costs of using it.

How to increase the benefits of the ISS?

- Increasing capabilities, not by adding new labs, but by reducing the bottlenecks such as storage, communications or download;
- Extending the range of scientific utilization towards new fields such as Earth observation, monitoring of natural disasters, climate change;
- Improving operations, for instance through a common transportation policy or a common operations policy, i.e., defining common interfaces between each partner's elements;
- Testing new systems and technologies, for instance in the fields of life support or resources recycling;
- Extending the partnership to other partners, on conditions to be defined. To be sustainable, the space station partnership cannot be closed.

My biggest fear as the Director General of ESA is that ESA becomes a dinosaur, not any more adapted to its environment. We have to change, to change continuously. This is not easy, in particular because we are a successful agency, and the easiest way would be to keep doing what has made us successful. But the future will not be made with the recipes of the past.

Commercial services may indeed be a way. We have already experienced that in Europe, by creating the commercial operator Arianespace for launch services, but this was 30 years ago. Reflections are ongoing to see how we can further adapt this scenario.

I refuse the much too simple statement that agencies are expensive and industry is cheap. The reality is as usual much more complex: agencies are working under substantial constraints imposed by their governments, such as distribution of activities. Agencies can also be cheaper, and we in ESA shall work together with the other agencies to reduce significantly these utilization costs. Agencies cannot do without industry, but industry also cannot do without agencies.

Develop robotic exploration plans

Last year, ESA and NASA have made a significant step by taking a joint initiative for a systematic robotic exploration of Mars: we have decided to use every opportunity to go to Mars together, and we have already defined joint missions that will be launched in 2016 and 2018. The ultimate goal is a joint Mars Sample Return in the mid-'20s. There also, the partnership is not closed and must be open to other partners.

A major interest of robotic investigation is to involve industrial expertise outside the traditional space industry, and therefore to widen the base of stakeholders and to increase the synergy between space-bound and Earth-bound interests.

Define a human space exploration scenario

As Administrator Bolden noted in his remarks to you earlier today, there is no common vision among international partners about a human space exploration scenario beyond the exploitation of the ISS. A Global Exploration Strategy has been developed by 14 space agencies of the world, including ESA. But this Global Exploration Strategy has not been addressed at political level and does not represent a political strategy shared by an enlarged community of international partners.

A high-level political forum, including the current partners as well as potential new partners of the ISS, should be set up with the objectives of developing a common vision for exploration.

At the space agency level we can develop a common architecture for human space exploration. But we can't develop the political vision. We are waiting for someone to take the initiative.

Which partner in the world has the willingness and credibility to propose such a political forum? I am convinced that the U.S. is the best suited to take such an initiative...but when?

As the French author and aviator Saint-Exupéry said, "...the question about the future is not to predict it, but to make it possible." So let us work together to make it possible.

Masters with Masters Event Highlights International Collaboration

June 30, 2010 — Vol. 3, Issue 6

The third Masters with Masters event explored the challenges and rewards of international collaboration with Mike Hawes and Lynn Cline.

Ed Hoffman, Director of the NASA Academy of Program/Project & Engineering Leadership, sat down with Mike Hawes, Associate Administrator of the Office of Independent Program Cost and Evaluation, and Lynn Cline, Deputy Associate Administrator for Space Operations Mission Directorate, to discuss insights about their careers, the International Space Station (ISS), and the future of international collaboration.

NASA First class member asks Lynn Cline a question about bringing Russia in as a partner on the ISS.

Ed Hoffman (left), Mike Hawes (center), and Lynn Cline (right) answer questions from the audience at Masters with Masters III Credit: NASA

Hawes and Cline arrived at their present positions from very different paths. Hawes, a self-proclaimed "space cadet" since childhood, joined Johnson Space Center at the dawn of the Shuttle program. Cline, an undergraduate French major, turned a three-month co-op position in the International Affairs Office into a 35-year career at the agency.

Both emphasized the importance of mentors who saw qualities in them that they couldn't see in themselves. Cline noted that she was often recruited for positions she hadn't considered. Hawes agreed, noting that, "It's not that you throw out the career planning—it's just that you need to be flexible to realize that there are always multiple paths."

As Deputy Associate Administrator for the ISS from 1999 to 2002, Hawes was responsible for coordinating and aligning engineering standards among the ISS's international partners. This posed significant challenges because NASA's engineering practices differed from those of some of their partners, which led to the need to build a common lexicon for concepts like "certification" or "verification."

As NASA's lead negotiator with the international partners for the ISS, Cline learned to manage differences in culture (Americans tend to be workaholics) and planning (Japan's fiscal year begins in April) as well as tectonic shifts in geopolitics (such as the dissolution of the Soviet Union). She also had to juggle the needs of the original ISS partners (Canada, Europe, and Japan) with those of the Russians, who joined later.

"I think folks may forget that we originally operated the partnership for nine or ten years before we invited the Russians to join," said Hawes. Even after the Russians came on board, it would be another five years before the first assembly mission.

"[The] Station didn't just start with an announcement by the president that we were going to do this program," explained Cline. "There had been years of in advance with the partners to pave the way so that when the President made such an announcement, they'd be prepared to accept the invitation."

Hawes and Cline agreed that the future of space exploration will demand collaboration. Final assembly and utilization of ISS is a fundamental interest of NASA and its international partners, Hawes noted. Beyond ISS, international collaborations will most likely include robotic precursor missions or technology demonstrations. "As you look beyond…this administration has a strong emphasis on international cooperation," said Cline. "I think NASA is going to be looking to see what interests other partners have… [and find] ways to work together to pool our resources as we plan for future exploration.

Masters with Masters Features Bolden and Dordain

October 29, 2010 — Vol. 3, Issue 10

NASA Administrator Charlie Bolden and European Space Agency (ESA) Director-General Jean-Jacques Dordain shared reflections and stories in a special Masters with Masters program.

Bolden and Dordain traded ideas about international collaboration and fielded questions from the audience in a lively discussion moderated by Academy Director Dr. Ed Hoffman at the 61st International Astronautical Congress in Prague on September 28, 2010.

Dordain emphasized that cooperation among space agencies is strengthened by personal relationships. "Behind any cooperation there are people. The personal relationship is very important. Yes, there is cooperation between NASA and ESA...but behind that cooperation, there is cooperation between Charlie Bolden and Jean-Jacques Dordain." He recalled that the first time he heard of Bolden was in the 1980s, when he headed ESA's astronaut office and Bolden was a NASA astronaut. ESA astronauts who were training in Houston at the time were being excluded from meetings with their American counterparts. "The one who took them by the hand and brought them to the meeting of the NASA astronauts was Charlie Bolden," said Dordain.

Bolden spoke about collaboration in terms of diversity and inclusion. "Diversity is a difference of ideas, a difference of philosophy, a difference of skills, a difference of geographic background. It's just differences that makes us strong," he said. "The inclusiveness means we listen to everyone's voice."

Both agreed that competition and cooperation were not mutually exclusive. "We need competition, but provided that that competition is organized to reach common objectives," said Dordain. "I think that cooperation is to set the common objectives: what are we ready to go do together? I think that is the sense of cooperation. But to reach these common objectives, I think that competition is very healthy."

"There should be very healthy competition of ideas," Bolden said. "I think if we ever stop competing for ideas, then we're dead."

Audience members posed questions about navigating bureaucracy in complex organizations. Dordain acknowledged that bureaucracy was inevitable within ESA. "When you are working with 18 governments, you have to accept the bureaucracy, but...a significant part of the bureaucracy is coming from a lack of trust," he said. "You cannot buy trust. You have just to build up trust, and that takes up time."

Jean-Jacques Dordain, Director-General of ESA, and Charlie Bolden, NASA Administrator, participate in the Masters with Masters knowledge-sharing session at the International Astronautical Conference in October 2010.
Photo Credit: ESA/S.Corvaja 2010

Bolden emphasized the importance of being able to compromise. "Many people today...feel that compromise is a weakness, that if you are willing to compromise, then you are not going to win," he said. "If you are not willing to compromise, in my mind, then you will never win."

Masters with Masters 4 Features Bobby Braun and Steve Altemus

October 29, 2010 — Vol. 3, Issue 10

Bobby Braun and Steve Altemus discussed informed risk management in technology development and engineering in a Masters with Masters session at NASA Headquarters.

For the Academy's fourth Masters with Masters event, Bobby Braun, NASA's Chief Technology Officer, and Steve Altemus, Director of Engineering at Johnson Space Center, sat down with Academy Director Ed Hoffman to share stories and experiences in a 90-minute session that streamed live to all NASA centers on September 13, 2010.

Braun talked about what he learned from working on the Mars Pathfinder and the Mars Polar Lander microprobe Deep Space

Bobby Braun and Steve Altemus share their stories of experience at the Academy's fourth Masters with Masters event. Photo Credit: NASA APPEL

2. Pathfinder was a success when it landed on the surface of Mars in 1997, while one year later the Polar Lander was a public failure. He indicated that he learned more from the failure, deeming it a necessary part of the learning process. "You're never as good as you think you are on the day you succeed, and you're never as bad as you feel on the day you fail," he said.

The important thing is to learn from failure, Braun emphasized. "If we're going to push the edge, if we're going to do cutting-edge work, we have to be continually learning," he said, "and the day we stop learning is the day this agency stagnates."

Altemus spoke about the connection between learning from past failures and communications. "We've gotten to the point now where we're talking about informed dissent," said Altemus, "where people who understand the complexities of the issue that we're working, they raise the issue up and then we deal with it squarely and maturely as we go forward."

Bobby Braun and Steve Altemus take questions from the audience at NASA HQ during the Academy's fourth Masters with Masters event. Photo Credit: NASA APPEL

Altemus said that he believes the agency has matured in its ability to manage risk, and to illustrate this point, he told the story of the STS-119 mission in 2009. Prior to the mission, another shuttle experienced an anomaly with a flow control valve. "We looked at the likelihood of failure and the consequence of failure. We were at the limits of our analysis tools to the point where we could not do any better," said Altemus. The team held three flight readiness reviews (one of which lasted thirteen hours) before all were satisfied that they understood the problem. The shuttle still flies with this flow control valve risk, said Altemus, but the difference now is that the program understands it and knows how to manage it. (Read the STS-119 case study.)

Braun and Altemus also shared their thoughts on innovation within the agency. "There's no doubt in my mind that we have the raw material…to be innovative, but what we need to do is remove those stumbling blocks," said Braun. Programs like the Center Innovation Fund will give innovative ideas a chance to grow, explained Braun. Altemus, who initiated "Project M," a challenge to put a bipedal robot on the moon in 1,000 days, sees funding such initiatives as an "unshackling" of innovation.

Both Braun and Altemus view the relationship between technology and engineering as healthy and critical to moving NASA forward. "If we have strong relationships between us as a community, technologists and engineering, leadership…we can solve just about anything," said Altemus. "The foundation of innovation, the foundation of moving us forward is in building strong relationships amongst us all."

Academy Hosts Second Principal Investigator Forum

May 28, 2010 — Vol. 3, Issue 5

Principal investigators, project managers, and project scientists gathered to exchange stories and knowledge at the second Principal Investigator Forum in Annapolis, Maryland.

The Academy's second Principal Investigator Team Masters Forum, hosted in partnership with the Science Mission Directorate, brought together teams from the New Frontiers Mission-3 and the Mars Scout-2 Mission, as well as others selected for a future Mission of Opportunity, to gain a better understanding of the role of a Principal Investigator (PI) at NASA. Master practitioners from past science missions shared stories, perspectives, lessons learned, and best practices with their colleagues.

"Unsuccessful missions are led by Napoleons," said Ed Weiler, Associate Administrator of NASA's Science Mission Directorate (SMD). "Successful missions are led by teams." He noted that small missions can accomplish valuable science in shorter timeframes than flagship missions like the James Webb Space Telescope, and he called for a balance between the two. "SMD is supposed to do the best science, not just do more science."

Orlando Figueroa (right), deputy center director for Goddard Space Flight Center, asks Dennis McCarthy (left), project manager on COBE, a question during his session on the first day of the Forum. Credit: NASA APPEL

John Mather, who won a Nobel Prize in physics for the research he did as PI for the Far Infrared Absolute Spectrophotometer (FIRAS) on the Cosmic Background Explorer (COBE), shared four main insights from that project:

1. No one person can be as essential as he or she thinks.
2. If you have not tested it, it will not work.
3. As a PI, you are basically a systems engineer, so study the discipline.
4. It takes a wide range of personalities to make a team.

Mather also addressed the risk of being good. "If you're the PI, people think you're right," he said. "You are a single-point failure walking on Earth." He suggested having an outside expert double-check the PI's work. He also acknowledged that not everything can be tested as it will perform in space, but added, "If something matters to you, then you'd better measure it at least two different ways. If they don't agree, you've got to resolve the discrepancy. You don't have to have an end-to-end test, but if you don't, you had better have two ways to make sure of something."

COBE deputy project manager Dennis McCarthy noted that he used to carry around a piece of paper in his wallet with two letters written on it: BP. It stood for "be professional, proved, practical, be protective of the people and the hardware, and to persevere," he said. While acknowledging that the work on COBE was hard, "I don't think anyone left [the project]," he said. "The passion that these people had and the fact that somebody would tell me this was Nobel-type science. No one left." Both Mather and McCarthy believe that COBE could be done again within NASA's current procedural requirements, such as NPR 7120.5D. Project managers just have to work with or around it as need be, according to McCarthy.

McCarthy also served as project manager on the Far Ultraviolet Spectroscopic Explorer (FUSE). FUSE, a twenty-foot-tall, 3,000-pound spectrograph, bounced back from cancellation when McCarthy and PI Warren Moos converted it into a PI-led mission with a greatly scaled-back budget. From McCarthy's perspective, FUSE was successful largely due to the systems engineering that took place over the project lifecycle.

Orlando Figueroa, deputy center director for Goddard Space Flight Center, reinforced McCarthy's point about systems engineering. "I think it is important to practice how systems engineering is applied," he said. "In the end we are all engineers of systems."

Steve Jolly of Lockheed Martin engaged participants in a discussion about systems engineering and the increasing complexity of software for space missions. In the world of software, said Jolly, "there are a thousand ways to fail…most have not been explored." There needs to be a shift in systems engineering, with an emphasis on recruiting people with software and engineering backgrounds, he suggested.

Many PI missions have to find ways to work inside the box. Dennis Matson, project scientist for Cassini, shared his story about employing a free-market system to manage project reserves. In order to deliver all of the eighteen instruments on time and within cost and mass limitations, the global project teams could exchange mass, power, and cost with others on the project. The "Casino Mission," as the teams dubbed it, established rules that reinforced transparency and a strong sense of teamwork, resulting in all 18 instruments flying to Saturn.

Sean Solomon, PI, Peter Bedini, project manager, and Eric Finnegan, systems engineer, presented their lessons learned on the Mercury Surface, Space Environment, Geochemistry, and Ranging (MESSENGER) mission, which is scheduled to arrive at Mercury on March 18, 2011. MESSENGER had both anticipated and unanticipated challenges, explained Solomon. The team knew its spacecraft would have to withstand the intensity of the sun at close range, but it did not expect management turnover or a sudden loss of expertise due to vendor changes.

PI-mission team members working through a knowledge capture activity at the end of the day. Credit: NASA APPEL

PIs don't know everything, cautioned Andrew Cheng, project scientist on the Near Earth Asteroid Rendezvous (NEAR) mission. He told participants that, "the decisions you have to make are going to be about topics that not only do you not know very much [about], you may not know anything about. But you have to make the decisions...because most problems, particularly in our business, do not get better with age."

On the final day of the forum, Chris Scolese, NASA Associate Administrator, took questions from participants. He spent a significant amount of time discussing the review process for flight projects and the NPR 7120.5 procedural requirements for space flight projects. "7120 doesn't have very many requirements," he said. "First, 7120 asks for a set of independent reviews, which help everyone understand what's going on in the project. Second, there must be a structure to the project, and third, everything must be documented. Fourth, anyone can disagree and voice their dissenting opinion. That's really what 7120 says."

Lessons are learned if they are shared, said Noel Hinners, former director of Goddard Space Flight Center, citing a primary reason for convening the forum. It is important to know and understand one another, he said. "Mission success is ultimately a function of superb leadership."

Masters Forum 19 Roundup

June 30 2010 — Vol. 3, Issue 6

Master practitioners shared lessons and stories from their work on the Shuttle and Constellation programs at Masters Forum 19.

Masters Forum 19 brought together current master practitioners and NASA veterans to participate in sharing knowledge gained from the Shuttle and Constellation programs.

"Here you are today, but tomorrow is going to be different," said Tom Moser, who hosted a panel on the formulation, development, and operations of the Space Shuttle Program. Panelists included Jody Singer, deputy project manager of the Shuttle Propulsion Office and deputy manager of the Ares Project Office at Marshall Space Flight Center; Russell Rhodes, Kennedy Space Center; and John O'Neill, former director of Space Operations at Johnson Space Center. Singer addressed the importance of testing and requirements. "You must understand what you must do and what you can do," she said.

O'Neill remarked that things have changed since his career began, "but you still have the same dedication, discipline, and experience." However, he expressed concern about the future of mission operations. "If you put that capability aside, it's going to deteriorate…and you can't rebuild it overnight."

Tommy Holloway, former program manager of the International Space Station at Johnson Space Center, emphasized the importance of building fundamental knowledge. "Learning while you're in a low-risk situation is extremely important," he said, referring to how the Gemini missions provided critical knowledge for Apollo and how the Shuttle-Mir program paved the way for the ISS. He also shared his four pillars of success: 1) the right attitude; 2) technical excellence; 3) character and integrity; and 4) humility, which he characterized as: "You're not as smart as you think you are."

The forum also covered the lessons from the first Hubble Space Telescope repair mission. Joe Rothenberg, former associate administrator for Space Flight and director of Goddard Space Flight Center, said his major lessons learned included recruiting good people, making stakeholders full partners, performing independent reviews, and not predicting success. When working a major failure, "you really get a lot of help," he said. "[NASA] won't let you fail."

Phil Sumrall, advanced planning manager for the Ares Project Office at Marshall Space Flight Center, shared his insights about establishing firm requirements early in a program. "A lot of people mistakenly think that if you have a box of parts, you have a vehicle," said Sumrall. "Putting all of those things together is tough."

The conversation also turned to political savvy. Presidents set the tone for what happens in human space exploration, said Noel Hinners, former director of Goddard Space Flight Center, and "the ability to foresee and advocate what you wanted to do was well in place in the '50s." In the face of potential shutdown of the Shuttle Program during the Carter administration, NASA was replanning the program every year, added Moser. NASA had to continuously sell its program. "This doesn't sound like engineering," he said, "but if you don't do it, [your work] doesn't get done."

"I don't think you'll ever change politicians," said Tommy Holloway. "They are what they are and they'll do what they'll do. You have to change how you operate with the politicians."

The forum also explored the life sciences and microgravity research happening on the ISS. Howard Ross, associate center director for planning and evaluation at Glenn Research Center,

An exhaust plume surrounds the mobile launcher platform on Launch Pad 39A as Space Shuttle Atlantis lifts off on the STS-132 mission. Credit: NASA/Tony Gray and Tom Farrar spoke about ISS microgravity research, which tackles questions like how a candle burns in zero g, how to use space technology to detect cataracts, and how to develop of better firefighting methods. "We can talk about all of the practical benefits, practical science, and incredible engineering, but there is an intangible benefit to what we do," said Ross.

Future ISS utilization was another hot topic. "It's one thing to build the ISS. It's another to actually use it," said Mark Uhran, of the Office of Biological and Physical Research at NASA Headquarters. Uhran discussed future findings for the ISS, focusing on a highly anticipated treatment of the bacterium Methicillin-resistant Staphylococcus aureus (MRSA). Millard Reschke, Chief Neuroscientist at NASA, presented the effects that gravity (and lack thereof) has on human perception, health, and function, wowing the forum with findings and videos of the atypical behaviors of astronauts returning from space. "Test what you fly, fly what you test, and hopefully you test what you've flown," said Reschke, referring to astronauts.

For an international perspective, Martin Zell, head of the ISS Utilization Department of the Human Spaceflight Directorate at the European Space Agency, discussed the benefits of the ISS. While ESA is also in a transition phase due to the retirement of the shuttle, he said, non-ISS partners should be invited to use the ISS in order to further global human space exploration.

Other speakers discussed the lessons from Spacelab, the Orion capsule, safety oversight and insight, and risk management. Forum participants also viewed the launch of STS-132, the last flight of the space shuttle Atlantis, on May 14, 2010.

Congressional Operations Seminar

April 26, 2010 — Vol. 3, Issue 4

A group of NASA systems engineers peeked behind the curtain of the legislative process, learning what it takes to manage projects in a political environment.

Capitol Hill sits three blocks east and three blocks north of NASA Headquarters. While the distance between these buildings is short, the differences are vast. For four days, the Government Affairs Institute (GAI) at Georgetown University designed and conducted a program for civil servants at NASA Headquarters, which included participants from the Systems Engineering Leadership Development Program (SELDP). The program took NASA through the halls of the House and Senate, giving them a crash course on the legislative branch of government, covering everything from the budget to the future of U.S. human spaceflight.

Blame Oliver Cromwell

NASA's introduction to the Hill began with a story by Charles Cushman, professor of political management at George Washington University:

Once upon a time, shortly after the Puritans landed at Plymouth Rock, King Charles I (reign 1625 – 1649) ruled the United Kingdom. He managed to start and lose a war with Scotland, start and lose a civil war in England, and eventually lose his head in the end. His ultimate antagonist was Oliver Cromwell, leader of the opposing army in the English civil war of 1648. Cromwell, the victor and hero, became the Lord Protector and tyrant of the United Kingdom until his death in 1658.

Over a century later, when the Framers of the Constitution gathered to form a more perfect union, the story of Cromwell's transformation from hero to tyrant was fresh in their minds. They were terrified of power, and as a result created a form of government best described as a "friction maximization machine."

American government is meant to be slow and frustrating. Only the agendas with significant support survive, and no single entity or individual has the ability to acquire power quickly enough to pull a Cromwell. It has been said that our federal government is 3% efficient, remarked Cushman, and the Framers might say that our government is 97% tyranny-free.

Bills, Laws, and Power of the Purse

The resulting Constitution created three branches of government: executive, judicial, and legislative. While NASA is positioned under the executive branch, it was created by the legislators in Congress.

Congress passed the National Aeronautics Space Act in 1958, turning the National Advisory Committee on Aeronautics (NACA) into NASA. The driving force in the Senate behind the Space Act was Majority Leader Lyndon Baines Johnson. Contrary to popular belief, this was not simply a response to the Russians launching Sputnik. As the launch of Explorer I in January 1958 showed, the United States had been preparing to launch its own satellite well before Sputnik.

The transference of military rocket hardware, engineering experts like Wernher von Braun, and facilities like the Jet Propulsion Laboratory and Langley Field to NASA, combined with the passage of the National Defense Education Act in 1958 (which pumped money into engineering education) transformed NASA into the agency that would put men on the moon. All of this depended on money from Congress.

NASA's existence hinges on the support of Congress. Members of the House of Representatives and Senators are elected to represent the needs of their constituents, but they must also balance national needs. After President Kennedy made the moon landing a national priority in the 1960s, NASA received four cents of every dollar in the federal budget. Today it receives just over one-half cent of every tax dollar.

Hill staffers explained the budget process to the SELDP group. Simply put, it begins when the President rolls out the budget request. The White House budget then goes to Congress for authorization and then appropriation. The last two steps must be approved by both Congress and the

President. Congress must pass appropriations bills to fund agencies like NASA—although they're not always done on time, which means using stopgap maneuvers like continuing resolutions to keep things moving until the process is finalized.

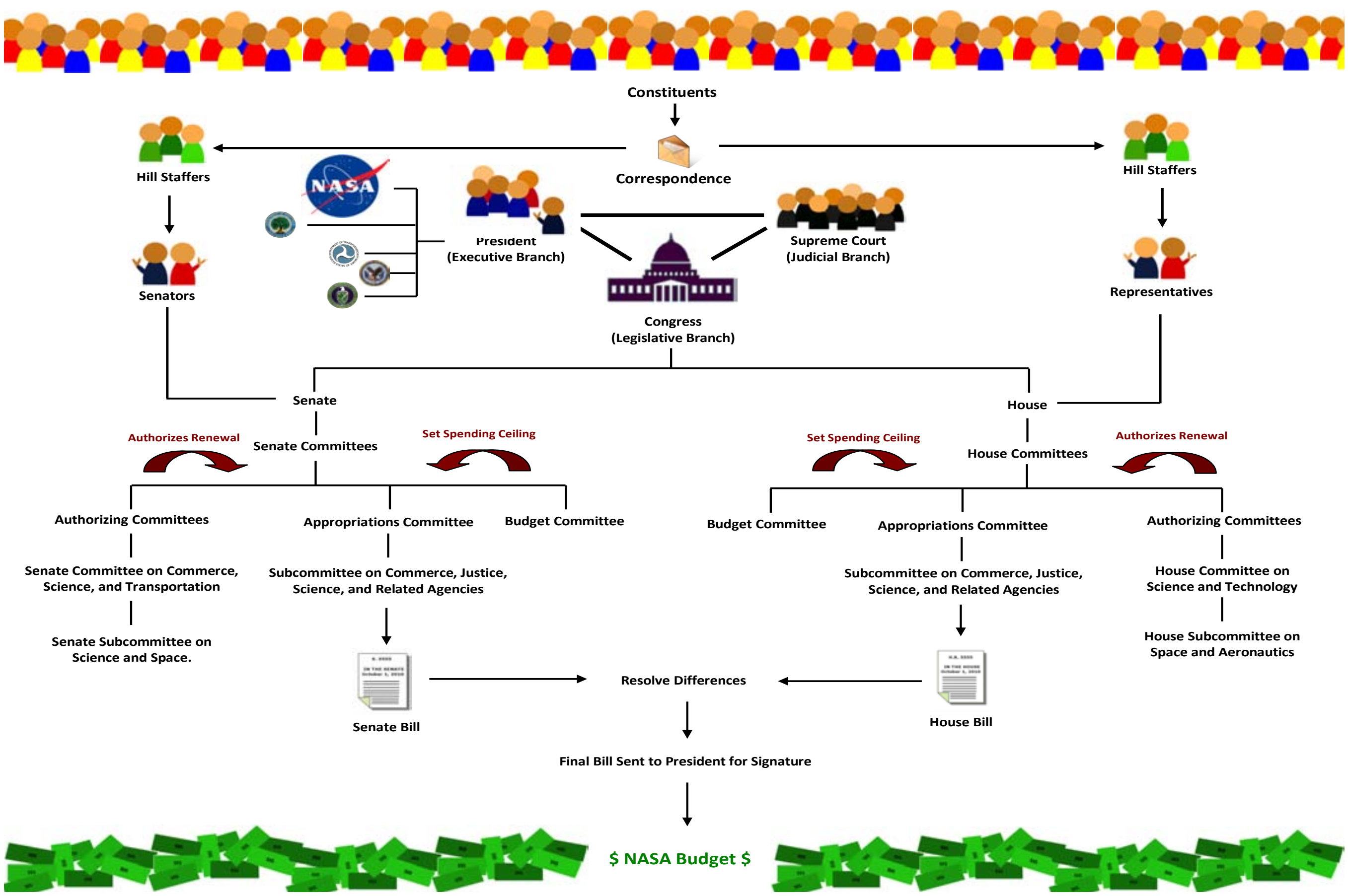
The devil is in the details. Authorizing committees pass bills which call for the establishment or renewal of a program or agency. The House and the Senate have their own authorizing committees and subcommittees that pertain to NASA. In the House, the Subcommittee on Space and Aeronautics falls under the Committee on Science and Technology. In the Senate, the Subcommittee on Science and Space falls under the Committee on Commerce, Science, and Transportation.

Once authorized, appropriations committees are in charge of setting expenditures for discretionary funds. The expenditure ceilings for these committees are set by House and Senate Budget Committees, who see the president's budget first. Like the authorizing committees, there are appropriations committees for the House and for the Senate that pertain to NASA. The names of the appropriations committees are the same for both the House and Senate: Committee on Appropriations. The subcommittees also have the same name: Subcommittee on Commerce, Justice, Science, and Related Agencies. Communication between appropriations subcommittees and the agencies they fund is essential. Ultimately, the House and Senate subcommittees play a zero-sum game with limited resources, and have to agree on how to distribute funds among the executive branch departments and agencies.

Another challenge comes from differing timelines. "NASA looks at a lifecycle. We try to plan and manage the unknowns, over a long-term lifecycle," said Scott Glubke, MESA Division Chief Engineer at Goddard Space Flight Center. "Congress wants to do cut and dry, one year at a time... It's two totally different systems, speaking two totally different languages."

SELDP Take-Aways

Knowing how Congress does its job and learning how to work with them is vital to NASA successfully working with them as a partner. This means forming relationships with representatives, senators, and staffers in their home districts, states, and on Capitol Hill. It means project managers talking to program directors at field centers and NASA headquarters so the correct information can effectively travel the six blocks to decision makers on the Hill. It means finding ways to communicate more clearly,



The budget for NASA is proposed by the President and then reviewed by the House and Senate Budget Committees.The budget is finalized once it has gone through the House and Senate Appropriations Committees, committee differences have been resolved, and the President signs the final bill.

eliminating jargon, and speaking a common language. It also means realizing that all American citizens have say in the process.

"Before I went into the course I was pretty 'civically challenged,' but I think I certainly benefitted a lot from this," said Rick Ballard, J-2X Engine SE&I Manager at Marshall Space Flight Center. He noted his rediscovery of the power of writing to Members of Congress to voice opinions. (Each Member and Senator has legislative correspondents, whose sole responsibility is to respond to individual letters and convey constituent concerns to decision makers.) "I do plan on going back to Marshall and telling the people on my team and trying to keep them held together."

Many SELDP participants said that they would think differently about how to plan and manage their projects and teams now that they better understand the context in which the agency operates. While over the course of the week many voiced frustrations with the Congressional system, they realized that the system is not theirs to fix.

"I started out always being frustrated with Congress and the budget process…and I think I came to the conclusion pretty early that everyone that we talked to was completely practical," said Matt Lemke of the Orion Project Office at Johnson Space Center. Over the course of the week, participants raised many questions concerning ways to solve the problems of government, but, as Lemke discovered, that isn't that point. "I came to the conclusion days ago that we're not going to solve those problems. It's not a problem that is solvable. We need to learn how to live within this chaos."

When asked how NASA should tell people to support NASA, Goddard Space Flight Center scientist John Mather replied, "[That] is…the challenge of life, isn't it? How do you explain to the world that the thing you want is the thing we all should want?" This is what NASA must do more effectively through closer relationships with Congress and better communication.

In the end, this is the way our federal government operates. NASA lives and dies by this system. The agency must address the needs of Congress in order to thrive, not the other way around. Don't like it? Then blame Oliver Cromwell.

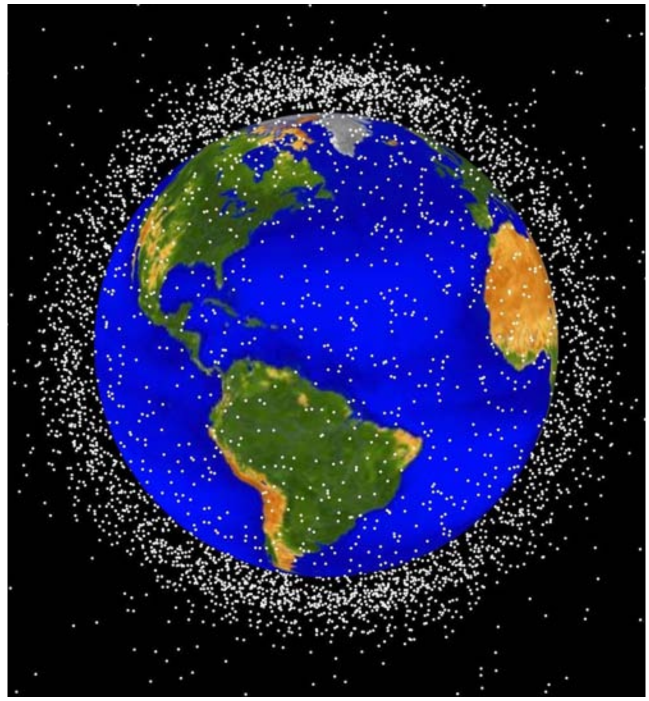
NEW ORBITAL DEBRIS MITIGATION COURSE

September 30, 2010 — Vol. 3, Issue 9

A new Academy course explores the challenges of designing spacecraft with debris in mind.

New national and global requirements have led to a "pack it in, pack it out" orbital debris framework for space missions.

Like the incremental introduction of car safety features such as airbags and seatbelts, orbital debris mitigation



Low Earth orbit spans the region of space 2,000km above the Earth's surface. It is the most concentrated area for orbital debris. Credit: NASA

practices are gaining momentum globally. "Orbital Debris Mitigation and Reentry Risk Management," a new course offered by the Academy, introduces space practitioners to today's orbital debris environment and their role in mitigating it.

With the exception of the moon, there are no other natural satellites in Earth orbit. The 20,000+ softball-sized or larger objects orbiting the Earth are all manmade. The numbers grow by four orders of magnitude if you account for smaller objects the size of a dot. Of the 4,700 space missions flown since the start of the Space Age, 10 missions account for one-third of all catalogued objects in Earth orbit.

"We recognized the potential for orbital debris issues long before they manifested themselves into adverse effects on our space program," said Nick Johnson, NASA chief scientist for orbital debris and instructor for the course. Now space agencies around the world are working to prevent it from getting worse. Reliance on debris falling back to Earth and burning up in the atmosphere is no longer a sustainable practice—and policymakers are aware of this.

Orbital debris mitigation is a key issue in the 2010 National Space Policy released this past June. The policy states that in order to preserve the space environment, the United States shall "require the head of the sponsoring department or agency to approve exceptions to the United States Government Orbital Debris Mitigation Standard Practices and notify the Secretary of State."

This means that if a mission cannot comply with the requirements, the NASA Administrator must provide an explanation to the Secretary of State.

After accidents like the 2009 collision of the Cosmos 2251 and Iridium 33 spacecraft, which released over 1,267 known particles of debris, it is clear why these measures are in place. Without mitigation and reentry risk management, the creation of new debris by accidental collisions will occur at a rate faster than it can fall out of the atmosphere. "What we can't have," said Johnson, "are people designing new spacecraft and not putting in the new requirements."

Compliance with debris mitigation requirements is not optional. "Just because you don't want to isn't a good enough reason," said Johnson. "The world has changed." Johnson's class is designed to define the world of fruitful space exploration in the context of mitigating orbital debris. The challenge the course poses to engineers is to find ways to implement these changes into their spacecraft and mission design. "It's so you can continue to explore space well beyond the end of your professions," said Johnson. "We want to do it for future generations and we have to do things differently."

The pilot ODM course was held on August 10 and 11 at Goddard Space Flight Center. Participants came from Goddard, Langley Research Center, Glenn Research Center, Marshall Space Flight Center, and the Jet Propulsion Laboratory.

The ODM course will be offered next at Johnson Space Center, November 9 and 10. To learn more or sign up for the course, please visit the SATERN portal.

Academy Interviews

Five Questions for Dr. Scott Page

June 30, 2010 — Vol. 3, Issue 6

Dr. Scott Page shared insights with ASK the Academy about complexity, cognitive diversity, and the learning opportunity posed by international teams.

Dr. Scott Page is the author of *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies* and *Complex Adaptive Systems: An Introduction to Computational Models of Social Life*. At the University of Michigan, Dr. Page is the associate director of the Center for the Study of Complex Systems and a research professor at the Center for Political Studies. His research focuses on the theory behind diversity, complexity, incentives, and institutions.

ASK the Academy: You've written that complexity comes from simplicity, using a children's game of tag to illustrate how a complex environment comes from the simple actions of running, trotting, and standing. When it comes to teams, what are the simple actions that create a complex team environment?

Dr. Scott Page: Complex systems consist of diverse interacting individuals whose actions influence the behaviors of others. In groups, diversity, feedback, influence, and the dynamic interchange of information can produce complexity when the underlying problem is challenging. On easy problems, someone likely knows a good answer so the team environment tends not to be very complex.

ATA: In your book *The Difference*, you made the case that cognitive diversity provides multiple perspectives (how a problem is viewed) and heuristics (how that problem can be tackled), which results in better teams. For organizations like NASA, which face grand challenges such as landing humans on Mars, what advice do you have for leaders in managing the complexity of decision making for tasks like this?

SP: A first step is to recognize the nature of the task. Is NASA making a forecast? Is it trying to solve a difficult problem? Is it trying to coordinate across tasks? Let's take a specific forecasting task—such as when a part of the project is likely to be completed. One approach would be to ask the person in charge to give an estimate. Another would be to cast a wider net and to seek input from people involved in a range of activities involved with the project. The second approach probably works better. Or, let's take a specific problem—like reducing the weight on a spacecraft. Here again, opening the problem to more sets of eyes is likely to produce new ideas.

ATA: Many organizations face the challenge of integrating a new generation of workers who have come of age in an era of social networking and no expectation that they'll remain in a single job for more than a few years. How do generational differences like these play into organizational complexity?

SP: Good question. I'm not sure. The empirical question lies outside my area of expertise. What I can say with some confidence is that increasing generational diversity will likely increase complexity as well. The nomadic expectations are a mixed bag. True, the new generation may feel they have less skin in the game, but they'll also be more willing to share novel ideas, as they'll be less concerned with reputation and more interested in just having fun and learning.

ATA: Increasingly, large projects such as the Large Hadron Collider and the International Space Station are achieved by international teams. Working with international partners adds new levels of diversity and complexity to projects. What are the key challenges you see in determining how to leverage this diversity and manage complexity on international projects?

SP: International teams offer several immediate opportunities. On technical problems, you have a good chance that people have learned the relevant material from different sources and have mastered slightly different techniques. That diversity can be useful. If you have all Ph.D.s from the University of Illinois or Purdue, you're likely to have people who all sat under the same bright lights poring over the same textbooks. With an international team, you've got a broader set of basic understandings. In contexts that involve the human element, international diversity produces diverse lenses on the human experience and leads to deeper understandings. Permit me a brief anecdote. The recent Netflix prize competition was won by an international team of collaborators. People from different countries brought different understanding of why people like moves and how to classify movies.

ATA: You have a book coming out on diversity and complexity. Can you give us a preview of what to expect?

SP: It's a book that should appeal to scientists. It's not an airplane book. It's a book that says—here's how people measure diversity (and variation), and here's how scientists—be they biologists, engineers, or economists—think about the roles that diversity plays in complex systems. For people who want to move beyond metaphor and gain a deeper understanding of how the diversity of species, firms, ideas, and ideologies creates good outcomes (like robustness and resilience) and also bad outcomes (like market crashes and mass extinctions), the book will be worth reading. I recently did a DVD course for The Teaching Company on complexity. This book is a wonderful follow-on to the DVD.

Wayne Hale in Houston's Mission Control Center prior to the launch of STS-92. Credit: NASA

Five Questions for Wayne Hale

July 30, 2010 — Vol. 3, Issue 7

On the eve of his retirement, former space shuttle program manager Wayne Hale looks back on a storied career at NASA.

Since March 2008, Wayne Hale has been the deputy associate administrator for strategic partnerships, responsible for coordinating interagency and intergovernmental partnerships for the Space Mission Operations Directorate at NASA Headquarters. He announced his retirement from NASA effective at the end of July 2010.

Hale began his career with NASA in 1978 as a propulsion officer at the Johnson Space Center, and later became a flight director in Mission Control for 41 space shuttle missions. He held numerous roles in the space shuttle program, including launch integration manager, deputy program manager, and program manager. He has received many honors and awards, including the NASA Space Flight Awareness Leadership Award, the NASA Outstanding Leadership Medal, the NASA Exceptional Service Medal, and numerous NASA Group Achievement Awards.

ASK the Academy: Throughout your career you worked in the shuttle program at just about every conceivable level, from propulsion engineer to flight director to program manager. Which jobs presented the steepest learning curves, and what did you do to get up to speed?

Wayne Hale: The first job that I had coming in as a "fresh-out" from college — trying to learn how to be a flight controller, trying to learn about the space shuttle and its systems, particularly its propulsion system — was a big challenge to me because it was unlike anything I'd ever done academically or with any other part of my career. It's a special culture, a special mindset. You take your engineering background, but you have to put it to use in ways that are completely different in operation than what they teach you in the university.

Fortunately, I was mentored quite a bit by some of the Apollo veterans who were still there in the group in the early days before shuttle. They helped teach us not just the facts, figures, and technical items, but how to think, how to make decisions, and how to communicate those decisions. That was a big change.

I got to be Flight Director, and going from being a person in Mission Control sitting in one of the consoles being responsible for one discipline, to being a Flight Director where you have to understand all 23 different disciplines that are present in the Shuttle Flight Control Room was also a big step. It was like going back to school again. There was so much technical (knowledge), so much rationale behind why things are done the way they're done. It's a huge amount of knowledge you have to amass to be able just to ask the right questions to lead the team toward having a safe and successful shuttle flight.

Then when I made the transition to the Space Shuttle Program Office, first as Launch Integration Manager, then Deputy Program Manager and finally Program Manager, I found out that there were gaping holes in my knowledge base and background, in particular regarding contracts, law, business, accounting, budgeting. All of these were things that for 20 or so years of working for NASA, I had never had to deal with. I had to learn about all of those things in very short order.

So each one of those jobs presented a different challenge, and the only way I know to get through any of those is the same thing that I've done every step of the way, which is to buckle down, and you talk to people who know how to do what you're attempting to do. You get a list of subject matter that you need to study, and you just roll up your sleeves and get after it. And of course you watch the people who are doing it, who are experts, and you ask a lot of questions. At some point you get to spread your wings and see how you can do, and sometimes you soar with the eagles, and sometimes you crash. That's part of the learning experience too.

ATA: You mentioned that you had mentors early on. Who were your mentors? Did you have different mentors at different stages of your career?

WH: I absolutely had different mentors at different stages. At the end game when I was in the program office, having never been in a program office before, Bill Parsons was a great mentor to me. He was the Program Manager. He taught me a tremendous amount about running a big program, about the things I didn't know, the things that I needed to learn. I also learned a lot from Lucy Kranz, who was our procurement/business office manager. In all those parts of my education that were blanks, she helped fill in. A large part of what I know about federal acquisition regulations, contracts, procurement, and how to do budgets comes from Lucy Kranz, who continues to do great work on different programs for the agency.

When I worked in the Flight Directors Office, the boss was Tommy Holloway, who was a master Flight Director. I also learned from some of those who had preceded me, like Chuck Shaw and Ron Dittemore. They were all great mentors to me. Going back to right when I walked in the door, there were several Apollo veterans who were ready, willing, and able to teach young graduates what it meant to work in Mission Control, and what sort of things you needed to prepare yourself for. And of course Gene Kranz was in charge of the organization in those days, and you learned a lot at what we used to call the Gene Kranz School for Boys. He taught us in no uncertain terms what was expected.

ATA: Nearly a year after the Columbia accident, when you were serving as Shuttle Deputy Program Manager, you wrote your team an email (which you reprinted in your blog) that said, "...we dropped the torch through our complacency, our arrogance, self-assurance, sheer stupidity, and through continuing attempts to please everyone." Do you have any thoughts on how large organizations can keep their edge and continue to improve even when they succeed?

WH: The best advice I ever got — Tommy Holloway told us over and over, "You're never as smart as you think you are." If you ever get to the point where you think you've got it under control, you really don't, and you need to be always hungry and looking out for the indications that things aren't going well. It's a difficult thing in a big organization to keep that edge, and it's particularly difficult when things are going well. The shuttle had had a long run of success. I think we flew 87 flights that were all successful in a row.

In particular, the political leadership in charge expected us to do more with less. They kept telling us that the space flight was routine and mature, and that we had solved all the major problems and just needed to not slip up on little things, and that it ought to be easier and faster and less expensive.

The truth of the matter is that with the current state of the art, space flight is extremely difficult. It is fraught with danger because of the high speeds and extreme environments involved. It requires extraordinarily close calculations on the amount of material and the physical structure of the space ship, because mass is at a premium in everything we do.

Wayne Hale (center) with LeRoy Cain (left) and Jeffrey Bantle (right) waiting for the launch of STS-106 in 2000. Credit: NASA

After a while of getting it drummed into your head that, "This is not as hard as you think it is. This is mature technology and a mature vehicle with large margins. We know what we're doing." Even though deep down in your heart you know that's not true, you begin to fall into that trap. I've seen that happen in other industries and other organizations that have had a long run of success. The fact of the matter is that particularly in space flight, you cannot let yourself get arrogant. You cannot think that you've got everything under control. You've got to be vigilant. I think that's true for any kind of high-risk, high-technology kind of endeavor, though it may be true in other fields as well.

A lot of us wish space flight were easier. I do. I wish it were easier and less costly. I wish it were like getting in your car and driving to the grocery store. But it's not there. There are many things in the media where people profess that it is easy, that it should be simple and cheap, and that somehow those folks who are currently in the field have not done a good job, and therefore it's costly and looks hard. I just don't believe that to be true. I believe it's a very difficult thing to do that requires a great deal of dedication and precision. And unfortunately it's not inexpensive at this point in history.

ATA: What are you most proud of from your tenure as shuttle program manager?

WH: The thing that I am most proud of is building a team that has been as successful as it has been in the last five years after we returned the shuttle to flight. Things have been going very well. Being basically I'm a worrier, I worry about things when they're going well, but the team is doing very well because I think they are paying attention to the fundamentals and looking very hard at the symptoms of things that are not going as well as one might wish. So I'm very proud of the team and the culture change that we brought about. You would think that returning the shuttle to flight would be at the top of the list, and it is in some ways, but the thing I'm most proud of is building the team that has been able to carry on and be so successful.

ATA: You mentioned the culture change. I'd like to get your perspective on what it was and what it became.

WH: Again, the culture change had to do with a mindset, an arrogant mindset that basically said, "We have been doing this for so long so well that we know what we're doing. We have got this difficult subject, this difficult environment under control, and we know we can get by with cutting corners because we know there's a lot of margin in the system." The culture change was to take a step back and say, "No, we really don't know." To go back to what Mr. Holloway taught me, we're not as smart as we think we are. This is a very difficult thing to do. The margins everywhere are very small. It's not ordinary, routine, or mature. And therefore we have to take great care with what we do.

And oh, by the way, our political overseers had kept cutting our budget to where we had emaciated our safety and engineering systems. We had to go back and tell them that that just would not do if we intended to fly this vehicle safely. It was going to take the resources to provide the proper oversight and insight, and we were able to convince them of that. And so it goes. I think that was a huge culture change, both for those of us that worked in the program and for those who were outside the program and in positions to make decisions about national resources.

ATA: In your blog, you've shared a lot of "stories from the trenches" of the shuttle program that had not previously seen the light of day. In your first post, you said you wanted to start a conversation. Did the purpose of the blog change over time for you?

WH: The purpose of the blog was outreach, to tell people a little bit about what it takes to fly human beings in space and run a big program, and (share) a little bit of "behind the curtain" of what goes on inside NASA, because I think people are interested. So much of what we at NASA put is what somebody once termed "tight-lipped and technical." Not very interesting, very arcane. This is a human endeavor, and there are people involved in it. The things that happen show us to be frail and mistaken at times, but strong, resolute, and innovative at other times, which is the way it is with people. I've enjoyed sharing some of these stories. Trust me, there are more out there, some of which I may never share (laughs) and some of which I have in mind to share, because it's not just about space flight. It's about people, and how people can rise to the occasion, react under pressure, and do something that is very difficult, with great élan and great pride in what they do.

Scientist-astronaut Edward G. Gibson after exiting Skylab on February 3, 1974. Credit: NASA

It's been a lot of fun. I do get a conversation. We get feedback. People get to make comments and post them. I get to review those comments before they go out, which is an interesting process. I originally thought I'd just approve them all. Then you find out that there are certain features of the Internet where people perhaps are trying to do some things that are not appropriate. You really do have to read them and evaluate whether or not they're appropriate to post. Those that are appropriate have been thoughtful in many cases, and frequently they have brought to mind another topic that I need to discuss. So it has been a conversation.

Jim Crocker on Systems Engineering

September 30, 2010 — Vol. 3, Issue 9

Veteran systems engineer Jim Crocker of Lockheed Martin talks about doing the right things versus doing things right.

James Crocker is widely regarded across the aerospace community as a leading practitioner of systems engineering. At the Lockheed Martin Space Systems Company, he is responsible for space science, planetary exploration, and remote sensing, including programs for the Spitzer and Hubble space telescopes; Defense Meteorological Satellites; International Space Station; Geostationary Operational Environmental Satellites; Mars Odyssey, Reconnaissance Orbiter, Scout; Phoenix; Juno; Jupiter Orbiter; and the GRAIL lunar mission. In the early 1990s, Crocker conceived the idea for the COSTAR system to correct the Hubble's flawed optics.

As director of programs for the Center for Astrophysics at Johns Hopkins University, he led the system design effort for the Advance Camera for Surveys (ACS), a scientific instrument installed in the Hubble Space Telescope in February 2002 that improved the performance of the telescope by an order of magnitude.

As head of the programs office at the Space Telescope Science Institute, Crocker led the team that readied the science ground system for operation of the Hubble Space Telescope through orbital verification and science operations on orbit. Crocker previously designed electronics for scientific experiments on Skylab in support of NASA's Marshall Space Flight Center.

He is the recipient of numerous honors including the Space Telescope Science Institute Outstanding Achievement Award and two NASA Public Service Medals for work on the Hubble Space Telescope.

Crocker spoke with *ASK the Academy* in August about how his career and his reflections on the discipline of system engineering.

ASK the Academy: Hubble has been intertwined throughout your career. What was your first involvement with it?

Jim Crocker: 1983 was the first time I was officially involved. The first time I got a glimpse of something related to it was actually down at Marshall. I was supporting the Marshall Space Flight Center in the mid-1970s, working on Skylab. We were getting to store some spare solar rays in a facility there, and there was this full-size model of this thing called the LST—the Large Space Telescope—and I thought, "Wow, that's cool. I'd like to work on that." Seven or eight years later, I was.

ATA: What was your job?

JC: I was at the Space Telescope Science Institute. AURA (the Association of Universities for Research in Astronomy) had won the science operations contract for Hubble. I was hired to help get the ground system ready, and ended up head of the program office there, getting a lot of the support systems for science operations, guide star systems, and other things ready to go on Hubble.

ATA: You started your career as an electrical engineer. How did you come to be a systems engineer?

JC: Much of my early career—and even today—focused on scientific instruments of one sort or another. When you think about it, Hubble is just one huge scientific instrument. A lot of my career has been focused on instruments, and when you get into building instruments, it drives you into systems

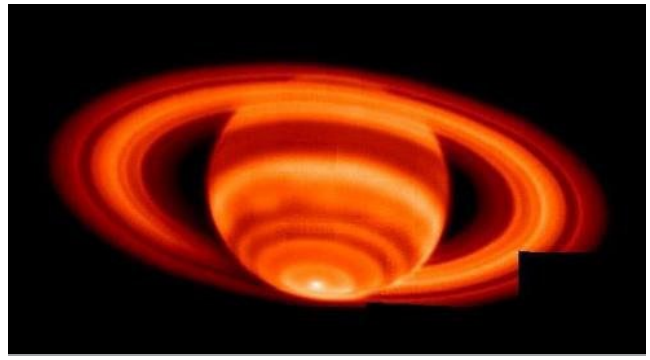


Image of Saturn's temperature emissions taken from the ground by the W.M. Keck I Observatory in Mauna Kea, Hawaii on February 4, 2004. Credit: NASA

engineering. Instruments are usually dominated by electrical engineering and optical engineering, which in most instances is kind of a sub-field of electrical engineering. It's usually taught in the electrical engineering department. As a result of that, you have to know thermal and optics and computers and software and all those ancillary disciplines beyond electrical engineering. It drives you in the direction of systems engineering.

When I went to school, I don't know that there were any formal systems engineering courses. You certainly couldn't get a degree in it. Since electrical engineering had expanded to include hardware and software as major sub-disciplines as well as electro-optics, it was kind of a place that a lot of systems engineers of my generation came out of. I think particularly the exposure to instruments early in my career started pushing me in that direction—at least giving me the background that I needed to do systems engineering.

A lot of the best systems engineers I've seen seem to come out of instrument backgrounds. There's another one (common background) too: a lot of them come off farms. I really think that when you're on a farm, you work on mechanical things and electrical things. Maybe it gives you that "having to understand something about everything" mentality. That's anecdotal, but I think a lot of people would concur with the (value of an) instrument background, because of the broad discipline scope that you have to have and the opportunity to do that. They're usually small enough where you can get your arms around the whole thing. It makes a great training ground for systems engineers.

ATA: You've said that a systems engineer has to have broad knowledge. How did you broaden your own knowledge base over time?

JC: It goes back to instruments. I'd been driven in the instrument arena to learn about these other disciplines. Once you get to a certain level of proficiency, it allows you to go deeper into a subject. I know when I was at the Space Telescope Science Institute, for example, part of my responsibility was being the liaison between the scientists at the institute and the engineering teams around the country who were building the instruments for the telescope. While I was familiar with optics from a cursory point of view, doing instruments for the Hubble

Space Telescope, where the optics were very complicated, very precise, and very large—that gave me the opportunity to broaden my understanding of optics, and it forced me to take some more formal coursework beyond the cursory coursework I'd done in college. That sparked a lot of my interest in larger optical systems, and because of that, I ended up going over to Europe with Riccardo Giacconi, who was the director of the Space Telescope Science Institute, when he went over to run the European Southern Observatory, where they were building four ground-based eight-meter telescopes.

It's not just depth. You go broad, and then you go deep. And then you go broader in another area, and then you go deep. It's very easy today just to continue going deeper and deeper in a narrower and narrower niche. To get out of that, you have to go broader, and then as you go broader you go deep, and then you find another area to go broad in again. It's a combination of expanding your knowledge about things and then going fairly deep into them.

Systems engineering is not just knowing the theory behind something. The real trick as you mature in these areas—the "going deep" part—is understanding how things are fabricated, what the risk in fabrication is. In optics, for example, you learn all about optical coatings and all the idiosyncrasies about how these coatings perform, how they get damaged and are not quite up to spec, and what in the process causes that. As you learn these things, it allows you to design systems that have more resilience. When you don't have at least an understanding of where the real challenges are, you'll design something that can't be built. You have to know enough to know what to stay away from, and what can and can't be done.

ATA: It's true of residential architects too.

JC: That's exactly the point. I use a lot of analogies to residential architects because people understand architecture and can relate to the fact that you have an architect and a builder. Systems engineering has this architectural part and this building part. Peter Drucker said it's more important to be doing the right thing than to be doing things right. Of course in our field, we have to do them both right, but Drucker's point was that it doesn't matter how well you do the wrong thing. A lot of my career in systems engineering has been focused on the architectural part—getting the thing conceived so that the end user gets what he or she expected.

ATA: What's an example of making sure you're asking the right question?

JC: I think we as a community are going through something right now that's relevant to that question. It has to do with cost and affordability. When I went over to ESA (the European Space Agency) and did a program review with Riccardo (Giacconi) to understand where this multi-billion dollar ground-based telescope program was—this was to build four enormous telescopes that were optically phased together, something that had really never been done before—I came to understand something at the end of the review. I said (to the team), "Let me tell you what I heard you say. What you said is that you are building the most wonderful, phenomenal observatory in the history of man, better than anything else in history, regardless of how long it takes or how much it costs." And they said, "Yeah, that's exactly what we're doing." I said, "Well, we have a problem then, because there's only so much time and so much money. On the time part, if we don't get this telescope built here on this new schedule that we're laying out, the Keck Telescope that the U.S. is building and others—the Gemini—their scientists will skim the cream. Theirs may not be as good as yours, but they will skim the cream. And there's only so much money. So we have to build the best telescope that's ever been built, but within the cost and schedule that circumstances are going to allow us to do, because getting there late is going to mean we're not going to be the first to do the science." That was a real paradigm change for everybody, and understanding that really led us to a place where we did come in within a few months of our schedule and right on our cost. It was a big paradigm change.

I think we're going through something similar to that now. Certainly in NASA programs, and I think in DOD programs as well. We've had this emphasis on schedule and now on cost. The thing I worry about—and here it gets into "make sure you're doing the right thing." In the "Faster, Better, Cheaper" era, people got focused on cost and schedule, but they missed the fact that what was increasing was risk. There was not a clear communication about what the real problem was, and because of that lack of clarity about understanding the right problem, what actually happened was we pushed the cost performance to a point that was so low that the missions started to fail and we weren't able to articulate what we were trying to solve. People thought we were just continually trying to do cheaper, cheaper, cheaper. Einstein said you should make things as simple as possible, but not simpler. My twist on that was that you should make things as cheap as possible, but not cheaper. Because of that, we got into mission failures across the industry as we pushed below a point while not clearly articulating what the problem was other than "Well, let's make it cheaper." It went off the cliff.

As we get into this next reincarnation of this cycle that we go through, we have to do a much better job of articulating the problem and knowing what it is we're trying to achieve. What we're trying to avoid here really is overruns—the unpredictability of a lot of our programs. We get into situations where not one but a large number of programs overrun. I'm not sure the desire is really to do it cheaper. It's certainly not to do it cheaper than possible. It's to do it predictably—both on cost and schedule—and still have mission success. At the end of the day, if you do it faster and cheaper and the mission fails, you've really wasted the money. So it's important to make sure this time that we've really understood what we're trying to accomplish and articulated it well, so that we can all be solving the right problem.

Remember the game "Telephone," when you were a kid, where you whisper something in somebody's ear? You go through ten or fifteen people and it comes out the other side, and you wonder, "Where did that happen?" What's fun is to go along the way and get people to write down what they've heard. You go back and you see where these things get very slightly changed from person to person, and it's totally different at the end.

Delta II rocket carries Kepler spacecraft into space on March 6, 2009. Credit: NASA/ Regina Mitchell-Ryall, Tom Ferrar

In companies the size of ours (Lockheed Martin) and in agencies the size of NASA, when we try and communicate some of these really challenging goals, the ability to really crisply and clearly articulate the problem we're trying to solve is enormously important. It's how we go wrong and end up in a ditch.

ATA: Your point about predictability is interesting. What we're trying to do is say we can reliably deliver on the cost and schedule that was promised at the baseline.

JC: That's right. We get into this thing of "We have to do it cheaper," and we've already started to miscommunicate.

In some instances, that's not true. Today if you look at the launch vehicle situation and the retirement of the Delta II, if we continue doing business the way we've been doing business, right now there's just not a Delta II class vehicle available, so you either have to go much smaller (Minotaur) or much larger (Atlas). So people say launch costs are unaffordable. That's true, but it doesn't necessarily mean you need a cheaper launch vehicle. It could mean you need to do more dual launches with a bigger launch vehicle. That has its own problems. Or maybe we can figure out how to do missions on smaller buses with smaller payloads and fly them on smaller vehicles. It's just so important in systems engineering to understand and be able to communicate to everybody what the problem is that you're trying to solve.

I think Dan Goldin's "Faster, Better, Cheaper," which everybody thinks was not successful, actually was successful. Dan said we're going to do more missions, they're going to cost less, we're going to have more failures, but at the end of the day we'll have done more with the money than otherwise. He said, "I think as many as three of ten could fail." Three of ten failed. If you go back and look, we did the other missions for less money with that approach. Two things happened. One, I don't think we had the buy-in of everyone involved, and we didn't properly communicate expectations. Two, we got into this thing where we might not have had any failures if people had understood where to stop, and that had been clearly communicated.

That's why I say it's important as we articulate where we're going this time that we understand is it "cheaper, cheaper, cheaper until we break," or do we want predictability so we can plan to do things right with no surprises?

ATA: What are the signs that you might not be working on the right question?

JC: I don't know who invented Management by Walking Around.

ATA: I've heard it was Hewlett and Packard.

JC: I've heard that too. I don't know if it's anecdotal or true. I think it was actually Packard who was the MBWA person. I certainly learned early in my career that as a systems engineer responsible for the architecture, getting around to the people who are flowing the requirements down to low-level systems and actually going as far down the path as you can and talking to people about what they're doing and what their objectives are and having them explain them to you is really the proof in the pudding. There are two pieces to this. One is you have to do the right thing, and then it gets distorted because of the "Telephone" effect. That's where going down and talking to people who are doing critical subsystem design—just talking them to make absolutely sure that you understand that they understand what the essence of this thing is all about. That's number one.

The second one is really making sure at the front end that you understand and you can communicate and have somebody tell you back at the high level what they thought you heard. Then you really have to capture that in the requirements. I'll use Faster Better Cheaper again as an example. Goldin said, "We're going to do this," but I don't think he articulated it well enough to get it into requirements. It's that first translation step into DOORS where you have to make sure that what got into DOORS, what got into the requirements database, really does the high-level thing that you want to accomplish.

There's really a third component too. We have a tendency in our business not to understand who the real true end-user is. Certainly we don't spend as much time as we often should really deeply understanding their needs operationally. This feedback of testing what you're going to accomplish with the end user is critical. That's a problem because you don't speak the same language that they do. One of the things that we (Lockheed Martin) actually do here in our Denver operations is really interesting. We actually have people who rotate through all the life cycles of a project. They might start a program in the proposal phase, and then many of those people will end up in the implementation and the design phase (and go) all the way into the assembly, test, and launch. And then, since we fly missions as well, they'll go in and fly the mission. That's where you see the light bulb go on in somebody's head when they say, "I'll never do that again." It really feeds back into the front of the design, and it makes people have a very rich understanding. A lot of times when we as systems engineers haven't had the experience of actually operating some of the systems that we build, we just don't know any better.

If you've ever changed the oil on a car, you sometimes ask yourself how the engineer could have been so stupid to put the oil filter where it is. It seems like it's just impossible to get to sometimes without pulling the engine. (Laughs.) But then you go back as the engineer, and you realize he probably didn't have visibility into the fact that a wheel strut was going to block access to the oil filter. So it's only when you've been there trying to change the oil filter that you really understand that you need to know about more than just the engine to decide where to place the oil filter. That's an important aspect of it too.

I think those three things, if you exercise them, can help you know that you're not doing the wrong thing.

Knowledge Briefs

From the X-15 to the Shuttle

March 31, 2010 — Vol. 3, Issue 3

The X-15 yielded valuable information for the development of the space shuttle, according to Major General Joe Engle, the only pilot to fly both vehicles.

Thirty-one-year-old Joe Engle looked to his left to see the oblique side of the B-52 carrying him inside the X-15 rocket plane. He flipped a switch to release cold nitrogen gas into the cockpit (a precaution for fire hazards) one minute before launch. When the seconds ticked down to zero, he released himself from the underside of the B-52's wing, hit the throttle and flipped each of the eight switches on the left-hand-side of the cockpit to ignite the engines, slamming his body back against his chair with 2gs of force.

Joe Engle standing next to the X-15-2 rocket plane in 1965. Image Credit: NASA

For the next 87 seconds the engines powered the 50-foot-long X-15 rocket plane before shutting down. The plane then soared out of Earth's atmosphere and into space. After a few minutes of weightlessness, Engle repositioned the plane to enter the atmosphere at just the right angle to avoid skipping off the top of the atmosphere like a rock across water. The rest of the flight was a sustained glide.

He looked out his windows to guide his landing into the dry lakebed at Edwards Air Force Base, and jerked the landing gear lever with the 20 pounds of required force to release the skids at the back of the plane. The skids touched down at speeds of 200 miles per hour, followed by the nose of the aircraft.

"It was a really ugly thing," recalled Engle, speaking before a crowd in the auditorium at NASA Headquarters in February. "You just kind of made sure that your teeth were together when the nose started down. It was a pretty good smack."

The entire flight lasted a total of ten minutes. "From launch to touchdown, I can remember flights...where I would be sliding to a stop, and I would be thinking, 'What happened? What did I just do?'" Engle broke the sound barrier sixteen times, and in 1965 he became the youngest person to receive his astronaut wings. Twelve years later, he commanded the second test-flight of the space shuttle Enterprise, and went on to command STS-2 and STS-51I, clocking a total of 224 hours in space.

The X-15 was the last in a series of X-planes designed in the 1940s and 1950s that shattered the existing boundaries of flight. Unlike earlier planes starting with the X-1, which focused solely on speed, the X-15's objectives included both altitude and speed. It was a collaborative effort among the Air Force, Navy, and the newly formed NASA. "If I didn't look at badges, I would not know who anybody worked for on that program," Engle said. "It was that kind of operation."

At the dawn of the age of space flight, the aerodynamic heating loads that the plane experienced were of particular interest to engineers. As the X-15 reentered the atmosphere, it increased in length by over three inches. During the expansion, "it [sounded] like someone is banging against the side of the plane with a sledgehammer....The old guys wouldn't tell you about that," laughed Engle. "They'd let you learn that on your own." The X-15 also informed designers about flight control systems for re-entry. In space, the X-15 could fly right-side-up or upside-down. Upon re-entry, however, flight positioning was critical — otherwise the plane would skip in and out of the atmosphere. (The longest X-15 flight was flown by Neil Armstrong, whose plane experienced skipping. He recovered control and was able to make a successful landing 45 miles south of Edwards.)

When designing the X-15, explained Engle, engineers thought that there would be "a magic altitude where you'll want to quit flying with the aerodynamic surfaces and start flying with the reaction controls." They estimated this would happen around 240,000 to 250,000 feet. The engineers tasked the pilots with determining where this magic altitude was during their flights as they left and re-entered the atmosphere.

Some pilots had a smooth transition between the two systems, while others didn't. For a long time, pilots and engineers thought that it had to do with the way that the plane was rigged, but this wasn't case. It turned out that there was no magic altitude — the atmosphere is gradual. "We learned that a blended adaptive flight control system really is…necessary for an entry from space back into the atmosphere." The shuttle today uses a flight control system similar in design to the one on the X-15.

Another important lesson learned from the X-15 program was having a chaser airplane following to assist with the glide and landing. The chase plane used for the shuttle during re-entry tells the shuttle crew how high above the ground its wheels are. Engle said that compared to the shuttle, the X-15 felt like sliding back down to Earth on a skateboard.

Finally, knowledge from the X-15 about energy management — balancing the right amount of energy and speed to land the aircraft in the correct place — informed the development of the shuttle. "People didn't think we could land the shuttle without a bit of powered flight," said Engle. Some engineers were concerned about the lift-to-drag ratio on the shuttle, so they designed an engine that would rise out of the payload area (taking up one-third of the bay) to power the shuttle to the ground. Fortunately for the payload people, remarked Engle, the engine never flew. The re-entry flight patterns for both the X-15 and shuttle are nearly identical — and un-powered.

The X-15 program ended in 1968 after 199 flights. To this day, it is considered to be one of the most successful flight research programs in the history of aviation. "I feel so fortunate to be a part of that time," said Engle.

OCO-2 Gets Underway

April 26, 2010 — Vol. 3, Issue 4

The Orbiting Carbon Observatory team is applying lessons learned in a unique way after getting a rare second chance to fly.

The early morning of February 24, 2009 was cold, wet, and beautiful. Patrick Guske, Mission Operations System Engineer for the Orbiting Carbon Observatory (OCO), sat in the Orbital Sciences Mission Operations Center in Dulles, Virginia. On a big screen, he saw the Taurus XL rocket rumble away from ground at Vandenberg Air Force Base in California. The rocket carried OCO successfully into the air with a bright blue streak trailing behind it—but not for long.

Taurus XL launch of OCO at 1:55AM PST from Vandenberg Air Force Base, California. Credit: US Air Force photos/Airman 1st Class Andrew Lee

OCO came down much sooner than anyone expected. "I [saw] people starting to get a little nervous," Guske recalled. "Then they got very nervous. Then they got very quiet." OCO had missed its injection orbit and plunged into Antarctic waters.

The OCO team later learned that during ascent, the payload fairing (the nose-cone covering that protects the satellite as it goes through the atmosphere) failed to separate from the launch vehicle. The additional weight prevented the final stage from boosting OCO into the injection orbit.

Guske had planned to stay at the Dulles site for two weeks. He boarded a plane to California in a matter of hours.

The Mission

OCO was an Earth System Science Pathfinder project run by the Jet Propulsion Laboratory (JPL). Its mission was to make precise, time-dependent global measurements of atmospheric carbon dioxide (CO2) that would help scientists better understand the processes that regulate atmospheric CO2 and its role in the carbon cycle. The observatory had three high resolution spectrometers dedicated to measuring Earth's carbon dioxide levels.

Scientists know that carbon dioxide from humans and natural processes is absorbed into "sinks," like the ocean and growing plants. "But we know that we have put more carbon dioxide into the atmosphere than we see," said Guske, "and we're not sure where all of this carbon dioxide is going. How is it being absorbed and where? Are there seasonal variations?" While OCO didn't have the opportunity to answer these questions, OCO-2 can.

OCO-2 will follow OCO's original plan. It will join the Afternoon Constellation (A-Train), a track formation of six satellites orbiting Earth and studying various aspects of Earth's natural systems. OCO-2 will compare its data with measurements from other instruments and observe daily and seasonal variations of atmospheric carbon dioxide.

"We have met the customer and he is us."

Within 24 hours after the launch failure, project closeout for OCO began. This included capturing lessons learned, a process that is often treated as a pro forma activity resulting in "lessons listed." Though no one knew it at the time, this had a different significance for OCO, because unlike most missions, it would ultimately get a second chance to fly.

Guske led the OCO lessons learned effort. He thought it was important to consider the people who would be reading the document his team was charged with creating. With cartoonist Walt Kelly in mind, Guske said, "We have met the customer and he is us."

"We wrote these lessons learned to ourselves because we're going to use these lessons learned," said Guske. The lessons had to be written so the team could understand them. "There is a difference between how we dealt with lessons learned on this project, OCO, and how other missions deal with their lessons learned," he added. For OCO, the lessoned learned would be active, not passive

From Listed to Learned

The process began with Guske sending out an email to everyone on the team: engineers, scientists, contractors, librarians, and secretaries. He asked for feedback regarding what worked and what didn't. When the responses came back he sorted through all of them to generate a streamlined list.

In total, Guske collected 78 lessons learned. Lessons ranged from secretaries asking that team lists be kept up to date to larger programmatic issues such as sorting out lines of authority and clearly defining deliverables. At their simplest, each lesson met three specific criteria: it was positive, didn't point fingers, and offered a solution to a problem. Guske welcomed all of the feedback – the good and the bad – and evaluated each of the lessons based on these criteria and how they would affect the team for the next time around.

During this process, Guske emphasized the dangers of "better is the enemy of good enough." The team wanted to avoid any attempt to make the spacecraft "better"—they wanted OCO-2 to be as close to the original as possible. Changes were considered only if improvements would reduce risk, or if components didn't have spares or had become obsolete. For the most part, OCO-2 is a near-clone of OCO.

Guske assigned each member of the OCO team specific lessons to implement when rebuilding the observatory. He also began documenting the implementation of the lessons learned effort, with the intention of conducting a post-launch evaluation of the effectiveness of the process.

Testing

One of the lessons the OCO team learned had to do with testing. Given the mission's low cost and compressed schedule, the team decided not to test the instrument detectors in flight-like conditions, instead accepting the detector screening done by the vendors. However, the screening processes did not mimic the operational use of the detectors.

After integrating the instrument and putting it into the thermal vacuum chamber, the team discovered a problem: the instrument had a residual image. The effect is similar to the bright spot you see after someone takes your picture with a flash, explained Guske. Faced with two choices—replace the detector or correct for the anomaly—the team decided to develop an algorithm that would correct for the residual image.

This time around, the OCO-2 instrument manager had time and money to test the detectors in flight-like conditions. By screening the detectors ahead of time, the team will know if there are any problems.

Transfer

Another lesson learned by the OCO team related to data transfer. While testing the observatory in the thermal vacuum chamber, the mission operations team in Dulles, Virginia, downloaded raw data from the instrument in three gigabyte-sized files (one for each spectrometer). It then had to send the data to JPL, which had responsibility for analyzing the data, but the JPL team couldn't receive it because of security firewalls at each location.

Since this problem cropped up late in the schedule, the solution the OCO team developed involved transporting the data on portable hard drives back and forth on commercial air flights. Although it was slow and inefficient, this fixed the problem for the time.

At one point, when the OCO team was asked to remove the observatory from the thermal vacuum chamber, it was hesitant to do so because it had not received and analyzed all of its instrument data (which was on a plane somewhere over the United States). There was the possibility that the team would not have all of the measurements needed for fully assessing the instrument and its operation.

The team went ahead and removed OCO from the chamber without the data. When the data did arrive, it was incomplete. Fortunately, the OCO team was able to reconstruct the necessary dataset using an ambient temperature chamber. Despite this successful mitigation, however, the OCO team added this experience to its lessons learned. For now, the team has discarded air travel as a method of data transfer and is exploring more efficient options.

Getting to Fly... Again

OCO made it to launch. Its design was mature and approved for flight. Since OCO-2 is nearly identical, the team has been granted what Guske called a "free pass" on reviews before their Critical Design Review in August. The Project is conducting a "tailored formulation phase" to ensure the updated OCO-2 is developed correctly and completely.

The team is still holding peer reviews for a few interface changes that resulted due to a lack of spare parts, but on the whole they are "just making sure things fit together and flow together," according to Guske.

The OCO-2 team will track the status of each of the 78 lessons learned. Guske said he believes the process is going well, and he looks forward to evaluating the process in hindsight after the launch in February 2013. "We're doing it," he said. "People have the battle scars to show the lessons they have learned, and they're getting to implement those changes now."

Goddard Hosts "All Things KM" Forum

August 31, 2010 — Vol. 3, Issue 8

Before Google, if you had to find out if a whale has a spleen, how many phone calls would it have taken?

The question above is known as the "whale spleen problem." Try to answer it. Who would you call? An aquarium? A university? The point is that the ability to find the knowledge to solve a problem, run a program, or build a team is vital to organizational success. This was the topic of a two-day forum on knowledge management hosted by the Office of the Chief Knowledge Officer at Goddard Space Flight Center (GSFC).

From an 8,000-pound balloon payload dragging through a line of parked cars to an oil well hemorrhaging crude into the ocean, government and industry participants shared stories, lessons and insights on the importance of managing knowledge. As one attendee put it, knowledge management is the lifeblood of organizations—without it, survival is tenuous. But this is not always apparent.

Orlando Figueroa, GSFC Deputy Center Director for Science and Technology, opened the forum by discussing the importance of support from leadership for knowledge management. Leadership support is growing at Goddard with continued efforts to host forums, storytelling events, and wikis. The support of leadership is a strong indicator of successful knowledge management, said Dr. Ed Rogers, Goddard's Chief Knowledge Officer. When the leadership knows who you are and directs project managers to you, you know you're doing your job and having an impact.

The forum also featured external perspectives from Raj Datta, MindTree Consulting; Kent Greenes, Greenes Consulting; Brian Hackett, Apex Performance; and Rob Johnston, Chief of the Lessons Learned Program at the Central Intelligence Agency (CIA). Politics, change, the pace of work, and resources all influence a program's success within an organization, but leadership support is vital. At the CIA, according to Johnston, the lessons learned program went through several iterations before succeeding. Johnston attributed their success largely to the support of the leadership within the organization. Greenes has observed that successful knowledge programs show, celebrate, and demand the impact of what they are doing. But most importantly, he said, successful programs keep knowledge management on the leadership's agenda.

Doug McLennan, Beth Keer, Sandra Cauffman, and Bob Menrad of GSFC's Flight Projects Directorate shared insights about success, failure, and learning. All agreed that listening to others and self-assessments are essential to the learning process. These activities are always works in progress, noted Cauffman. To this day, Menrad revisits the work of his mentors. Learning also involves being wrong and humbled. When McLennan left working in the lab, he was convinced that managing the technical knowledge would be the hard part, he recalled. Wrong.

"Every problem you're going to run into will have to do with people," he said, "but you also have to realize all of your successes will be because of people."

Other presenters included Jon Verville, who is leading the wiki movement at GSFC; Michelle Thaller, Assistant Director for Science Communication and Higher Education, who offered insights about how knowledge circulates in the world of scientists; Peter Hughes, GSFC Chief Technology Officer, who discussed the knowledge coordination across center technology offices; Steve Denning, author of several books on knowledge management, who discussed radical management principles for keeping knowledge management on the agenda; and Jay Pittman, Chief of Range and Mission Management Office at Wallops Flight Facility, who spoke about organizational silence.

Larry Prusak, Editor-in-Chief of ASK Magazine, moderated the final panel, which included Adrian Gardner, Chief Information Officer at GSFC, Robin Dixon, GSFC Library Director, and Mark Goans of the Systems Review Office. The panel discussed the use and expansion of embedded "knowledge medics" on project teams. These individuals, who could be librarians or information officers, would fit in seamlessly with the team and function to fill knowledge gaps.

The forum closed with a trip to the Goddard Visitor Center to see the "Science on a Sphere" exhibit and reflect on the forum's discussions. A common sentiment was that knowledge management, while critical to organizations, is passed off as a supplement for success. In order for an organization to thrive, knowledge cannot be static, whether the work is launching rockets, selling computers, or drilling oil.

Knowledge Forum Focuses on Project Effectiveness

May 28, 2010 — Vol. 3, Issue 5

The Academy's second Knowledge Forum addressed how organizations acquire and transfer the knowledge they need to staff successful projects.

The Academy convened a global group of knowledge experts from government, academia, and industry to share insights and stories about knowledge sharing during the Academy's second Knowledge Forum, which was hosted by MITRE on Thursday, April 22, 2010 in San Diego, California.

The forum opened with a discussion led by Paul Adler, professor at the Marshall School of Business at the University of Southern California, about defining communities to better understand the ways in which project organizations can continue to thrive and innovate. Participants agreed that communities share a vision, purpose, or identity in addition to a common language, commitment, and information. Some communities are traditional (e.g. religious), while others are more innovative (e.g., scientific).

"Traditional forms of communities are antithetical to innovation," said Adler. "There is a very distinct type of community that encourages innovation." Adler emphasized that traditional communities have their place, but "if you want an organization in which innovation is a crucial performance outcome, you need to be looking carefully at the possibility that the traditional community is hampering your progress," he said.

The type of community affects how organizations staff projects with knowledge and talent. The forum explored how organizations tend to staff projects with people with whom they are familiar. "The majority is done by relationships," said Vic Gulas, senior advisor and former Chief People and Knowledge Officer for MWH Global. "There may actually be a better person out there, but… there's an element of this trust concept that [someone has] delivered and they'll deliver again that is a huge bias."

Ed Rogers, Chief Knowledge Officer at Goddard Space Flight Center, said that this practice is common at his center. "The question isn't always the knowledge. It's 'I want Joe on my team' or 'I want Sally on my team,'" explained Rogers, but "it shouldn't matter what engineer is matrixed to your group…. It's not 'You get Sally,' [it should be] 'You get the electrical engineering branch's knowledge applied to your project.'"

David Coomber, Director of Operations at MITRE, explained that his organization is structured to support staffing the appropriate knowledge on projects. They use web-based tools to navigate networks of knowledge within the organization, and have integration directors who search

From left to right: Jo Spencer, Director of Communications and Partner Relations for the International Center for Complex Project Management; Paul Adler, professor at the Marshal School of Business at the University of Southern California; and Ed Rogers, Chief Knowledge Officer at Goddard Space Flight Center. Credit: NASA APPEL

Forum attendees converse during a break. Credit: NASA APPEL

for knowledge outside of typical networks and integrate it. "If I know I need talent in a certain area, I'll go to them," said Coomber.

Communication and transfer of knowledge is often treated as a simple task, said Nancy Dixon, Principle Researcher for Common Knowledge Associates. She emphasized the importance of understanding the customer, and noted the shift in organizations towards "pull" mechanisms for knowledge through the use of systems like wikis. At the same time, she cautioned that, "You can only learn from a pull mechanism if you know what you don't know."

The customers for the knowledge should have the greatest say in what the knowledge looks like in the end, said Kent Greenes, CEO of Greenes Consulting. He shared that while working at British Petroleum, the importance of spending time in the environment of the customer played a large role in understanding how knowledge transfers within an organization.

While motivation is certainly a necessary driver for knowledge transfer, it cannot be done without resources and the support of leadership. "It's not always money. It's people," said Hal Bell, Director of NASA's Advanced Planning and Analysis Division in the Office of the Chief Engineer. "It takes management and commitment to make these discussions happen. It's all too easy to get caught up in the here, now and today, and not five years down the road."

The one-day forum concluded with discussion about developing the next generation of workers. While change takes time, participants agreed, it is important to facilitate change by inviting younger workers to participate in knowledge conversations and make them feel like the custodians of knowledge. They are the ones who will inherit the decisions made by today's generation of knowledge managers.

Organizations expecting to thrive cannot close themselves to outside knowledge, remarked Larry Prusak, Editor in Chief of ASK Magazine. "The world is too complex," said Prusak. "No one can possibly know everything. The world will beat you in the end."

NASA Co-Hosts Third Knowledge Forum with ETS

October 29, 2010 — Vol. 3, Issue 10

The third event in the Academy's Knowledge Forum series addressed building and managing knowledge networks.

The Academy convened a global group of knowledge experts from government, academia, and industry to share insights and stories about knowledge sharing during the Academy's third Knowledge Forum. The event was co-hosted by the Educational Testing Service (ETS) on Tuesday, September 21, 2010 in Princeton, New Jersey.

"A crowd is not a network" began T.J. Elliott, Chief Learning Officer at ETS. Simply connecting members in a crowd is insufficient for sharing and synergizing knowledge in networks. Most of the information that we care about is difficult to index and not all that obvious, he pointed out. Quoting authors John Seely Brown and Paul Duguid, he said, "It is not shared stories or shared information so much as shared interpretation that binds people together."

NASA APPEL Knowledge Forum attendees discuss building networks. Photo Credit: NASA

Accomplishing a shared interpretation relies heavily upon building trust, said Emma Antunes, Web manager at Goddard Space Flight Center. She added that connections and collaborations are not the same. "Networks are me-centric," continued Antunes. "A community has more of a sense of ownership, we-centric." Organizations have to trust people and empower them to develop both. This trust originates from and grows with transparency, which is a matter of "matching what I say with what I do," according to Antunes.

"People want to help out," added Jeanne Holm, Chief Knowledge Architect at the Jet Propulsion Laboratory, who is currently serving as communications and collaborations lead for DATA.GOV. "Join the community and share what you know versus joining the community to find friends and connect with them." Trust, tasks, and talent play significant roles in maintaining a network, she said.

Determining the work and making it explicit is also key to the success of a network, said Daniel Wilson of the Harvard Graduate School of Education. The work of a social network or a terrorist network is well defined, but what is the work of a knowledge or learning network? According to Wilson, these networks have three components: transmission, transaction, and transformation. Transmission is similar to what Facebook users do on their "walls," explained Wilson: they broadcast lots of information through posts. Transaction occurs when a conversation begins. Transformation is where we are failing, he said, and will be the focus for improvement over the next decade.

Naoki Ogiwara, Senior Consultant of Knowledge Management at Fuji Xerox, shared how his organization is creating physical spaces and environments for network building. These spaces, explained Ogiwara, are designed to enable employees to build and share social and intellectual networks related to topics such as sustainability or innovation.

The impact social media tools are having on organizational structure has triggered a shift. "I think traditional hierarchies are finished," said Larry Prusak, Editor in Chief of ASK Magazine, suggesting that organizations are crumbling under the weight of their own hierarchies.

Klaus Tilmes, advisor to the World Bank, expressed concern about data overload. Communities are becoming accustomed to "throwing data over the fence and expecting people to do something with it," he said. There must be a purpose behind the data flowing through networks. He provided the successful stories of the emergency response community, where social networks facilitate rapid circulation of up-to-date information.

For Rich Roberts, Senior Research Scientist at ETS, personality is among the most important factors to having a successful network, especially for teams. Successful networks consist of individuals who have a good work ethic, practice effective communication, and are agreeable, emotionally stable, and open to new experiences. If you're going to have a healthy kind of network…personality is one of the best predictors of outcomes," he said.

At the end of the day, forum attendees each received a large Post-It® the size of a flip chart and a felt-tipped marker so they could respond to the following questions:

- When you look for new ideas, to whom do you turn and what tools (if any) do you use?
- When you have something to share, with whom do you share and how do you share it?
- When you need to solve a problem, to whom do you turn and what tools do you use?

Knowledge Forum participants put pen to paper and draw out their knowledge networks. Photo Credit: NASA

Participants were asked to visually represent their answers on paper. Everyone was given ten minutes before all the charts were displayed on the walls for everyone to view and compare. Walking around the room, participants immediately noticed that no two drawings looked alike. Some 30-plus participants had visualized and drawn their go-to knowledge network differently.

On a majority of the posters, social media figured prominently as a source or tool for finding or sharing new ideas. Many participants said that the depiction of their network depended on the topic or question. Upon reflection, many agreed that an important consideration for tapping into knowledge networks is the approachability of people within a network. As people become more accessible and more findable, the issue of privacy rears its head.

Jay Pittman on the "Anatomy of a Dragon"

October 29, 2010 — Vol. 3, Issue 10

A twelve-year-old accident serves as a constant reminder that "there be dragons" in NASA projects.

In 1998, a commercial jet approached the research runway at the Wallops Flight Facility to perform an engine water ingestion test. This test was supposed to be routine—just like the many that had come before it. All jet-powered aircraft designs flown in the United States are required to pass it. However, this particular test, the eleventh run in a planned series of twenty, did not end like its predecessors.

The plane approached the flat runway, which had a pool of water strategically placed for the plane to land in. Manned, high-speed cameras surrounded the area to capture the imagery for later analysis. As the plane touched down, a crosswind caused the plane to swerve and flip over—just missing a cameraman. The aircraft burst into flames, destroying a nearby support vehicle. Miraculously, no one was hurt.

Later review showed that the test that day was not, in fact, business as usual. The operations team had made a series of small changes to the planned procedures. The puddle's position on the runway moved several times. The cameramen were repositioned for a better shot. No one openly questioned these seemingly harmless changes for what was perceived as a routine operation.

"To this day, [that incident] marks my standard of worry," said Jay Pittman, Chief of the Range and Mission Management Office at Wallops. For nearly a decade, he has been responsible for granting flight permission at Wallops. Worrying about risk is his job, and he takes great care to remain cognizant of it.

"There comes a comfort level with things that you've done before, and that can be a dangerous thing," said Pittman, who was not part of the team involved in the incident that day. "I don't believe that there was a specific instance of intentional negligence on the part of the team that oversaw what ended up being a disastrous event, but there was a slow and silent accumulation of a number of things." What seemed like very small additional requirements and unreviewed changes added up to a dramatic change that brought new risks, explained Pittman.

Aerial photograph of Wallops Island. Photo Credit: NASA

As a leader, Pittman wanted to be able to convey to his teams the seriousness and helplessness that emerges when conducting risky missions—even the ones that seem routine. To him, risk looks like a dragon. "The dragon for me is this notion of quiet risk that accumulates into a critical mass and then explodes in your face."

This metaphor of a dragon comes from the story The Hobbit. Pittman recalled the fear of the residents who live below Smaug, the dragon, who inhabits the Lonely Mountain above. When living in such an area, argues Pittman, how can you not factor in the risk a dragon imposes on your daily life?

For Pittman, the anatomy of the dragon includes a number of elements. Number one, he said, is complexity. "Don't tell me that you've done [something] before. Everything we do has incredible complexity, and it's ludicrous for us to say that it's not."

Schedule and cost pressure are also omnipresent. Congress, NASA leadership, the mission directorates, and the public all want to see a final product, a mission. The pressure to make everyone happy is immense.

There is also the feeling of being 100 percent a part of a team, which is good, said Pittman, but there can also be a downside to this. "That means there's pressure not to be the stick in the mud," said Pittman. "You don't want to be the person who says, 'I'm not really comfortable. I'm not sure this will work. I'm not really sure this is the same as last time.'"

"Nothing is the same as last time because today is a different day," said Pittman. He looks for the uniqueness in each of his projects, particularly the ones that seem routine. It's too easy to be lulled by paperwork and checklists. During reviews, Pittman makes sure that he invites people who have never seen the project to every mission review panel. "It's the fresh eyes that keep us from doing truly stupid things that you could just drift into little by little."

He also emphasizes learning lessons rather than listing them. He thinks of lessons learned as actionable tasks that act as liens against projects. "If we haven't turned it into something real, then that lesson learned from some mission long ago is a lien against future missions." This generates what he calls "reasoned assessments" of why it's OK to keep going in spite of the lien. They keep the team ready in spite of a challenge, he explained. "It's that reasoned assessment that goes missing when we become comfortable."

Pittman offered his final thoughts on risk.

"Sometimes the leadership, managers like me, are too far removed from what is really going on. Sometimes everybody knows the real story except for the leader. It's the job of a leader is to find a way to make public what 'everybody knows.'" He offered a few examples of those types of things:

Everybody knows…
- What almost hurt someone last time.
- Who doesn't get along and how that affects communication.
- How stuff really happens and what rules to follow.
- What really went wrong.
- What almost went wrong.
- Lessons learned equals lessons listed.
- Places that don't get seen during audits.
- The checklist doesn't matter, the checkers do.
- Organizations don't fix problems, people do.
- Which managers you can go to…and which ones you can't.

Despite the risks that come with NASA missions, the NASA workforce certainly has something to be proud of, added Pittman. "We do things that normal people would never think of doing," he said. Things like putting a satellite in space, going to the moon, going to Mars, measuring the temperature of the universe, or quantifying the energy of a raindrop falling in the ocean.

At the end of the day, however, NASA teams are made up of people. "Sometimes people don't do what you expect," said Pittman. "We're capable of leaps of creativity and insight that nothing else can do, but sometimes you have a bad day… The fact that we are human means that we have strengths and weaknesses. It's our job as responsible leaders to maximize the strengths of our people and our teams and to enable them to see clearly the risks involved in our missions in spite of the fact that we are human."

Young Professional Briefs

Kat Coderre

November 30, 2010 — Vol. 3, Issue 11

Kat Coderre's career started with a phone call from out of the blue. "Can you be in Houston tomorrow night?" When Lockheed Martin won the Orion contract in 2006, it had Kat Coderre's application on file—one of 32,000. "We want you to come out," Coderre remembers the voice on the other end of the line saying.

"I flew from New York to Houston that evening," she says with a laugh. Fresh out of college with a degree in Aeronautical and Mechanical Engineering from Rensselaer Polytechnic Institute, Coderre was among 1,200 engineers asked to join the Lockheed Martin team. Standing with her peers, she recalls thinking, "I am fresh out of school and working on a spaceship. That's pretty cool."

Kat Coderre in the Cockpit Operators Station Mockup, which is used to run rendezvous docking simulations for Orion. Photo Credit: Lockheed Martin

The journey leading up to that phone call began with an early fascination with the moon, her first telescope, and a trip to Space Camp, where she later became a counselor. Four years after the trip to Houston, she is part of Lockheed Martin's Engineering Leadership Development Program, an active member in a variety of outreach programs, and a member of the Space Generation Advisory Council. In short, Coderre is part of the generation of young professionals who entered the aerospace workforce when the Vision for Space Exploration reshaped the landscape in the middle of the last decade. Today she's working to take her aerospace career and professional community to the next level.

Doing, Learning, and Mentors

"They'd let me go off and learn, and gave me tough tasks to do. They weren't holding my hand."

As a 22-year-old starting out as an engineer on the Orion Flight Operations Integration Team, her job was to make Orion a more operable vehicle.

"I didn't necessarily know what I was doing all of the time when I started, but there was a lot of encouragement, a lot of mentoring from the management, the more experienced folks," she says. "They'd let me go off and learn, and gave me tough tasks to do. They weren't holding my hand."

Her growth as an engineer continues with her participation in the Engineering Leadership Development Program (ELDP) at Lockheed Martin. For three years, Coderre will spend six months to a year broadening her skill set and capabilities by jumping from project to project, in addition to getting her Masters degree. Her first ELDP rotation placed her with the cockpit design team for Orion, working on displays and controls for the system. The experience exposed her to a high customer-contractor interface, a team dynamic that she hadn't yet experienced, and taught her how to work with the

Kat Coderre in the Human Engineering Structural Mockup. This full-scale Orion mockup is used for crew evaluations such as ergonomic assessments and emergency egress operations. Photo Credit: Lockheed Martin

customer as a teammate. Coderre is now working on Lockheed Martin's International Space Station Cargo Mission Contract team.

Throughout her four years at Lockheed, she has appreciated her mentors and their open-door policies. "I can just wander in if I see them in their office or if I need to discuss anything," she explains. Her conversations range from technical discussions to broader topics such as uncertainty in the federal budget.

Working in Teams

Most of her professional challenges have revolved around people: learning how to work with different personality types, communication styles, and work styles.

She is quick to say that she has had great support, but has run into the occasional colleague who "looks at you like you're a youngin'." She views it as a challenge to prove that "I can do my job right, and do it well," she says. "And when I do fail, [I] fess up to it." Simply admitting, "I made a mistake," Coderre adds, can go a long way. "If you don't fess up to [a mistake], then they lose respect for you."

Young, Old, and In Between

Her work and professional activities bring her into contact with people ranging from school children to retired aerospace veterans. She dedicates her time to public outreach, which started with her work at Space Camp, and expanded to volunteering at museums, the NASA Speakers Bureau, and the Challenger Learning Center. The next step to re-ignite the next generation's interest in space "is trying to get exposure into other areas where [kids] don't typically get [exposed to space]," she says. "It's our duty to really give back and be that mentor, be that spark of interest to a student, whether they are elementary school or college level."

At the other end of the age spectrum, Coderre looks to the generations above her to learn from their knowledge and experience from the past. "Spaceflight is a tough business," she says. "Taking those lessons and those various experiences, sitting down and talking with [the more experienced generation], showing them that we are interested and we want to hear what they've done [is important]." Coderre says that her generation is eager to make the most of lessons learned the hard way. "We respect their experience and we really do want to learn [from it]."

"The key is interaction; having as much small group interaction as possible." She remembers a conference where she was able to bring her questions and discussion topics directly to veteran engineers seated at various tables in a room. The forum was so effective that at the end of the evening, said Coderre, "no one wanted to leave."

As for her peers, Coderre advocates for flexibility and patience. "I believed in it (Orion). I put my heart and soul into it," she says. The nation's direction in human space flight changed, and her generation needs to respond appropriately. "The government and the way the government does business is changing." Her focus is to not get discouraged. With the aerospace industry being asked to do more with less, says Coderre, her generation as a whole must believe in what they do and continue to move forward.

International Collaboration: Wait and See

As a member of the Space Generation Advisory Council, a regular attendee of the International Astronautical Congress, and a team member on the ISS Cargo Mission Contract at Lockheed Martin, Coderre is no stranger to the international scene. She loves hearing colleagues speak different languages down the halls and in offices for her ISS work, and hopes to see international cooperation heightened in the future.

A wide view of the lab with the Human Engineering Structural Mockup in the foreground and the Cockpit Operators Station Mockup in the background. Photo Credit: NASA

"The world is getting smaller, we're more connected, and we can learn a lot from each other."

In her conversations with international peers, there is always great enthusiasm about working with NASA. At the same time, she finds it is nearly impossible to talk with colleagues about international collaboration without discussing export and import regulations like ITAR, which are often viewed as stunting the expansion of international projects. Until things change, Coderre encourages her international peers to continue building their experience and developing their expertise.

"I believe in international cooperation," she says. "The world is getting smaller, we're more connected, and we can learn a lot from each other."

Networking Forum at IAC

October 29, 2010 — Vol. 3, Issue 10

Three leaders in the aerospace world offered reflections and career advice to a packed room of young professionals at the International Astronautical Congress.

The International Astronautical Federation's Young Professionals Program offered a series of events for young professionals attending the 2010 International Astronautical Congress (IAC) in Prague, including a plenary session, a virtual forum, and several networking receptions.

The Young Professionals event on the second night of the IAC featured a lively discussion among three global leaders in the industry with very different backgrounds: European Space Agency Director-General Jean-Jacques Dordain, Lockheed Martin Vice President and former space shuttle pilot Ken Reightler, and Dr. Yasushi Horikawa, a veteran of the Japanese Aerospace Agency (JAXA) who is soon to be the head of the United Nations Committee on the Peaceful Uses of Outer Space. Academy Director, Dr. Ed Hoffman moderated the discussion.

A common theme among the panelists was the importance of teamwork. "I would not say I was successful," Dordain said. "I was lucky enough to work on successful teams." Reightler spoke of his experience as the pilot of the first joint U.S./Russian space shuttle mission. "Watching how that worked, how the people came together" was a key experience in his career.

Horikawa echoed the sentiment. "Space is team work." He also stressed the need to learn together. "You have to work hard and study lots of things—not only by yourself, but with other people."

Reightler counseled young professionals to remain focused when they encounter opportunities and difficulties. "You need to take a long view and not look at next year or five years from now, but twenty years down the road," he said.

Looking to the future, the space agencies with advanced capabilities will have an important leadership role to play as increasing numbers of developing nations seek the benefits of space. Horikawa pointed out that Japan was still a developing nation when it started its space program. "We are pleased to share that knowledge with developing countries," he said.

Dordain stressed that most global space activity today concerns improving the quality of life on Earth. "The future of planet Earth is a global future. There is no individual future," he said. "This is a global challenge. You all have to work together to make the future happen."

The career and knowledge sharing event was sponsored by Lockheed Martin.

2010 Young Professionals Study Released

September 30, 2010 — Vol. 3, Issue 9

Aviation Week, industry leaders, and the Academy collaborated on the launch of an inaugural Young Professional and University Student Research Study.

Increasing concern among aerospace and defense leadership about new technologies and up-and-coming sectors siphoning young talent elsewhere prompted this addition to the long-standing workforce research Aviation Week has performed since 1997. With a 15.7% voluntary attrition rate for young professionals in 2009, an advisory board of industry and academic leaders and young professionals took on the challenge of underst anding this critical population of the workforce. The result was a survey of young professionals (under 35 years old) and university students that shed new light on this critical demographic in the aerospace workforce.

The study yielded several key findings:

- Young professionals and university students are interested in aerospace and defense careers.
- The demographics for this population do not exactly mirror those found in the corporate world or society.
- Over one-quarter report they would prefer to remain with their current employer for their entire career, and over half say they would stay in the same industry.
- Expectations and reality regarding time between promotions are not aligned.
- Strong relationships with direct supervisors, flexible work environments, independence, and variety in assignments drive work satisfaction (among working professionals).
- Personal interest and the ability to make money drive the selection of a college major (among students).

Among the university students, two-thirds (67%) of those studying engineering report interest in a career in aerospace and defense. Within the first 18 months on the job, over half (57%) expect to be promoted, with fully eight in ten (80%) foreseeing promotion within 24 months.

The study reports that mentoring relationships are important for the transfer of both company processes and technical expertise. Organizations need to acknowledge a difference in culture between twenty-something employees and those in their thirties, as the younger cohort is still transitioning from the intensive feedback environment of college. Additionally, the report recommends that industry and government organizations continually recruit their current employees by keeping them engaged and challenged.

The study also reports that changes in NASA's mission and strategy affect the current and future workforce. Across the board, the aerospace and defense workforce is concerned about how changes in the industry will influence recruiting the next generation into STEM fields.

The Advisory Board for the study emphasizes the importance of continuing to track the individuals who volunteered for this study.

SpaceUP DC — An Unconference

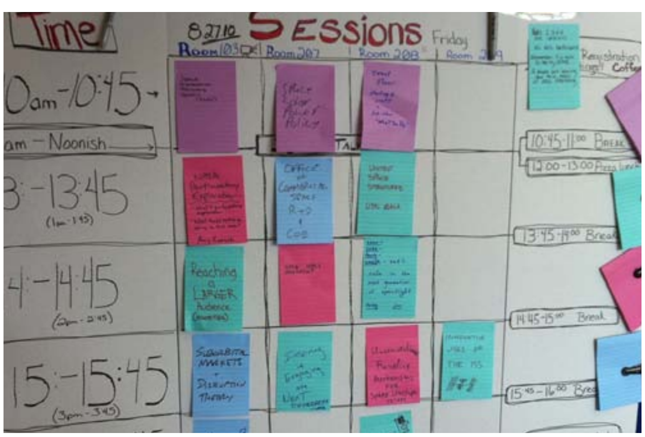
September 30, 2010 — Vol. 3, Issue 9

"Whoever comes are the right people. Whatever happens is the only thing that could have. When it starts is the right time. When it's over, it's over." [1]

No agenda. No keynote speakers. No audience members in rows of uncomfortable chairs fidgeting through serial PowerPoint presentations.

After a debut event last February in San Diego, SpaceUP made its way to Washington, D.C. in August. SpaceUP breaks the typical conference paradigm of mediocre food, large registration fees, and rigid lecture schedules. It engages and motivates all attendees to participate because they want to, not because they have to.

I had never been to an unconference. Quite frankly, the concept made me uncomfortable. But as I discovered, that's the point.



Session board for SpaceUP DC on Day 1. Credit: Cariann Higgenbotham

[1] Credit: Chris Corrigan "Open Space Technology" Flickr stream.

Nothing is pre-arranged at an unconference. The participants bring the topics, choose the time and place, and spark the discussion. If you aren't in a place where you can contribute, you go somewhere where you can. At an unconference, no one gets to be a fly on the wall (my usual modus operandi). Everyone contributes.

As I introduced myself to people filling up the main room of Funger Hall at George Washington University, I found that participants hailed from all over: California, Minnesota, Florida, and Texas, as well as the DC area. Some worked in the space industry. Some didn't. Participants ranged from a nine year-old to retirees. Most had never been to an unconference. All were space enthusiasts. We were an odd bunch, but, as I would come to find, a thoughtful, inspiring, and intelligent group dedicated to space exploration.

"This is kind of a weird experiment," unconference coordinator Michael Doornbos told us. While the discussions over the next two days were bound to be productive, he reminded us that SpaceUP is about taking what we discuss and doing something after we've all gone home. "SpaceUP isn't a destination," said Doornbos. "It's a springboard."

The unconference revolved around a large board with a grid showing open time slots and rooms. Next to it were piles of Post-It notes and Sharpie pens. After Doornbos's introduction we left the main room for the board. We stood around it like eighth-graders at a dance, anxiously waiting for the first brave soul to get things started. But it wasn't long before Post-It notes began filling up the empty spaces: "Space Solar Power Policy," "Suborbital Markets & Disruption Theory," "Nuclear Rockets," "Reaching a Larger Audience (minorities)," and "Innovative Uses of the ISS."

Then the group scattered. This is how it starts, I thought. Engineers, designers, educators, scientists, writers, parents, grandparents, and kids were going to discuss space policy, nuclear rocket engines, reinfusing the aerospace workforce, innovation, technology development, and grand space challenges. If you couldn't participate in person, you could participate virtually. Every room was equipped with live video, audio, chat, and wiki capabilities. If you missed a specific talk, the videos were online the next day. Heading off to my first session, my own discomfort with the lack of structure melted away. At an unconference, everyone is on even ground. To solve big problems, everyone needs to contribute. As with brainstorming, every idea counts.

One of the first talks I attended was by Amy Kaminski from NASA's Participatory Exploration Office. She sought input on what NASA could do better to engage the public its missions. With $5 million in the FY 2011 budget for her office, she wants to make every penny count. One participant suggested that NASA make participatory exploration a priority for missions. This will require a shift in culture, but these missions exist to help people learn, she said. Participatory exploration is just as important as the science coming out of the mission. Be nimble with your approach, said another participant. What worked to engage the public the first time may not work the second and third

Above: Group shot of SpaceUP DC participants on Day 2 of the unconference. Credit: Dennis Bonilla

Emory Stagmer, a satellite flight software lead engineer for Northrop Grumman who worked on the LCROSS mission, hosted a session on nuclear power. He became interested in the topic after receiving several books on the topic for Christmas, and has been a proponent ever since. Our discussion determined that the promotion of nuclear-powered spacecraft faced three main obstacles: international diplomacy, leadership buy-in, and changing the public's perception of nuclear technology.

Justin Kugler, a systems engineer for SAIC working in NASA's ISS National Laboratory Office, continued Stagmer's discussion with his session, "To Mars and Back in 80 Days." Kugler said there was a need to "start talking about new and innovative ways to do propulsion." New propulsion methods could be implemented gradually as redundant systems on science missions or on small-scale demonstration missions.

"Free range rocket scientist" and educator Tiffany Titus, who just moved to the Space Coast of Florida, hosted a session on the impact that Twitter has had on her life. Twitter is how she communicates her passion for space at a grander scale and keeps a conversation going about that passion. Cariann Higgenbottom, one of the founders of Spacevidcast, said that prior to the start of the unconference, she hadn't met 98 percent of the people in sitting in the room in person, but she knew them through Twitter. For the vast majority of the people in the room (myself included), NASA is the reason they joined Twitter.

I co-hosted a session with Goddard Space Flight Center's Jon Verville on CubeSats. One participant said that watching the Mars Exploration Rover landings inspired him to want build his own CubeSat in order to experience that thrill of success. Alex "Sandy" Antunes shared that he has already built one, describing it as a "midlife crisis sort of thing. I could buy a motorcycle or launch a satellite." Called Project Calliope, the picosatellite will relay measurements taken in the ionosphere back to Earth in the form of sheet music. Musicians will be able to remix the data however they like. Antunes built the entire spacecraft in his basement. "We're at the point where the engineering is not the hard part anymore," he said. The challenge, we all agreed, is finding and paying for a ride into orbit.

While many other fruitful discussions took place, one particular session epitomized the spirit of an unconference. "Engaging the Next Generation of Explorers" lasted for nearly two and a half hours. By the end, the number of participants in the room doubled. Nobody left. Other scheduled activities were cancelled because nearly everyone was in this session.

There was broad agreement that there is a lack of connection between the public and space, so conversation focused on deriving the missing "X factor." One participant suggested the need to find a way to get the public to connect with space like they do with the fishermen from the television show "Deadliest Catch." Make it personal, and make it affect people, others agreed. "You've got to create moments that [people] can connect with," said Dennis Bonilla, a graphic designer and NASA contractor. "Effective outreach is about meeting people where they are," said another participant. Effective outreach starts with telling a story and making it one everyone can be a part of.

Educating leaders and children was another component of the discussion. Many participants reiterated that it has to be OK to fail. Failure is mandatory. Failure is part of inquiry, part of science, part of exploration, part of learning. Innovation is driven by failure. If this is a problem for today's generation, it is likely to persist for the next.

In addition to the individual session, SpaceUP DC featured a series of Ignite talks, a format that allows speakers five minutes and twenty slides to share their topics. Doug Ellison from the Jet Propulsion Laboratory (JPL) previewed the Explorer Engine JPL is developing that will let users explore the Solar System in a completely new style this October. "Brace yourselves," he said. "The solar system is coming to your desktop."

Lesson from "Engaging the Next Generation of Explorers" session hosted by Tim Bailey. Credit: Cariann Higgenbotham

Jim Adams, Deputy Director of the Planetary Science Division in the Science Mission Directorate, went through the exciting things happening at NASA right now. "Right now, it's raining liquid methane on Titan," he said, encouraging the audience to "share the cool" of space exploration.

Tim Bailey shared his experiences as Assistant Director of Yuri's Night, a world-wide celebration of the first man in space. The celebration at Ames Research Center attracted 10,000 people over two days, said Bailey. "People are interested," he said. "They want to know what's going on… they need to be able to connect." Bailey encouraged the audience to get involved for the 50th anniversary of the first man in space in April 2011.

Other participants included: Kirk Woellert, a space entrepreneur, who spoke about citizen satellite opportunities; Ken Davidian, a former NASA engineer who discussed commercial space activities at the Federal Aviation Administration; and Jason Marsh, who explained his work with Copenhagen Suborbitals. The Ignite talks were topped off with a performance of "Bake Sale for NASA" by singer CraftLass.

An important aspect of the unconference was the opportunity to have fun and enjoy the things that interested us in space in the first place. We fiddled with pipe cleaners (out of which one person constructed the space-time continuum), built spaceships and rovers out of Legos (our "green" ship was powered by Lego conifers), conducted a MoonPie eating contest (beware the banana flavor), and held what is probably the first Tribble war ever (they're not as soft as they look). If this all seems quite silly, then take a moment to think on what sparked your interest in space and what fuels it now. When did you realize that space is cool?

The conversations I was part of last August continue today. Follow-up SpaceUP unconferences for San Diego and Washington are in the works, and new cities like Houston and Minneapolis starting their own.

While getting to Mars, global cooperation in space, or pushing the boundaries of space technology all come with technical, political, and budgetary challenges, space exploration is fueled by the imagination and enthusiasm of both fifty-year-old engineers and eleven-year-old kids like Caleb Doornbos, whose disarming intelligence and freedom from limitations made us all walk away asking, "Why not?" Why not inspire the next generation about space? Why not go to Mars and back in 80 days or less? Why not launch your own satellite? Why not?

Research Briefs

Students View Aerospace as Exciting, Innovative, and Challenging

May 28, 2010 — Vol. 3, Issue 5

Aerospace compares favorably to other industries in terms of challenge, excitement and educational opportunities, according to a Massachusetts Institute of Technology survey of students.

The demographic challenges facing the aerospace industry have been the subject of extensive discussion by NASA, the National Academies of Science, and other organizations concerned about the long-term viability of the U.S. aerospace workforce. As the Baby Boom generation reaches retirement age, many analysts and policymakers have raised questions about the strength of the pipeline of young professionals who will lead the industry in the decades ahead. In an effort to bring more quantitative data to these dialogues, Massachusetts Institute of Technology Professor Annalisa Weigel developed a web-based survey to understand aerospace engineering students' attitudes toward their educations, motivations, career aspirations, and job offers.

Over 600 sophomores and seniors from 23 universities responded to the 30-minute survey. The results provide illuminating insights about the expectations and experiences of the current generation of students, the oldest of whom were not born at the time of the Challenger accident. Weigel plans to create a longitudinal dataset spanning both college and early career stages

When asked about the first words that come to mind when describing the aerospace industry, roughly one in six (17 percent) said aerospace is "exciting," followed closely by "innovative" and "challenging." Interest in aerospace begins early. One-third of respondents (35 percent) indicated that they first became interested in aerospace when they were 5-9 years old, with another 27 percent saying that their interest began when they were 10-13 years old. Familiarity with engineering is also common: 60 percent indicated that one or more family members or close friends are engineers.

NASA is virtually unique among government organizations in its focus on exploration, which is an intrinsically visionary pursuit. The earliest space visionaries were storytellers, not scientists or engineers. The very idea of space exploration was outside the realm of the possible until the dawn of flight in the early twentieth century. In 1930, three science fiction writers founded the American Rocket Society, a predecessor of today's American Institute of Aeronautics and Astronautics (AIAA). It's hard to think of another technical profession where one generation's fantastic story becomes the next generation's reality. Stories are powerful tools for sharing a vision with others.

Student perceive aerospace as a challenging, rewarding industry that comes with some lifestyle drawbacks. Aerospace stacked up favorably compared to other industries in terms of salary, benefits, educational opportunities, challenge, and excitement, but scored less favorably in areas such as flexible schedule, work/life balance, and location.

When asked about the role their university experiences played in developing their career interests, students cited hands-on experience and faculty as the strongest positive influences on their desire to work in aerospace. At the other end of the spectrum, engineering classes and career fairs had the most negative impact on interest in aerospace.

Aerospace engineering students expect job mobility and project variety in their careers. Strong majorities indicated interest in working for multiple organizations and on a variety of projects over their careers. Just 11 percent say they expect to stay at their first company or organization for at least 10 years. This suggests a profoundly different career path than that followed by the generation approaching retirement age, which came of age professionally with multi-decade programs such as the Space Shuttle and the Hubble Space Telescope.

Students report that recruiting in aerospace depends less on personal connections than is the case in other industries. Career fairs were overwhelmingly cited as the top recruiting avenues for aerospace job offers, followed by internships and online applications. For non-aerospace jobs, knowing someone in an organization was the most commonly reported recruiting avenue.

Fully eight in ten graduating aerospace engineering students who received offers in the industry took aerospace-related jobs. Salary, location, challenge and work environment were the top four factors mentioned for accepting a job in aerospace, while leadership opportunities, excitement, challenge, and benefits were the top four factors for accepting a job offer outside of aerospace.

Professor Weigel intends to follow on with her respondents over time to see how attitudes shift as the students graduate and join the working world.

Study Examines Executive Leadership at NASA

June 30, 2010 — Vol. 3, Issue 6

A study of executive leadership identified the behaviors and personal attributes of successful NASA executives.

What do successful executives at NASA have in common? Executive Leadership at NASA: A Behavioral Framework, a study conducted by the Office of the Chief Engineer, investigated the behaviors and personal attributes of 14 NASA executives regarded by senior leaders as highly effective in their roles. The research team identified a shared set of effective executive behaviors and attributes that fall under six broad themes:

Leadership. Top executives are capable of creating organizational structure by defining roles and responsibilities, identifying and acquiring the sources needed for a project, and drawing on the expertise of others and involving them in the process. They are flexible and responsible in addition to being self-aware.

Attitudes and Attributes. At the core, successful executives are inquisitive, curious, patient, and organized. They have a passion for learning and keep an open mind. They are conscious of creating a safe environment with a calm and positive attitude, but maintain an "executive presence" to affirm self-confidence and courage w hen difficult issues arise.

Communication. Top NASA executives are good communicators and good listeners. They are communication chameleons capable of tailoring a conversation to a variety of audiences (e.g. politicians, within the organization, and other agencies). Linking people, ideas, and organizations in addition to making themselves available to others were common amongst the study group.

Problem Solving and Systems Thinking. Highly effective NASA executives look at a problem from multiple perspectives. Having a breadth of knowledge across technical disciplines is a greater asset than a depth of knowledge in a single discipline.

Political Savvy. Successful executives know how the political system works while knowing how to work the political system. Knowing who makes decisions, when they make them, and what they need is critical to maintaining political staying power. They know how to communicate consequences and implications of decisions and can integrate historical perspectives and lessons learned to provide a context for decisions.

Strategic Thinking. These successful executives can see the big picture. They maintain an agency-wide view, balancing decisions across portfolios, programs, and projects. They seek to build relationships nationally and internationally by building informal networks and connecting with organizations and individuals that might otherwise remain isolated.

The study of executives is the second of two studies by the Office of the Chief Engineer. The first, NASA Systems Engineering Behavior Study (2008), identified the behaviors associated with high-performing systems engineers. The findings from these studies are being applied to programs such as the Systems Engineering Leadership Development Program (SELDP) and elsewhere to better update and design systems engineering training, development, coaching, and mentoring programs to better achieve mission success.

Academy Bookshelf

William Langewiesche's Fly By Wire

January 29, 2010 — Vol. 3, Issue 1

When US Airways Flight 1549 suffered a dual engine failure moments after takeoff from LaGuardia Airport, the pilot did a remarkable job. So did the aircraft, writes William Langewiesche.

After pulling off a flawless emergency landing and evacuation in the Hudson River on January 15, 2009, Captain Chesley "Sully" Sullenberger, the pilot of US Air Flight 1549, virtually became a household name. Sullenberger did everything right, proving himself an exceptional pilot in extraordinary circumstances.

The other hero in Langewiesche's *Fly by Wire: The Geese, the Glide, and the Miracle on the Hudson* is the Airbus A320. This aircraft, the first commercial passenger jet to employ a digital fly-by-wire control system, is "the most audacious civil airplane since the Wright brothers' Flyer," Langewiesche contends. By optimizing the plane's technical performance under any given set of parameters, the fly-by-wire system "radically redefines the relationship between pilots and flight."

Fly-by-wire technology had its origins at NASA's Dryden Flight Research Center in the 1970s. A decade later, Bernard Ziegler, a French engineer and former test pilot, convinced the management team at Airbus to develop an aircraft that would rely on flight control sensors and computers rather than mechanical and hydraulic systems. The fly-by-wire system would not allow a pilot to execute a maneuver that would push the plane beyond its capabilities and cause it to stall or break up. The result was an intelligent airplane that was both more automated and more forgiving of pilot errors.

Langewiesche intersperses a gripping minute-by-minute account of Flight 1549 with chapters about bird strikes, gliding, commercial airline pilot culture, and the evolution fly-by-wire technology. He contrasts "the miracle on the Hudson" with a Continental Airlines crash near Buffalo that took place a month later. When the plane unexpectedly came close to stalling, the pilot pulled back hard on the controls, overriding a safeguard system designed to prevent over-stressing the aircraft. The plane veered out of control, resulting in the deaths of all the passengers and crew aboard. The fly-by-wire control system in the Airbus A320 would not have permitted the same maneuver.

Langewiesche is careful not to present fly-by-wire as a failsafe system. He notes that it introduces the risk of complacency, which he calls the Titanic effect: "If you believe your ship is practically unsinkable, you might start charging across icebergs." He also acknowledges that an outstanding pilot like Sullenberger might well have achieved the same result in a conventional airplane, but suggests that the fly-by-wire system significantly narrowed the possibility of human error. "Sullenberger was brilliant at it [flying], as was the automation he commanded."

Being Wrong: Adventures in the Margin of Error

July 30, 2010 — Vol. 3, Issue 7

Being Wrong tells stories of screwing up and how we react to it.

Being right feels good. Being wrong does not. It's uncomfortable, irritating, maddening, and even nauseating. We don't like it and avoid it at all costs. In *Being Wrong: Adventures in the Margin of Error*, Kathryn Shultz explores this squeamish response to error in looking at how our culture thinks about error, how we feel about it, and how we cope with it. Shultz aims to alter our reaction to error in that it is possible for being wrong to feel as satisfying as being right.

Shultz makes her point with stories about blind patients who believe they can see, collapsing financial markets, close-minded government organizations, and even people jumping into the wrong car. In order to try and eliminate error, she writes, we must understand that it is inevitable. She proposes a change in the stigma surrounding error. "If we assume that people who are wrong are ignorant, or idiotic, or evil — well, small wonder that we prefer not to confront the possibility of error in ourselves." According to Shultz, by being wrong we learn how to correct our perceptions and beliefs about how the world actually is.

By and large, Shultz makes the case that we haven't mastered the ability to simply say, "I was wrong" with no caveats. Her hope is that in being wrong and acknowledging it, we will have learned something that will enable us to get it right the next time. "You might never have given a thought to what I'm calling wrongology," she writes. "You might be the farthest thing in the world from a wrongologist; but like it or not, you are already a wrongitioner. We all are."

This Month in NASA History

20th Anniversary of Hubble Launch

April 26, 2010 — Vol. 3, Issue 4

Former astronaut John Grunsfeld reflects on what the Hubble Space Telescope has taught us over the past 20 years.

Dubbed the "Chief Hubble Repairman," John Grunsfeld flew three of the five on-orbit servicing missions to the Hubble Space Telescope (HST). Selected by NASA as an astronaut in March 1992, Grunsfeld has flown five space flights total, logging a total of 58 days in space and 58.5 hours of Extra Vehicular Activity over eight spacewalks. During his on-orbit servicing missions, Grunsfeld dealt with everything from installing telephone booth-sized instruments to removing 100-plus tiny screws on Hubble.

Grunsfeld, now Deputy Director of the Space Telescope Science Institute, offered ASK the Academy his thoughts on lessons from Hubble.

ASK the Academy: You started your career as a scientist in academia before training as an astronaut. How early were you aware that NASA was developing the Hubble? What was your level of interest in it at the time?

John Grunsfeld: I knew that NASA was developing the Hubble Space Telescope while I was in graduate school at the University of Chicago. My PhD thesis was on the flight of Space Shuttle Challenger, STS-51F, the mission before the tragic loss of Challenger and crew. At the time I knew this meant that all missions slated to fly on the Shuttle were in jeopardy. Of course this delay was crucial for the completion of Hubble, but I was at the time more interested in the Compton Gamma Ray Observatory. This next great observatory after Hubble was more central to my field of high energy astrophysics. It is interesting to note that both the Hubble and the Compton depended on astronauts doing spacewalks for the success of the observatories.

Perched on the robotic arm, Andrew Feustel takes a close-up photo of John Grunsfeld. Credit: STScI/NASA

ATA: As robotic technology continues to develop, how do you see the division between human and robotic servicing capabilities changing in the future?

Grunsfeld: The constant debate between performing science with robots or people has always struck me as asking the wrong question. We always do science in space now as a human/robotic partnership. It's only a question of degree. The Hubble Space Telescope has never discovered anything, astronomers using the telescope make the discoveries, and in the case of Hubble, astronauts servicing the telescope have made it orders of magnitude more productive.

For locations that people can't go, clearly robots are the way to explore. When we can go, we will go with our robotic counterparts, both of us as pathfinders to extend our reach. The extraordinary robots on the Martian surface now have proven to be great tools for exploration, in as much as we can't go (yet). But the process is very slow and tedious. A real geologist would have performed at a higher level on the surface of Mars in terms of quality science, and done the last five years of science in a week of exploration. Unfortunately, right now we can't send a geologist to Mars.

What is intriguing is that in field of dexterous robotics we are making great strides, such that some of the space servicing that we do now with astronauts will in the future be possible for these capable robots.

ATA: As one of the pioneers of on-orbit servicing, how do you see these capabilities maturing as NASA and its partners prepare to spend the next decade utilizing the International Space Station?

Grunsfeld: The Special Purpose Dexterous Manipulator on ISS since 2008, and soon the Robonaut-2, provide us with an opportunity to test out in an operational setting the utility of dexterous robotics. We will learn how to use these tools to perform real and simulated servicing on orbit. With their success we can then move out to plan for this kind of capability in future exploration efforts.

ATA: What lessons can we take from Hubble in terms of international collaboration?

Grunsfeld: Our collaboration with the European Space Agency on Hubble has been very fruitful. We work as a seamless team, under the banner of science. These lessons are being applied successfully to the James Webb Space Telescope and form a basis for future collaboration.

ATA: Looking back on the twentieth anniversary of the Hubble launch, what are some of the major lessons learned about the long-term operations of a complex system like this?

Grunsfeld: From a project management point of view, having the opportunity to operate, upgrade, and provide many years of science from Hubble has shown us the value and leverage a space observatory provides as compared to a short-lived, single-purpose space science experiment. The extended team, across centers, institutes, and contractors has consistently risen to meet high-performance challenges across the spectrum of disciplines. The great power of the long-lived nature of Hubble is that the experience has crossed many generations of engineers and scientists who have been able to apply their knowledge to other programs.

Shuttle Atlantis *sits on Launch Pad 39A ready to accept the HST payload for STS-125. Credit: NASA/Kim Shiflett*

Origins of the Hubble Space Telescope

1923 German physicist Hermann Oberth proposes the idea of a large orbiting, multipurpose telescope capable of making observations without atmospheric obstruction.

1946 American astronomer Lyman Spitzer publishes his paper "Astronomical advantages of an extra-terrestrial observatory," which argues for the advantages of space-based telescopes.

1958 Congress passes the National Aeronautics and Space Act, which authorizes the creation of NASA.

1962 The United Kingdom launches Ariel 1, the first space telescope designed to study solar ultraviolet and X-ray radiation.

1962 NASA initiates the Orbiting Solar Observatories (OSO) program, which is designed to launch a series of satellites to cover the entire 11-year solar cycle. The eighth and final OSO satellite launches in June 1975. The program ends in October 1978.

1963 Stratoscope II, a 36-inch balloon telescope, successfully takes pictures of planets, satellites, and galactic nuclei. It flies its sixth and final successful mission in 1971.

1966 NASA launches the first satellite in the Orbiting Astronomical Observatories (OAO) program. Two of the four satellites in this program fail before or shortly after reaching orbit. The program ends with OAO-3 Copernicus, which operates until February 1981.

1969 National Academies urge construction of a large space telescope.

1971 NASA executive George Low approves feasibility studies by the Large Space Telescope (LST) Steering Group.

1975 European Space Research Organization (now European Space Agency) partners with NASA on LST.

1977 Congress approves $36 million in funds for the LST program in the FY78 budget.

1979 Astronauts begin training for the mission in underwater tank at Johnson Space Center.

1983 The Large Space Telescope is renamed the Hubble Space Telescope after Edwin Hubble, the astronomer who discovered the expansion of the universe from measurements of the red-shifted spectra of distant stars.

1981 The Space Telescope Science Institute is established in Baltimore to evaluate proposals for telescope time and manage the science program.

1985 Hubble Space Telescope construction completed.

1986 Challenger accident delays Hubble's October 1986 launch.

1990 Hubble launches on the STS-31 mission aboard space shuttle Discovery on April 24, 1990.

THE LUNAR-ORBIT RENDEZVOUS DECISION

June 30, 2010 — Vol. 3, Issue 6

On June 7, 1962, Dr. Wernher von Braun tipped the scales in a heated debate of how to put men on the moon.

The heat was on. Thirteen months had elapsed since President Kennedy declared that the United States would land men on the moon by the end of the decade. NASA, created less than four years earlier, was charged with getting them there. But NASA didn't have a clear path to the moon.

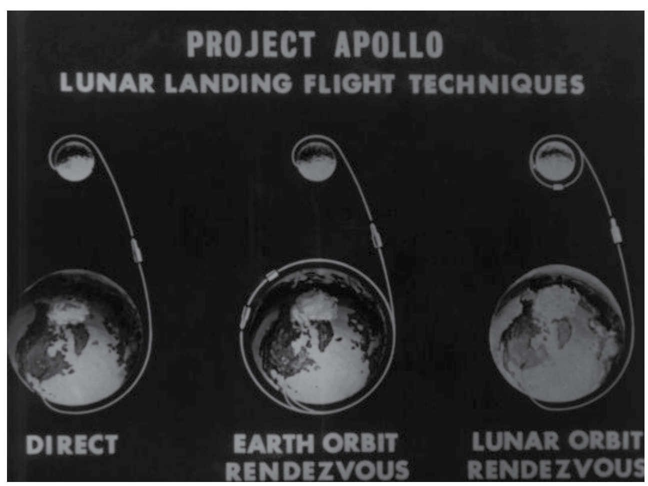
Just as there are several ways to reach the summit of Mt. Everest, there were multiple ways to get to the moon: 1) blast straight off the ground on a direct path to the surface and return the same way; 2) launch into Earth orbit, refuel and assemble the spacecraft, and then take the entire craft to the moon; 3) or launch into lunar orbit and land a small lander on the lunar surface while the remaining spacecraft stays in orbit.

The first path—called "direct ascent"—was initially the most popular option. However, it became clearer with more discussion that this option wouldn't meet the President's deadline. The twelve-million-pound-thrust, battleship-sized "Nova" rocket didn't exist yet and was sure to run over schedule.

This left the other two approaches: the Earth-orbit rendezvous (EOR), the second favorite, and lunar-orbit rendezvous (LOR), the "dark horse." By the beginning of 1962, determining the path to the moon would come down to the two main manned spaceflight centers: Marshall Space Flight Center (MSFC) and the Manned Spacecraft Center (now Johnson Spaceflight Center). However, when Brainerd Holmes, director of the Office of Manned Space Flight, tasked his deputy director, Joseph Shea, with determining the best path, the two centers were decidedly split. Shea would spend the next six months coordinating meetings, initiating studies, and seeking expert advice to get MSFC and MSC to agree on one path.

Marshall favored the EOR approach. It called for launching two pieces of hardware independently on the Saturn V rockets under development. The two pieces would assemble together in Earth orbit to make a lunar mission vehicle, fuel up, and head for the moon. Astronauts would have to land the entire craft on the moon and then return to Earth. While this approach offered the advantage of using a launch vehicle that was already in development (unlike the direct ascent approach), there wasn't a clear concept of how to land the large mission vehicle on the unknown surface of the moon.

Houston, after several years of persistent advocacy by John Houbolt, an engineer at Langley Research Center, supported the LOR approach. It involved firing three spacecraft (command module, service module, and lunar module) aboard one Saturn V rocket into Earth orbit. Once there, the last stage of the Saturn boosted the spacecraft on a lunar trajectory and eventually into orbit. Only the lunar module would go down to the surface. It would then return and re-dock with the orbiting command module in the top-half of the lunar module (leaving the base on the moon). The astronauts would return to Earth in the command module, while the remainder of the lunar module was ejected into space.



The three principal contending lunar landing techniques: direct ascent (left), earth-orbit rendezvous (center), and lunar-orbit rendezvous (right). Credit: NASA

The LOR option had lots of pros. It required less fuel and new technology. It didn't require a rocket larger than the gargantuan Saturn V. It employed just a small lunar lander, and each of the modules could be tailored independently. But there was a drawback. LOR didn't offer a rescue option if the tricky rendezvous failed. The thought of three astronauts out of help's reach 240,000 miles from home didn't sit well with the engineers.

The complexity of this decision rested upon politics, money, schedule, mass, fuel, technology, center culture, work distribution, and, most importantly, human lives. As June approached and the path debate was still unresolved, Shea saw that the LOR approach really was the best decision, but he wanted unanimity. This meant appealing to Marshall's director, Dr. Wernher von Braun.

This wasn't an easy task. Von Braun worried about the loss of relevance and work Marshall would suffer if the LOR approach won out. Despite several meetings, studies, and even campaigns (one of which was called "Charlie Frick's Road Show," named after Charles Frick from Houston, stopped by Marshall on the way to Washington), von Braun's decision remained firm.

But that changed on June 7, 1962. For six hours, Marshall representatives presented their argument for using the EOR approach. At the end of the day-long meeting, after months of steadfastness, von Braun stood up and read from a sheet of paper he had been scribbling on over the course of the day:

We at the Marshall Space Flight Center readily admit that when first exposed to the proposal of the Lunar Orbit Rendezvous Mode we were a bit skeptical—particularly of the aspect of having the astronauts execute a complicated rendezvous maneuver at a distance of 240,000 miles from the earth where any rescue possibility appeared remote. In the meantime, however, we have spent a great deal of time and effort studying the [three] modes, and we have come to the conclusion that this particular disadvantage is far outweighed by [its] advantages.

We understand that the Manned Spacecraft Center was also quite skeptical at first when John Houbolt advanced the proposal of the Lunar Orbit Rendezvous Mode, and that it took them quite a while to substantiate the feasibility of the method and fully endorse it.

Against this background it can, therefore, be concluded that the issue of "invented here" versus "not invented here" does not apply to either the Manned Spacecraft Center or the Marshall Space Flight Center; that both Centers have actually embraced a scheme suggested by a third source....I consider it fortunate indeed for the Manned Lunar Landing Program that both Centers, after much soul searching, have come to the identical solutions.

In the weeks that followed, the final decision to go to the moon using the LOR approach made its way to the desk of Administrator James Webb (a proponent of the direct ascent approach). On June 22, 1962, the Manned Space Flight Management Council announced in favor of the LOR approach.

Starting July 16, 1969, NASA flew eight missions to the lunar surface, and although Apollo 13 didn't land on the moon, all the astronauts made it home safely.

Resources

Studies and Reports

STS-119 Case Study
http://www.nasa.gov/offices/oce/appel/knowledge/publications/STS-119.html

Executive Leadership at NASA: A Behavioral Framework
http://www.nasa.gov/pdf/460856main_NASA_Exec_Behavior_Study_06_03_10.pdf

NASA Systems Engineering Behavior Study
http://www.nasa.gov/news/reports/NASA_SE_Behavior_Study.html

Survey of Aerospace Student Attitudes project website
http://web.mit.edu/caspar/aerosurvey.htm

2010 Young Professionals/University Student Survey
http://img.en25.com/Web/AviationWeek/2010_YP_Univ_WP.pdf

2010 National Space Policy
http://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf

White Papers

Knowledge Forum #1 White Paper
http://www.nasa.gov/offices/oce/appel/knowledge/forums/knowledge_forum_10_15_09_detail.html

Knowledge Forum #2 White Paper
http://www.nasa.gov/offices/oce/appel/knowledge/forums/knowledge_forum_06_17_10_detail.html

Presentations

Dr. Ed Hoffman's presentation on trends in project management that he delivered at NASA's PM Challenge in Galveston, Texas, on February 10, 2010
http://www.nasa.gov/pdf/432514main_Hoffman_PM_Trends_.pdf

Online Resources

Wayne Hale's Blog
http://blogs.nasa.gov/cm/newui/blog/viewpostlist.jsp?blogname=waynehalesblog

NASA Orbital Debris Program Office website
http://www.orbitaldebris.jsc.nasa.gov/

Multimedia

Masters with Masters event full length videos
http://www.nasa.gov/offices/oce/appel/knowledge/multimedia/index.html

NASA APPEL YouTube channel
http://www.youtube.com/user/NASAappel

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Research Brief: Assessment of Impediments to Interagency Collaboration

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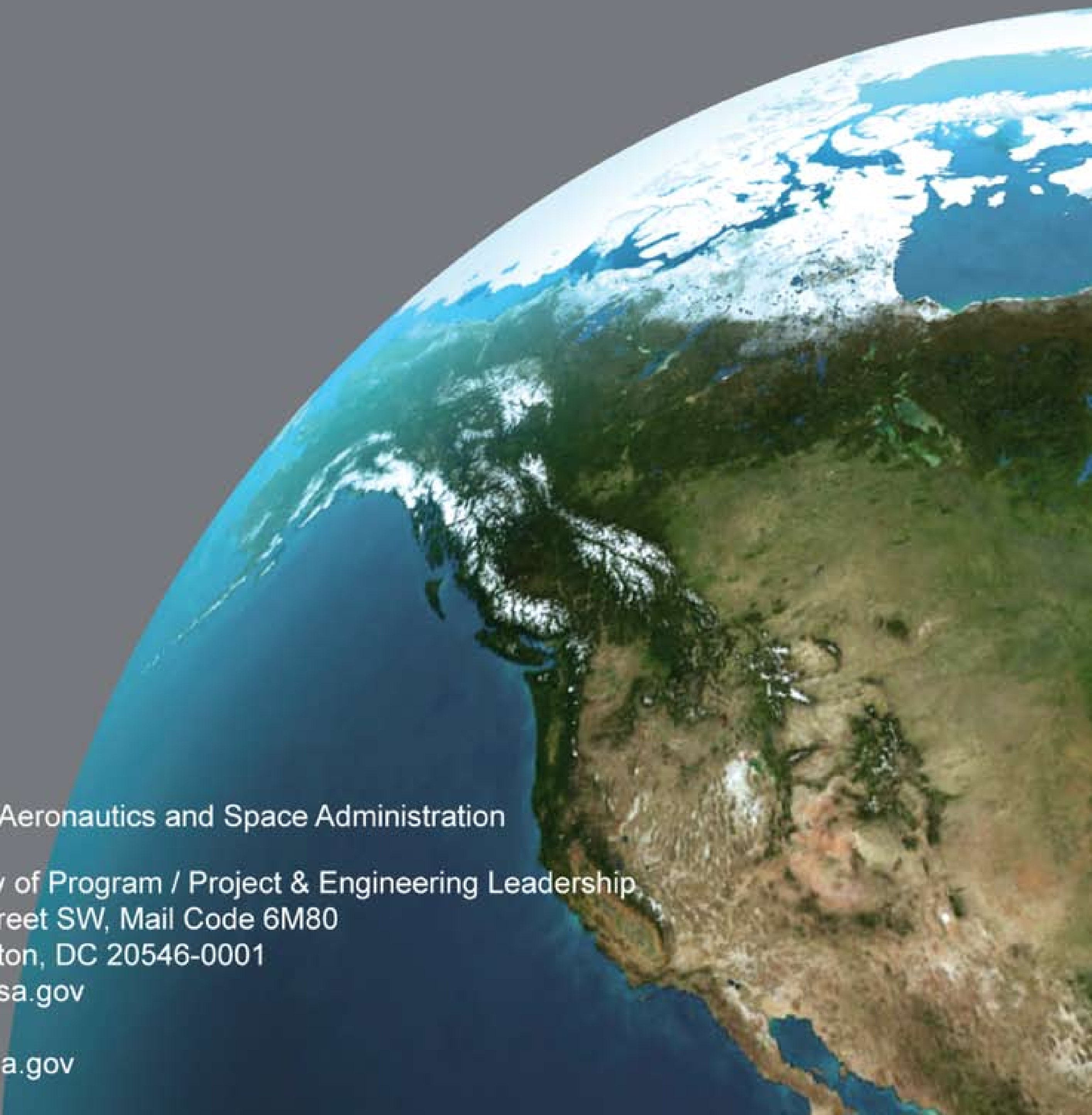

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