National Aeronautics and Space Administration

NASA'S JOURNEY TO PROJECT MANAGEMENT EXCELLENCE

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Chapter One

WHY A PROJECT ACADEMY?

BECAUSE FAILURE *IS* AN OPTION.

Ever tried. Ever failed. No matter.
Try again. Fail again. Fail better.

— Samuel Beckett

As a cold front approached Florida's Atlantic coast on the afternoon of Monday, January 27, 1986, the weather was on the mind of everyone associated with NASA's space shuttle program. Shortly after noon, the Mission Management Team scrubbed the scheduled launch of space shuttle Challenger on mission STS-51L due to high winds, after experiencing a delay in the countdown earlier that morning due to a minor mechanical problem. It was the fourth launch delay in five days. The forecast for Tuesday called for unseasonably frigid temperatures, with the mercury predicted to dip to 18° F overnight.

STS-51L would be the twenty-fifth space shuttle mission, and the twenty-first since President Reagan had declared the shuttle "operational" after four test flights. Originally slated for launch in July 1985, STS-51L was rescheduled for November 1985 and then January 1986. The crew of seven included Christa McAuliffe, a school teacher from New Hampshire who had been selected from among 11,000 applicants to serve as the first teacher in space and the first citizen passenger on a space shuttle mission. Interest in the McAuliffe story had led to a wave of publicity for the flight. CNN planned to provide live coverage of the launch on cable television.

On Monday afternoon after the scrubbed launch, a team of engineers at Morton Thiokol, NASA's contractor for the solid rocket boosters that provide the majority of the liftoff thrust for the shuttle, held a meeting to discuss the potential impact of cold temperatures on the hardware. The focus of their discussion was the O-rings that served as seals in the joints between the segments of the solid rocket boosters. The concern was that at the predicted temperatures, the rubber-like O-rings would lose resiliency and fail to create a seal. Thiokol engineers had tested the O-rings at various temperatures and found troubling performance data at temperatures of 50º F. Lower temperatures would only make the problem worse. The meeting, which took place at Thiokol's facility in Utah, lasted roughly an hour, with the engineers agreeing there was a real danger of mission failure for a launch at the predicted temperatures.

Managers set up an early evening teleconference with Thiokol and NASA representatives from Kennedy Space Center and Marshall Space Flight Center, which had responsibility for the shuttle's propulsion systems, including its solid rocket boosters. During this 45-minute call, some NASA officials thought that representatives from Thiokol were saying the launch should be delayed, while others thought Thiokol was raising issues but not making a formal recommendation to delay. A second call was scheduled for a few hours later so that Thiokol could fax its engineering documentation to NASA officials.

More engineers and managers participated in the second teleconference, which began at 8:45 PM. Engineers from Thiokol reviewed data from previous flights and evidence of erosion of the O-rings, and recommended not launching at temperatures below 53º F, which was the lowest temperature at a previous shuttle launch. Managers from NASA expressed surprise at this recommendation, pointing out that it represented a sweeping change in the launch criteria for the solid rocket boosters. Thiokol and NASA then took a break from the teleconference and held offline caucuses with their own teams.

When the call resumed, Thiokol's vice president in charge of booster programs said that Thiokol had reassessed the data and found it inconclusive. He read a written rationale recommending launch as the company's official position, which was later sent to NASA. The call ended shortly after 11 PM.

As predicted, the next day was unusually cold. Final launch preparations proceeded apace. At 11:38 AM, the space shuttle Challenger lifted off into a clear blue sky. The temperature on the launch pad was 36o F. Just over 58 seconds into the launch

HEARTH STUDY

A 1980 study led by Langley Research Center Director Donald P. Hearth identified four major reasons for cost/schedule growth in several NASA projects:

- Technical complexity of projects.
- Inadequate definition prior to NASA's budget decision and external commitment.
- Effect of NASA's tendency to select on the basis of bid price and low contractor bids.
- Poor tracking of contractor accomplishments against approved plans in a timely fashion.

JACK LEE STUDY

In the summer of 1992, the NASA Administrator asked Marshall Space Flight Center Director Jack Lee to lead a six-month agency-wide study of 30 recent NASA projects. Lee's team identified eight factors that drive program costs and technical risks:

- Inadequate Phase B definition (i.e., before Preliminary Design Review)
- Unrealistic dependence on unproven technology
- Annual funding instability
- Complex organizational structure, including multiple unclear interfaces
- Cost estimates that are often misused
- Scope additions due to "requirements creep"
- Schedule slips
- Acquisition strategy that does not promote cost containment

sequence, a flame became visible in the area of the right solid rocket booster. In the next few seconds, the flame grew into a well-defined plume, and the vehicle's control system made adjustments to counter its physical forces. There was a sudden change in the shape and color of the flame, indicating the presence of hydrogen from the shuttle's enormous External Tank, which was now leaking. At 73 seconds, the vehicle erupted in a ball of fire, and the shuttle orbiter broke into several large sections. The crew did not survive.[1]

WHY DO PROJECTS FAIL?

Why do projects fail? There are plenty of opinions on this subject. A quick Google search on the phrase "why projects fail" turns up hundreds of thousands of hits. Scholars of project management have yet to reach a consensus. Some propose that project failure is under-theorized, while others say that an emphasis on success and failure is narrow and counterproductive.[2] For a publicly accountable organization like NASA, understanding the causes of project failure is not an abstract concern. Rather, it is critical to mission success and the agency's continuous growth as a learning organization.

NASA has done several internal studies of project management, including some that have attempted to target why projects fail to meet cost and schedule criteria.

The federal government has also examined project performance issues. For the past two decades, the Government Accountability Office (GAO) has studied how well government agencies manage acquisition projects. Every two years GAO updates its "High-Risk Series," which identifies government programs at risk. Based on these studies, GAO has come to its own conclusions about government project management:

> *"GAO's work has shown that agencies confront several interrelated challenges, including separating wants from needs; executing acquisition programs within available funding and established timeframes; using sound contracting arrangements with appropriate incentives and effective oversight; assuring that contractors are used only in appropriate circumstances and play proper roles; and sustaining a capable and accountable acquisition workforce."* [3]

This list offers some insights about the nature of project failure. A closer look at each reveals a common denominator.

GAO HIGH RISK SERIES

The February 2011 GAO High Risk Series had four entries under "Managing Federal Contracting More Effectively." (Dates indicate the year the item was added to the high-risk list.)

- Department of Defense Contract Management (1992)
- Department of Energy Contract Management for the National Nuclear Security Administration and Office of Environmental Management (1990)
- NASA Acquisition Management (1990)
- Management of Interagency Contracting (2005)

The inability to separate wants from needs is fundamentally a communication failure that can compound at multiple levels. A project team solicits its "needs" — the requirements for a project — from its customer or client. Requirements definition, a critical factor in project success, is essentially an iterative conversation between the customer and the project team to determine what the customer is asking for and how the project team can deliver it. As the project team develops its approach, it will inevitably suggest options to the customer, all of which have cost, schedule or performance implications. Some of those options may include the project team's "wants" — the tools, resources, or flexibilities it would like to have to execute the project. When the project leader allows the team to confuse wants with needs, the

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1 This brief summary of events leading up to the Challenger accident draws from the following sources: "Report of the Presidential Commission on the Space Shuttle Challenger Accident" (Rogers Commission Report), Chapter V, accessed 30 June 2011 at http://history.nasa.gov/rogersrep/v1ch5.htm; U.S. House of Representatives, Ninety-ninth Congress, Second Session, "Investigation of the Challenger Accident: Report of the Committee on Science and Technology," (Washington, D.C.: U.S. Government Printing Office 64-420 0, 1986), "Hearing Before the Committee on Science, Space and Technology," U.S. House of Representatives, One Hundredth Congress, First Session, (Washington, D.C.: U.S. Government Printing Office 73-363, February 26, 1987), and Diane Vaughan, *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA* (Chicago: University of Chicago Press, 1986), pp. 1-7.

2 See, for example, Svetlana Cicmil, Damian Hodgson, Monica Lindgren and Johann Packendorff, "Project Management Behind the Façade," ephemera 9(2) (2004) 78-92; and Jonas Söderlund, "Building theories of project management: past research, future questions," *International Journal of Project Management* 22 (2004) 183–191.

3 U.S. General Accountability Office website, accessed 21 June 2010 at: http://www.gao.gov/highrisk/challenges/acquisition_management/home_acquisition_management.php

team cannot deliver optimal performance, and the customer always loses. At its core, this represents a failure of a project leader to define reality for the team and communicate that reality clearly.

The challenge of "executing acquisition programs with available funding and within established timeframes" is a long way of saying that projects fail because they don't meet cost and schedule constraints. Along with technical performance, these are the bedrock concerns of traditional project management. There is a well-known tendency for project teams to underestimate costs in the proposal process, regardless of whether the project is a spacecraft or a skyscraper. Decades of overruns have demonstrated that many, if not most, teams tend to be overly optimistic in the project formulation phase. As early as 1959, a report by the RAND Corporation concluded that early estimates on projects are "strongly 'biased' toward overoptimism."[4] This hasn't changed in the past fifty years. Despite overwhelming historical data, project teams convince themselves that they can work smarter, faster, and better than other teams have in the past. As a result, they underestimate cost and schedule from Day 1 of the project life cycle, and inevitably fail to meet their unrealistic goals. Overly optimistic estimates are another example of a leadership failure to define reality for the team.

The next three items — using sound contracting arrangements, employing contractors effectively and appropriately, and sustaining a capable and accountable acquisition workforce — are all about how to use people effectively. Do contracts provide people with the right incentives? Are the right people tasked with the right work? Is the workforce up to the job?

What do GAO's high-level conclusions, based on two decades of research and analysis, tell us about the nature of project failure? Simply put, project failure is a people problem. Separating needs from wants is a problem familiar to anyone who has bought a house or even a car — it's hardly unique to projects. Overly rosy cost and schedule projections stem from errors in judgment similar to those studied by behavioral economists and psychologists about how people perceive risk. Decisions about the use of contractors and in-house staff (including make-buy considerations) boil down to which people to use on a project. The success or failure of a project depends wholly on decisions and actions taken by people. Even if the decision-makers are not part of the formal project team — they may be external stakeholders — the implications are the same.

The GAO list cited above doesn't claim to be comprehensive or reflect the entirety of GAO's knowledge about projects. (GAO typically looks at one department, agency, or class of projects at a time, e.g., major weapons systems or space systems developments.) Many other analysts have developed their own lists of "usual suspects," which include inadequate risk management, the introduction of new or immature technologies, lack of corporate sponsorship, inadequate processes or process implementation, all varieties of communication breakdowns, and a lack of qualified talent.

These are all important reasons that projects fail. Each can be reduced to one of the following types of failures: to define reality accurately, communicate, or get the right people for the job. Stephen B. Johnson, a historian and NASA engineer, has estimated that "80 to 95 percent of failures are ultimately due to human error or miscommunication."[5] With that in mind, what can be done to improve project outcomes?

Our subject is the importance of developing a strategy to address the human dimension of complex projects. By removing one word from the last challenge on GAO's list, we arrive at a broader goal that's essential for any successful project-based organization: sustaining a capable and accountable workforce.

This emphasis on the human dimension calls for a full disclosure of our basic philosophy and assumptions.

1. The practitioner knows best. Academic researchers, policy experts, and other thought leaders can provide important insights and a diversity of perspectives, but the best way to develop project capability within an organization is to talk to people who manage or work on projects. Their driving passion is project success. Daron Roberts, assistant defensive coordinator for the Detroit Lions, told Kohut that pro football players are interested in anything that will give them an edge in Sunday match-ups against opposing teams. "Players want the info that's going

[4] A.W. Marshall and W.H. Meckling, "Predictability of the Costs, Time, and Success of Developments," RAND P-1821, October 14, 1959 (revised December 11, 1959), p. 1.

[5] Stephen B. Johnson, "Success, Failure, and NASA Culture," *ASK Magazine* (Fall 2008), accessed 30 June 2010 at: http://askmagazine.nasa.gov/issues/32/32i_success_failure_nasa_culture.html

to enable them to be successful on Sundays. Period." Project practitioners bring the same sense of relentless focus to their work. They have little patience for abstractions or theories unless they can see a tangible benefit in terms of project performance.

2. Experience is the best teacher. Practitioners have told us many times over that 85 to 90 percent of learning takes place on the job. This assumption informs every decision about how best to design learning opportunities for a project-based organization. Academic work and training courses provide a crucial foundation, but they are no substitute for learning by doing. Our colleague Larry Prusak, Editor-in-Chief of *ASK Magazine*, uses a personal anecdote to underscore this point. As a baseball player in junior high school, Larry was a lousy hitter who wanted to improve his performance. His father bought him Ted Williams's book The *Art of Hitting*, which Larry proceeded to read twice, only to find that it didn't make him a better hitter. "The skills involved are too complex and subtle, too internal; they can't be expressed in words that can be put to much use," Larry writes. The same is true about leading a complex project — the skills are too complex, subtle, and internal to be written down in a how-to guide or codified in a way that can be reproduced outside of a project setting.

3. Context is king. What works in one time and place may be useless in another. At NASA there are many examples resulting from the diversity of the agency's missions. Cindy Hernandez, a software engineer who worked on modeling the Orion crew capsule at Johnson Space Center, did a developmental assignment on a software project for the F-18 aircraft at Dryden Flight Research Center. Much of what she knew from her experience with spacecraft was simply not relevant in this context, which meant she had to learn a new way of thinking. Similarly, each career stage has different learning needs. For example, engineers fresh out of college are more receptive to coursework than mid-career practitioners with twenty years of experience. Early career learning at NASA requires building a foundation of strong technical skills, while later development often emphasizes management and leadership. In short, a one-size-fits-all model for learning cannot meet all needs.

4. Performance happens at the team level. Complex projects are always team endeavors that depend on a diversity of knowledge and talent. After the space shuttle experienced an in-flight anomaly during the launch of STS-126 in November 2008, it took the coordinated efforts of roughly 1000 people working at NASA and contractor centers across the country to understand what had happened and what risk this might pose to future shuttle flights. Experts in disciplines ranging from ballistics to computational fluid dynamics brought different knowledge and perspectives to bear on a problem that did not have a "silver bullet" answer. (We'll explore this case in detail in chapter 5.) The centrality of learning in the team context becomes critically important when we examine the shortcomings of traditional approaches to learning in project-based organizations.

5. A project workforce needs an integrated learning model. Workforce development efforts in project-based organizations typically focus exclusively on training for individuals. Given the criticality of team performance and knowledge sharing (as mentioned above), a robust development model needs to account for individual competence, team performance, and the effective sharing of knowledge across the organization.

Project failure is our starting point because it is a proven catalyst for learning.[6] At NASA this is well understood as a result of painful lessons like *Challenger.* The quote attributed to Gene Krantz in the film *Apollo 13* — "Failure is not an option" — is truly inspirational in a moment of operational crisis. But on large-scale projects that stretch over months or years, failure is an option. History has shown this to be true time and again, at NASA and elsewhere.

> **"A large organization can emphasize to its engineers that talking and thinking about failure are not signs of pessimism, but are ways to keep the principal goal — the obviation of failure — in the forefront. Success is best achieved by being fully aware of what can go wrong in a design — and designing against its happening."**
>
> Dr. Henry Petroski, Duke University,
> ASK OCE e-newsletter Vol. 1, Issue 10

[6] Through an empirical study of the global orbital launch vehicle industry since its inception in the 1950s, Peter M. Madsen and Vinit Desai conclude that "learning from large failures, rather than learning from success or small failures, primarily drives organizational improvement." See Peter M. Madsen and Vinit Desai, "Failing to Learn? The Effects of Failure and Success on Organizational Learning in the Global Launch Vehicle Industry," *Academy of Management Journal* 2010, Vol. 53, No. 3, p. 472.

In the aftermath of *Challenger*, NASA commissioned retired Air Force General Samuel C. Phillips, the former director of the Apollo program, to lead a NASA Management Study Group and make recommendations to the NASA Administrator. Among other things, his report called for the agency to "strengthen agency-wide leadership in developing and managing people." This led directly to the establishment in 1989 of the Program and Project Management Initiative. Sponsored by then-Deputy Administrator J. R. Thompson, it consisted of a series of training courses in the fundamentals of project management knowledge. This was the direct precursor to today's NASA Academy of Program/Project & Engineering Leadership. In short, the project academy is a legacy of NASA's commitment to learn from the *Challenger* failure.

The response to the *Challenger* accident was a starting point that focused on building individual competence. A decade later, NASA suffered the back-to-back failures of the Mars Climate Orbiter and the Mars Polar Lander. In the aftermath of those setbacks, NASA Administrator Dan Goldin made it clear that he expected the Academy to develop the capability of teams as well as individuals. It was a wake-up call that helped set the Academy on its present course of offering direct support to project teams in the field. Similarly, a report by GAO in January 2002 that looked at the Mars failures found "fundamental weaknesses in the collection and sharing of lessons learned agency-wide."[7] This spurred the Academy to expand the scope of its 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."[8] The Academy increased its support to teams and looked for new ways to address communications, organizational learning, and technical excellence. (Later chapters will go into detail about the Academy's activities to promote individual, team, and organizational learning.) In short, the Academy's core initiatives have their roots in failure.

One of the reasons for the gap that the Academy has sought to fill at NASA is that project management has evolved greatly over the past fifty years, but methodologies for developing practitioners have not kept pace. Even as project complexity has increased significantly in recent decades, most professional development efforts have remained focused on the iron triangle of cost, schedule, and technical performance. (We'll talk more about project complexity in the next chapter.)

Advances in technology are just one piece of the puzzle. Global supply chains, virtual teams, and the role of the customer are all different, to name just a few things. Cost, schedule, and technical performance are still critical, but the picture is significantly more challenging.

PRINCIPAL RECOMMENDATIONS OF THE NASA MANAGEMENT STUDY GROUP (1986)

1. Establish strong headquarters program direction for each major NASA program, with clear assignment of responsibilities to the NASA centers involved.
2. Improve the discipline and responsiveness to problems of the program management system.
3. Place shuttle and space station programs under a single Associate Administrator when the Administrator is satisfied that recovery of the shuttle will not thereby be compromised.
4. Increase management emphasis on space flight operations.
5. Place special management emphasis on establishing NASA world-class leadership in advanced technology in selected areas of both space and aeronautical technology.
6. Establish a formal planning process within NASA to enunciate long-range goals and lay out program, institutional, and financial plans for meeting them.
7. Strengthen agency-wide leadership in developing and managing people, facilities, equipment, and other institutional resources.

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[7] U.S. General Accountability Office, "NASA: Better Mechanisms Needed for Sharing Lessons Learned," GAO-02-195. Accessed 30 June 2010 at: www.gao.gov/new.items/d02195.pdf

[8] Columbia Accident Investigation Board, *Report Volume 1* (Washington, D.C.: Government Printing Office, August 2003), p. 12.

“The incorporation of new technology in a megaproject almost ensures that the project will make more mistakes than money. The use of new technology is the only factor that is associated with bad results in all three dimensions: cost growth, schedule slippage, and performance shortfalls.”

— Edward W. Merrow,
“Understanding the Outcomes of Megaprojects: A Quantitative Analysis of Very Large Civilian Projects,”
RAND Corporation (Santa Monica, CA, 1988).

Fortunately, there has been growing interest in the global project management community in new ways of building organizational capability. This book will offer an overview of the landscape for complex projects today as well as an account of some of the strategies and methods employed by the NASA Academy of Program/Project & Engineering Leadership to help develop the project management workforce at NASA. The approaches described here represent a way — not *the* way — to build capability. Other organizations may find very different solutions that better fit their needs.

Hoffman learned this lesson while working at Goddard Space Flight Center in the late 1980s before becoming involved with the precursor to the project academy. At one point he met with the Center Director to suggest different courses and offerings that might be valuable for the workforce.

“This isn’t what I need,” the Center Director told Hoffman. “You know what I need? I need something that’s going to tell me when my projects are getting into trouble. And then I need something that can turn them around. When you have that, come back to me.”

The direct quote above may have been burnished by time, but the sentiment remains correct. The only measure that matters in the end is project success.

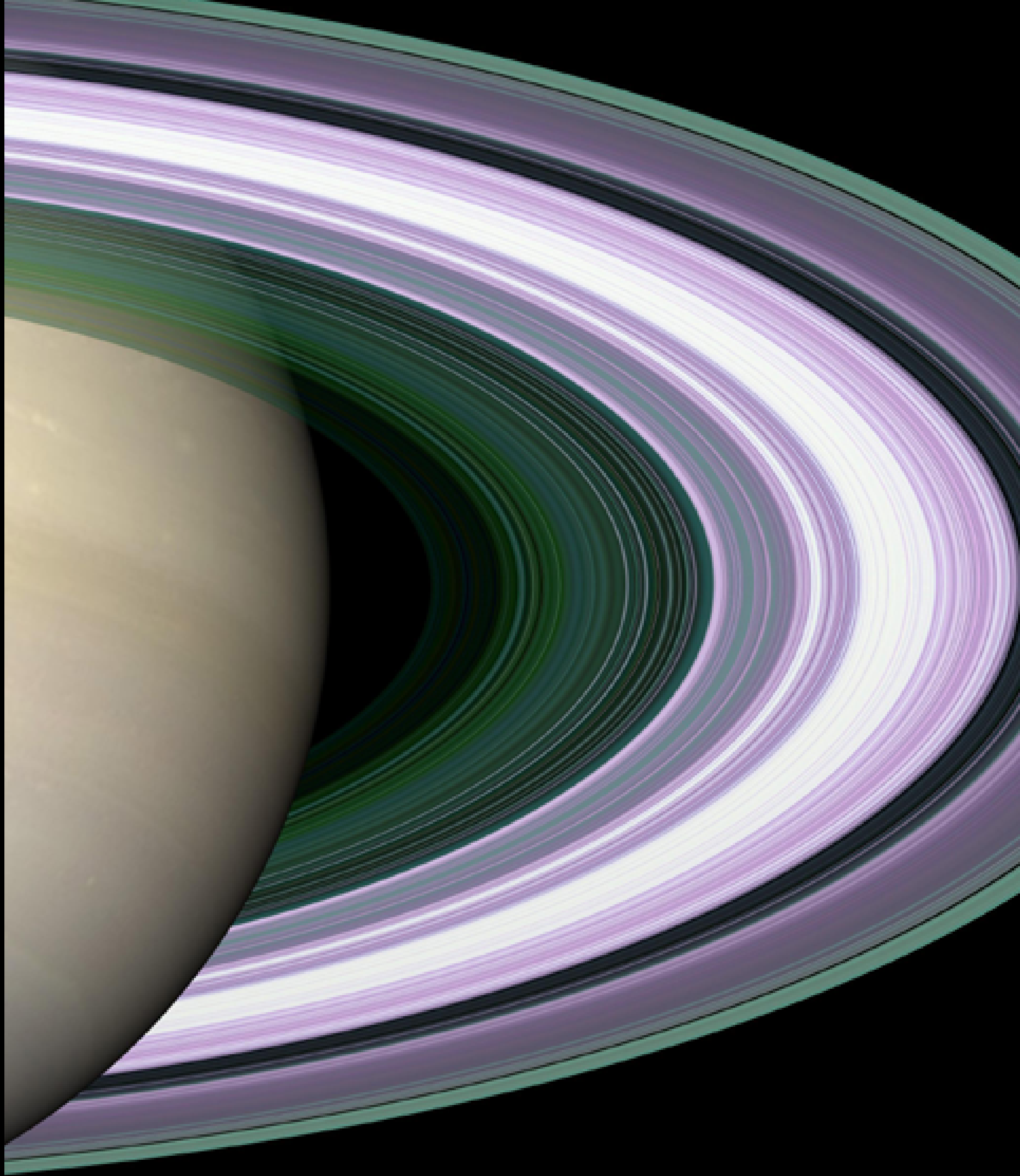
Chapter Two

COMPLEX PROJECTS AND THE RISE OF PROJECT ACADEMIES

If there is a sense of reality, there must also be a sense of possibility.

— Robert Musil

Saturn and its rings have fascinated astronomers since Galileo first observed it with his telescope in 1610. Nearly 50 years later, Dutch astronomer Christiaan Huygens, using a more sophisticated telescope than Galileo had, was able to identify the planet's rings as well as its moon Titan. Two decades after Huygens, Jean-Dominique Cassini discovered four more moons and the largest gap between the planet's rings.



Three centuries later, Cassini and Huygens served as the inspiration for two spacecraft that sought to explore Saturn and its moons up close. Cassini-Huygens, a partnership among NASA, the European Space Agency (ESA), and the Italian Space Agency, began a 1.5-billion km voyage from Earth in October 1997. The missions were ambitious. NASA's Cassini spacecraft would ferry ESA's Huygens probe to Titan, Saturn's largest moon, and release it for a dramatic descent to the lunar surface. Cassini would then continue on to conduct detailed observations of Saturn, its rings, and its moons.

By any standard, this was a complex undertaking. The science team alone included 260 scientists in 17 countries spanning 10 time zones. All the scientists involved wanted to maximize the opportunity to conduct experiments on this once-in-a-lifetime mission. All were equally aware that on a flagship mission like this, runaway costs would likely lead to de-scoping — the mission would be simplified, and some science instruments would get cut.

With 18 instruments slated to fly on the spacecraft, project manager Dennis Matson developed a free market system to manage payload reserves. After negotiating contracts with each of the Principal Investigators (PIs) for the instruments, he distributed the payload margin for each instrument — the dollars (per fiscal year), mass (in kg), power (in watts), and data rate to the spacecraft bus (in kilobytes per second) — directly to the PIs. This gave the PIs control over the fate of their respective instruments. Matson and his team then established a mechanism that enabled the PIs to trade those resources with each other, with all offers and trades recorded electronically. (The project manager, project scientist, and payload manager maintained veto authority over any trade.) The trades became quite complex, sometimes involving three or four parties and a "broker" to facilitate multiparty exchanges. The "Casino Mission," as the teams dubbed it, established a win-win ethos among the PIs and a strong sense of teamwork. In the end, all 18 planned instruments ended up flying on the spacecraft.

As Cassini-Huygens traveled through space on its journey to Saturn, a full test of the data communication system between the Cassini and Huygens spacecraft revealed a failure in the telemetry system. If not corrected, significant data from the Huygens spacecraft about Titan would be lost. The solution required changing Cassini's trajectory as it entered Titan's orbit. It proved to be a major technical challenge, and it used much of the Cassini spacecraft's fuel reserve. Since the terms of the international agreement between the agencies did not permit an exchange of funds that would enable ESA to compensate NASA for the use of Cassini's reserves on behalf of Huygens, ESA provided NASA with a different kind of resource: people. A small team of ESA engineers traveled to the United States to join their colleagues at the Jet Propulsion Laboratory. It was a creative exchange that proved beneficial to both sides.

In 2004, Cassini entered Titan's orbit and released the Huygens probe, which landed successfully on Titan's surface in January 2005. Cassini then went on to execute the rest of its mission through June 2008. With the spacecraft still in excellent operating condition at that point, NASA extended the mission until September 2010, renaming it the Cassini Equinox mission. Cassini-Huygens has unleashed an explosion of knowledge about Saturn, its rings, and its moons.

WHAT DO WE MEAN WHEN WE TALK ABOUT COMPLEXITY?

Cassini-Huygens exemplifies the complexity that characterizes many projects today. What do we mean by complexity in the realm of project management? Every organization or analyst grappling with the issue has a different definition. Terry Cooke-Davies of Human Systems, a UK-based project management consultancy, has quoted Professor Terry Williams of Southampton University as saying, "If you don't know what will happen when you kick it—that's complex." More seriously, Cooke-Davies writes, "A project can be said to be complex if it consists of many interdependent parts, each of which can change in ways that are not totally predictable, and which can then have unpredictable impacts on other elements that are themselves capable of change."[9] Professor Lynn Crawford of Bond University (Australia), noting the lack of consensus, writes that organizations often describe projects as complex based on multiple factors such as scope, clarity of goals and objectives, and level of ambiguity and uncertainty.[10] Applying Occam's Razor to the problem, we propose thinking about project complexity in three dimensions: technical, organizational, and strategic.

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[9] Terry Cooke-Davies, "Managing Projects in a Complex World," *Project Manager Today* (UK), June, 2011, p. 40.

[10] L.H. Crawford, "Beyond Competence: Developing Managers of Complex Projects." In *Proceedings of AIPM National Conference,* Darwin, October 2010 (Sydney: Australian Institute of Project Management).

DIMENSIONS OF PROJECT COMPLEXITY

Dimensions	Technical	Organizational	Strategic
Characteristics	• number and type of interfaces • technology development requirements • interdependencies among technologies (tight coupling vs. loose)	• number and variety of partners (industry, international, academia/ research) • distributed/ virtual team; decentralized authority • horizontal project organization • intensive learning needs	• number and diversity of stakeholders • socio-political context • funding source(s) and process(es) • geopolitical interests (international partnerships)

Figure 2.1. Project complexity can be described in terms of three fundamental dimensions.

Technical complexity is what it sounds like: the degree to which a system is so interconnected that a change in one place leads to a thousand complications in others. One of the key drivers of technical complexity is integration. George Low, the legendary leader of NASA's Apollo program, knew this was a key to Apollo's success.[11] He noted that only 100 wires linked the Saturn rocket to the Apollo spacecraft. "The main point is that a single man can fully understand this interface and can cope with all the effects of a change on either side of the interface. If there had been 10 times as many wires, it probably would have taken a hundred (or a thousand?) times as many people to handle the interface," he wrote. The space shuttle, on the other hand, had to be a highly integrated system because of its requirements for re-usability and landing like an aircraft, among other reasons. Due to advances in information technology and software, projects have become even more integrated in the decades since the shuttle was developed.

Organizational complexity stems from the number and types of partners involved in a project. Cassini-Huygens, for instance, included government, industry, university, and nonprofit research organizations. Complex project teams are typically distributed and virtual, posing challenges ranging from differing degrees of team situational awareness to logistical matters such as scheduling teleconferences (e.g., the Cassini-Huygens team crossed ten time zones). Organizational complexity raises larger questions of governance and authority, and can impede project team learning. We will come back to these issues shortly.

Strategic complexity refers to the number and diversity of stakeholders in a project. As a government agency in the Executive Branch, NASA is accountable to the White House, Congress, and ultimately the American public. Every dime spent on a NASA mission comes through the Congressional budgeting process, which involves a highly complex set of negotiations. NASA also receives guidance about how to prioritize its mission selection from the National Academies of Science, which draws on expertise from the science community. When international partners are involved in a mission, strategic issues multiply, as other government space agencies have to satisfy the needs of their own stakeholders. International missions also face regulations intended to stem the transfer of technologies that could be used to make weapons (e.g., the International Traffic in Arms Regulations, or ITAR). As Edwin Merrow noted in a RAND study of megaprojects, "Because the relationship between a project and its political environment are so important to project success, greater demands are placed on the skills of project managers."[12]

THE PROJECT-BASED ORGANIZATION

Once we acknowledge the role of complexity in projects, it is worth examining the context of an organization focused on complex projects and to determine how it differs from a functional organization.[13]

	Complex Project-Based Organization	Functional Organization
Problems	Novel	Routine
Technology	New/invented	Improved/more efficient
Team	Global, multidisciplinary	Local, homogeneous
Cost	Life cycle	Unit
Schedule	Project completion	Productivity rate
Customer	Involved at inception	Involved at point of sale
Survival skill	Adaptation	Control/stability

Figure 2.2. There are significant differences between complex project-based and functional organizations.

Projects provide a means for achieving an organization's strategic goals and objectives: "…projects are initiated to implement business, corporate, or organizational goals into action. They are the vehicles with which organizations execute their strategies, things get done, and decisions are being

[11] Thanks to T.K. Mattingly for bringing this to our attention. NASA SP-287 "What Made Apollo a Success." George M. Low, introduction. Accessed 4 October 2010 at: http://klabs.org/history/reports/sp287/ch1.htm

[12] Edward W. Merrow, "Understanding the Outcomes of Megaprojects: A Quantitative Analysis of Very Large Civilian Projects," RAND Corporation (Santa Monica, CA, 1988), p. 62. Accessed 28 June 2010 at: www.rand.org/pubs/reports/2006/R3560.pdf

[13] Michael Hobday, "The project-based organisation: an ideal form for managing complex products and systems?" *Research Policy* 29 (2000). A prosaic example of a functional organization might be Adam Smith's pin factory.

implemented."[14] The problems that complex projects seek to solve are novel in nature—they are often "firsts" or "onlies." The Chunnel, the Hubble Space Telescope, and the sequencing of the human genome are all examples of complex projects focused on novel problems; new technologies and processes had to be invented to accomplish them.[15]

Given the nature of these kinds of challenges, the customer is typically involved from the start in defining the project requirements. The teams that undertake these projects are multidisciplinary, bringing together experts in technical disciplines, business processes, logistics, information technology, and a variety of other domains, and often work virtually across time zones, geographic borders, and business sectors.[16] Cost and schedule are measured in terms of the project life cycle rather than at the unit level, though unit measurements (such as lines of software code completed per unit of time) can be significant indicators of overall project completion. Most significantly, the watchword for complex projects is adaptation, not stability, as many variables remain outside the direct control of the project manager throughout the duration of the project.[17]

STRENGTHS AND WEAKNESSES

The strengths of complex project-based organizations—adaptability to changing needs and circumstances, early and extensive involvement with customers, ability to mobilize necessary resources and people, and the intense focus on the end product of the project—are also the sources of three principal weaknesses. First, with factors such as virtual teams, international partnerships, and global supply chains shaping the environment of complex projects, authority is diffuse; the project manager often lacks control over important elements that can affect project success. Consider, for example, the International Space Station. The NASA program manager has no direct authority over Russian, Japanese, or other international partners. Second, the intense focus of a project team can lead to tunnel vision, limiting its ability to resolve problems that demand the free flow of ideas and knowledge from others within the organization, international partners, industry, the scientific community, and academia. Third, organizational cohesion and sustainability is difficult to foster in an organization of teams independently pursuing complex projects. Learning is decentralized, with individuals taking new experiences and expertise with them as they move from one project team to the next. This decentralization also makes knowledge sharing across the organization a challenge.

LEADERSHIP OF COMPLEX PROJECTS

The dynamics of complex projects pose leadership challenges that did not exist a generation ago. The changing nature of work—with virtual teams and cross-boundary collaborations and partnerships—has moved far from the beginnings of project management in command-and-control organizations defined by rigid hierarchies and clear lines of authority. For complex projects, mastery of traditional dimensions of project management such as cost, schedule, and performance is necessary but insufficient. With international partnerships, decentralized teams, and working alliances among government, industry, universities, and nonprofit organizations all increasingly common, complex projects also require leaders with advanced skills in areas such as negotiation, persuasion, and collaboration.

The lack of direct control in a complex project environment goes against the grain of a managerial culture, which values control and stability.[18] "Managers see themselves as conservators and regulators of an existing order of affairs with which they personally identify and from which they gain rewards," wrote Harvard Business School professor Abraham Zaleznik in a classic article on the distinction between leaders and managers.[19] Since complex projects are undertaken to transform the existing order of affairs—think of the Hubble Space Telescope or the Large Hadron Collider—and demand innovation as a precondition of success, their very nature is antithetical to linear management. Complex project leadership requires the ability to adapt to constantly changing dynamics. In this context, rigid control-based approaches represent a finger in the dike.

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[14] Aaron Shenhar, Michael Poli, Thomas Lechler, "A New Framework for Strategic Project Management," white paper from International Association for the Management of Technology, November 26, 2000, p. 2. Accessed 6 July 2011 at: http://www.iamot.org/paperarchive/101B.PDF

[15] For example, see Eric Chaisson, The Hubble Wars, p. 52.

[16] "Five Challenges to Virtual Teams: Lessons from Sabre, Inc."

[17] Heifetz, Linksy, and Grashow, *The Practice of Adaptive Leadership*

[18] Zaleznik, "Managers and Leaders: Are They Different?" HBR

[19] Ibid.

COMPLEX PROJECTS AND LEARNING

Given that one-of-a-kind complex projects require innovation, learning is a precondition of success. From a competitive standpoint, the abilities to learn and apply knowledge are the only advantages an organization has in a world of complex projects. A key risk in a complex project environment is not learning from what has worked or failed in the past. Learning by trial and error adds cost, inefficiency, and risk to an already complex endeavor.

As mentioned in chapter 1, most efforts to promote learning in a project-based organization focus on core competencies for project management. While clearly important, this emphasis on individual competencies overlooks the importance of team performance and knowledge sharing across the organization.

GOALS FOR LEARNING AT THREE LEVELS

Learning Level	Goal
Individual	Competencies
Team	Project success
Organization	Execution of corporate strategy

Figure 2.3. Learning strategies for individuals, teams, and the organization should recognize that each have different goals and objectives.

Effective learning strategies have to look beyond individuals and address goals for teams as well as the larger organization. This leads to the need for an integrated learning model, which we will address shortly.

THE PROJECT ACADEMY

In the fall of 2008, representatives from Shell, Rolls Royce, BAE Systems, Motorola, Siemens, Fujitsu, NASA, and other global organizations met for a workshop facilitated by Human Systems in Amsterdam to discuss their respective project academy initiatives. The fact that these diverse organizations came together to address this common interest raises a question: what is a project academy? How can it meet the unique needs of a project-based organization?

A project academy is a response to the need for continuous learning in a complex project-based organization. By tailoring its approach to the unique needs of the project community while maintaining strategic alignment with the organization, a project academy can bridge a gap between the needs of the project workforce and those of the organization.

Like a project itself, a project learning organization has to be nimble and adaptive. Project knowledge is not timeless—it is local in nature and changes constantly. The project academy has to follow suit and be adaptive to the needs of its customer, which in this case is the project workforce. There are other stakeholders in the project academy, but the direct customer is the project practitioner.

PROJECT ACADEMY ROLES AND RESPONSIBILITIES

While the purposes and objectives of project academies differ according to organizational needs and cultures, there are some common roles and responsibilities:

Project workforce development. A primary function of any project academy is ensuring that project practitioners have the necessary professional development tools and training. This begins with the identification of competencies and culminates in the mobilization of talent, performance support, and knowledge for targeted projects.

Advocacy for the learning requirements of practitioners. The project academy serves as the voice of the practitioner community with regard to its professional development needs. It has the responsibility to advocate for the leadership support and resources necessary to meet those needs.

Defining key concepts and vocabulary for the project community. The project academy is uniquely suited to play an integrating role across the project community. This can include providing thought leadership as well as a common framework and terminology for projects.

Alignment with corporate strategy. Corporate strategy plays a large part in defining the context in which projects operate. The project academy is responsible for ensuring that competencies and associated activities are consistent with corporate strategy, goals, and policies.

Alignment with external stakeholders. Depending on the organization, external stakeholders can have a great influence on requirements for the project community. As with corporate strategy, the project academy is responsible for aligning competencies and associated activities with external stakeholder requirements and goals as necessary.

Promotion of communities of lifelong learning. Given the previously mentioned challenges that project-based organizations face in terms of learning, the project academy has an important role to play in bridging these gaps. By promoting learning at all stages of a career through a range of activities, the project academy helps to create a community of practitioners who are reflective and geared toward sharing.

Promotion of sustainable organizational capability. As with lifelong learning, the project academy plays an important role in building institutional knowledge that enables the organization to sustain itself as projects come and go. By promoting knowledge sharing across the organization, the project academy can ensure that key lessons and knowledge remain accessible.

ORIGINS OF THE NASA ACADEMY OF PROGRAM/PROJECT & ENGINEERING LEADERSHIP

As mentioned in chapter 1, the origins of the NASA Academy of Program/Project & Engineering Leadership date back to the 1986 space shuttle *Challenger* accident. Since then it has expanded its scope and range of offerings in response to project failures (such as the Mars Climate Orbiter and the Mars Polar Lander in the late 1990s) as well as feedback from external stakeholders such as the U.S. Government Accountability Office (GAO). We will talk more about those developments in future chapters.

From an organizational standpoint, NASA established the Academy in its Office of Human Capital in the mid-1990s. A decade later, after the *Columbia* accident, the Academy moved to the Office of the Chief Engineer, a technical organization with much closer working relationships with project and engineering practitioners than the Office of Human Capital. Since the Office of the Chief Engineer is responsible for project management and engineering policies and standards, it functions as a *de facto* central project management office (PMO) for NASA. This alignment of the Academy with the agency's policy and strategy is essential to its goals. (See below.)

PROJECT & ENGINEERING LEADERSHIP

Mission: To support NASA's mission by promoting individual, team, and organizational excellence in program/project management and engineering.

Goals:

- Provide a common frame of reference for NASA's technical workforce.
- Provide and enhance critical job skills.
- Support engineering, program and project teams.
- Promote organizational learning across the agency.
- Supplement formal educational programs.

The Academy has developed its approach to workforce development based on four underlying assumptions, some of which we discussed in chapter 1. First, we assume that project practitioners know best. All knowledge sharing activities are practitioner-centered, and extensive efforts are made to maintain close ties with the practitioner community. Second, internal qualitative research has found that practitioners say 90% of learning takes place on the job. Workforce development offerings have to reflect the importance of on-the-job learning. Similarly, practitioners have made it clear that learning is contextual, and that different career stages have different requirements. As a result, the academy employs a multi-level career development framework with associated activities for each career level. Finally, in recognition of the fact that project work takes place through teams, it assumes that optimal performance and learning come together at the team level. This has led to the development of a range of activities for supporting project teams.

The NASA project academy focuses its activities at three levels: individual practitioners, project teams, and the organization.

- ***Individual practitioners.*** The project academy offers competency-based training, developmental assignments, and hands-on opportunities to help individual practitioners develop their skills at each level of their careers.

- ***Project teams.*** Since most learning takes place within the project team, our best chance of facilitating project success is at the team level. The NASA project academy currently supports over 100 project and engineering teams by offering a variety of tools and services: online assessments measuring team performance, workshops focusing on team effectiveness, technical life cycle support, and intensive coaching, mentoring, and consulting with expert practitioners.

- ***Organization.*** At the agency-wide level, the academy invests in knowledge sharing strategies that emphasize the power of telling stories through forums and publications in order to help create a community of practitioners who are reflective and geared toward sharing.

We will go into detail about the activities at each level in subsequent chapters. By focusing on individuals, teams, and the community as a whole, the Academy creates multiple "touch points" for professional development. In the process, individuals build their competencies skills, teams get the support they need in the field, and the agency matures as a learning organization. It is a flexible model that we will continue to adapt as the needs of NASA's workforce, projects, and stakeholders continue to evolve.

DEVELOPING INDIVIDUAL, TEAM, AND ORGANIZATIONAL CAPABILITY

	APPROACH	ACTIVITIES
INDIVIDUAL	• Training curriculum • Development programs	• Core curriculum • In-depth offerings • Hands-on opportunities
TEAM	• Direct support to project teams	• Online assessments • Workshops • Mentoring/coaching • Expert practitioners • Mentoring/coaching • Technical support
ORGANIZATION	• Knowledge sharing	• Forums • Publications • Case studies • Multimedia • Communities of practice

Figure 2.4. The NASA Academy of Program/Project & Engineering Leadership builds individual, team and organizational capability.

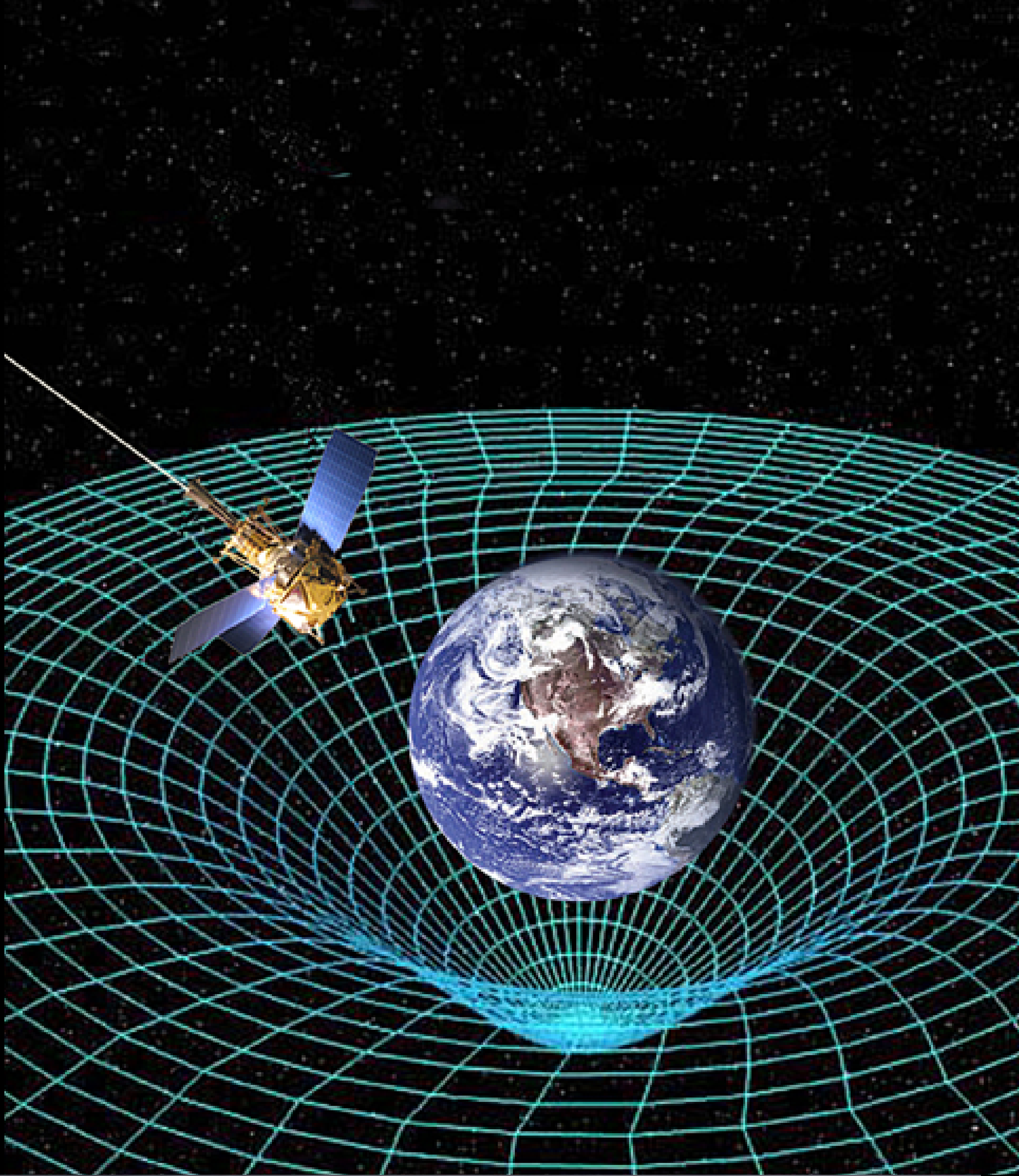
Chapter Three

BUILDING INDIVIDUAL CAPABILITY

"You never really understand a person until you consider things from his point of view — until you climb into his skin and walk around in it."

— Harper Lee

In the summer of 2003, Rex Geveden, Program Manager for NASA's Gravity Probe B (GP-B) mission, was eager to ship the GP-B spacecraft to Vandenberg Air Force Base for integration and testing and then launch. Geveden, whose involvement with GP-B began in 1995 while he served as Spacecraft and Systems Manager at Marshall Space Flight Center, retained the title of GP-B Program Manager even after becoming Deputy Center Director at Marshall. Earlier that year, the program had undergone a termination review, which in his estimation, had been a close call. Getting the spacecraft to the launch pad would remove the threat of imminent cancellation. "We have to ship this thing to Vandenberg as fast as we can possibly ship it, because nobody will 'un-ship' us," he thought.



GP-B was no stranger to the threat of cancellation. By this point, it was in the home stretch of its development after earning the distinction of being NASA's longest-running project in the history of the agency. Its scientific experiment was originally conceived in 1959, just a year after NASA's founding, and it first received funding from the agency in 1964. During its nearly 40-year history, the program had faced cancellation numerous times, only to have its funding restored, often as a direct result of the personal lobbying efforts of Principal Investigator Dr. Francis Everitt of Stanford University. Even after the spacecraft had been shipped to Vandenberg, the possibility of cancellation due to a delay still loomed large for all parties involved.

Cancellation wasn't the only dark cloud on the horizon; other issues cast long shadows that year as well. NASA endured intense scrutiny after the loss of the space shuttle *Columbia* on February 1, 2003. An accident investigation took place throughout the spring and summer, culminating in the release of the Columbia Accident Investigation Board (CAIB) Final Report in late August. The report was highly critical of NASA, faulting its approach to risk management and safety as well as its organizational culture. In this heated political context, everyone working with or for NASA was keenly aware that all eyes were on the agency.

GP-B arrived at Vandenberg in July 2003. As NASA and its contractor teams from Stanford and Lockheed Martin checked out the spacecraft and its various systems in preparation for its Flight Readiness Review, engineers reviewing the data from functional tests of the satellite's payload turned their attention to a problem with the Experimental Control Unit (ECU), a box on the spacecraft that housed a number of electronic components. The ECU, which had been slated for testing months before, created significant signal interference ("noise") in the Superconducting Quantum Interference Device (SQUID), the highly sensitive magnetic field detector that would provide measurements critical for the mission's science objectives.

Once engineers discovered that the interference originated in the ECU, they constructed a massive fault tree to determine the possible causes of the problem. Engineers from Stanford and Lockheed Martin, the contractor that had built the box, agreed that there was a grounding issue, and that the ECU power supply was the likely culprit. Fixing the ECU would not prove easy. The resolution of this very specific technical problem would ultimately require a significant management decision involving all the key organizations with responsibility for the development of GP-B.

The GP-B experiment, which sought to test two of the predictions of Albert Einstein's general theory of relativity, required one of the most sophisticated spacecraft designs ever utilized for a NASA mission. It employed the world's most precise gyroscopes, spinning in a vacuum that insulated them from the effects of any external forces. The gyro's rotors were the most spherical objects ever produced, rotating at high speed in tight casings that they could not touch. The maintenance of a perfectly drag-free environment required the spacecraft to use micro-thrusters to make constant minute adjustments in its position in order to keep the gyros perfectly in place.

A critical piece of hardware was a dewar, a nine-foot tall Thermos bottle that formed the main structure of the space vehicle. The dewar was filled with liquid helium cooled to a temperature of almost absolute zero, transforming the helium into a "superfluid" state so it could serve as a completely uniform thermal conductor. Filling and cooling the dewar to the proper temperature was a process that took several weeks; once cooled, its maintenance at that temperature was no simple task.

Given the complexity of the dewar and the continuous calibrations of the spacecraft's position required to sustain the drag-free environment, it is not much of an exaggeration to say that the entire spacecraft *was* the instrument. There was zero room for technical performance error.

Within this highly integrated structure, the ECU housed multiple electronic instruments and gauges. Its most critical role was to control the Gas Management Assembly (GMA) that would spin up each of the gyroscopes by blowing a stream of 99.99% pure helium gas over each gyroscope's rotor. In addition to housing the GMA, the ECU's instruments also monitored the dewar, acting as a fuel gauge.

Because the ECU was already on the spacecraft, which was far along in its integration process, fixing it would be no easy matter. By the time the analysis of the ECU problem was completed in October 2003, the dewar had been filled, cooled, and sealed. The spacecraft's four solar arrays were being installed. Momentum was building toward the launch, which was scheduled for December 6, 2003.

The leader of the Stanford team, Program Manager Gaylord Green, was confident that the ECU did not pose a risk to the mission because of the extensive test program he had implemented. From his point of view, the ECU only had to work long enough to spin the gyros up to speed; it could then be turned off so the noise in the signal did not interfere with the experiment data. "I was fairly comfortable that the ECU would work on orbit for the length of time (necessary)," he said. "If we shut the ECU off at that point, what we lost was the dewar monitoring and some of our instrumentation on our cryogenics. I was confident that it would spin up the gyros, I was confident that we could succeed through the mission, and so I pushed hard that we should go ahead and fly."

Bill Bencze, Stanford's electronics manager at the time, saw the problem differently than Green did. "My chief worry was ECU reliability; the system had to function during the checkout phase of the mission or the mission would fail," he said. "Experience with other DC-to-DC converters (power supplies) of this type in other boxes showed them to be quite fragile when operated improperly."

Lockheed Martin, which had built the ECU, had its own Mission Assurance team at Vandenberg working the problem. Bill Reeve, Lockheed's Program Manager for GP-B, focused on the reliability question. "You couldn't initialize the experiment without the ECU working. It only needed to work for a few months, but it did need to work. If the ECU failed initially when it got up on orbit, we wouldn't have been able to initialize the science experiment and the whole mission would have been a failure."

The prospect of de-integrating GP-B, pulling the ECU, and then reintegrating the spacecraft carried the significant risk that something would be damaged in the process; none of the parties working on it underestimated its complexity. Every day at the launch pad added risk to the overall mission. There was also pressure in terms of human resources. The Boeing team at Vandenberg in charge of the Delta launch vehicle for GP- B was scheduled to move on soon to another mission.

The ultimate authority for the decision rested with NASA, which had final responsibility for the mission. Ed Ingraham, a member of the NASA team at Vandenberg, requested that Stanford compile a list of everything that would need to be re-handled if the ECU was taken off the spacecraft. In order to remove and repair the ECU, the following items would have to be removed and re-installed: all four solar arrays, which were extremely touch-sensitive; numerous thermal blankets; and the Forward Equipment Enclosure (FEE), which housed a majority of the science electronics boxes. The dewar would also have to be serviced to maintain its superfluid temperature and pressure. The original installments took three months, and the solar arrays would become particularly vulnerable by being handled twice. There was also the issue of "unknown unknowns," such as earthquakes.

At Marshall Space Flight Center, Rex Geveden chaired a Configuration Control Board meeting for GP-B. He and Marshall Center Director Dave King solicited opinions from the Center's engineering and safety & mission assurance organizations about how to handle the ECU. Buddy Randolph, the GP-B Chief Engineer, and Jeff Kolodziejczak, NASA's GP-B Project Scientist, both advocated in favor of proceeding to launch without pulling the ECU.

No decision was made at the Configuration Control Board meeting. Afterward Geveden met with some members of the Marshall GP-B team in his office, including Ingraham, who had flown out from Vandenberg and was on his way back. Ingraham mentioned the concerns of Bill Reeve from Lockheed. Geveden had worked with Reeve in the past and respected his expertise. He decided to speak privately with Reeve. He also spoke privately with Gaylord Green.

As the integration process continued at the launch pad, tensions neared a boil. The Payload Attach Fitting (PAF), which joined the spacecraft with the launch vehicle, had been mated. The next step was the installation of the explosive bolts that would allow the spacecraft to separate from the launch vehicle during ascent. This was the point of no return, after which it would be impossible to pull the ECU. It was time for a decision that only the program manager could make it.

★ ★ ★

How does an organization prepare individuals in its workforce to exercise leadership in a highly dynamic environment? On a personal level, this raises a question that serves as the title of a book by Rob Goffee and Gareth Jones: why should anyone be led by you?[20]

[20] Rob Goffee and Gareth Jones, *Why Should Anyone Be Led by You? What It Takes to Be an Authentic Leader* (Boston: Harvard Business Press, 2006).

NASA is an embarrassment of riches in the area of scientific and technical expertise. The excitement of the agency's mission enables it to attract leading practitioners in a wide variety of disciplines ranging from robotics to earth science to space medicine. Individuals come to NASA with outstanding academic backgrounds, often in highly specialized fields requiring advanced degrees. Many have worked in private industry and bring valuable knowledge of commercial best practices. The professional development challenge for the agency is ensuring that these highly talented individuals have the opportunity to succeed within NASA.

LEARNING AT NASA

In the spring of 2007, we asked 70 expert practitioners attending Masters Forum 14 to answer the question, *"How do you learn to do your job?"* Participants discussed the question in small groups of six to eight, recorded their responses on flip charts, and then shared their reflections with the larger group. The responses from that session yielded so much valuable information that we repeated the activity with participants at Masters Forums in April 2008, October 2008, and May 2009.[21] The qualitative data gathered from these small and large group discussions with roughly 275 experienced practitioners have enabled us to draw some conclusions about how successful individuals learn to do their jobs at NASA, including the identification of four key dimensions of effectiveness. (See Figure 3-1.)

[21] Masters Forum participants, who have been selected to attend by their NASA Center Directors, are typically mid-to-senior project managers and engineers with 15-20 years of experience at NASA. Each forum also includes a few junior participants who exhibit high potential as well as guest attendees from non-NASA organizations.

THE 4 A'S

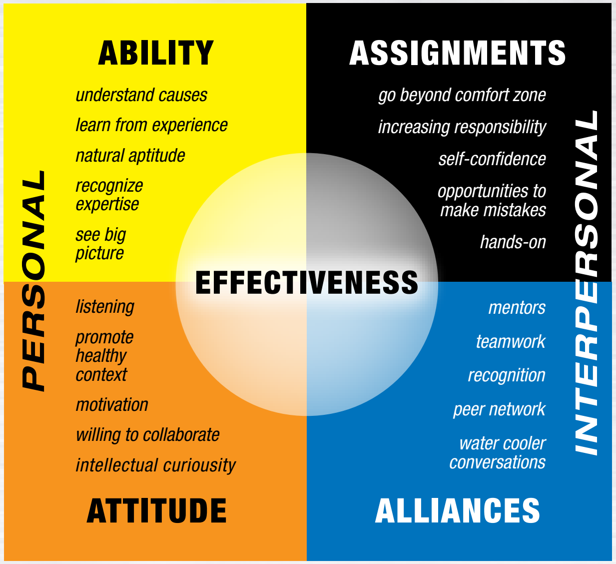


Figure 3-1. There are four dimensions to personal effectiveness at NASA.

In her 1977 book *Men and Women of the Corporation*, Rosabeth Moss Kanter identified activities and alliances as avenues to power, which for the purposes of her study she defined as "closer to 'mastery' or 'autonomy' than to domination or control over others."
While we examined a different question than Kanter did, two of the dimensions that emerged in our research, assignments and alliances, corresponded roughly with Kanter's findings. The other two, ability and attitude, reflect the nature of NASA as a project-based organization that demands high levels of technical expertise as well as teamwork.

Ability is a combination of natural aptitude, skill level (which increases with practice), and the capability to assimilate new knowledge and learn from experience. While innate talent is certainly part of the equation—just as very few people possess the right attributes to become concert pianists or Olympic athletes, very few are also likely to succeed as NASA scientists or engineers—continuous improvement and learning is a critical element of skill development. In the context of NASA, this includes being able to learn from errors and failures and identify causes and patterns that can lead to future successes. Ability also refers to systems thinking and "seeing the big picture." In an organization where many projects are best understood as systems of systems, the importance of being able to conceptualize large, integrated systems increases as an individual progresses through his or her career.

Attitude is closely related to the development of ability. Motivation and intellectual curiosity are prerequisites for success at NASA: expert practitioners never stop asking questions or wanting to know more. They possess a relentless focus and a passion for their subject that drives them to work hard for the sake of learning more about their subject area. This passion translates into going beyond expectations to ensure success. In a project-based organization, attitude also encompasses the willingness to work successfully as a member of a team. Since all work at NASA takes place in team settings, it is impossible to overstate the importance of mastering the attitudes and behaviors that enable optimal teamwork. This calls for developing skills such as empathy, listening, and self-awareness.

Assignments are the core learning experiences that lead to the development of personal expertise. When aligned properly with an individual's career level, assignments represent opportunities to develop specialized knowledge, learn from mistakes, build self-confidence, and take on increasing responsibility. Assignments move in two directions: experts seek assignments that will enable them to pursue their areas of interest, and difficult situations demand experts who possess specialized knowledge. Individuals who have gained recognition for their expertise are rewarded with high profile, challenging assignments that are meaningful and valuable to the organization. Work assignments are the proving ground for effectiveness, whether an individual's expertise is technical or managerial, and success leads to a positive feedback loop of more progressively difficult assignments.

Alliances are relationships that enable an individual to succeed within an organization. Mentors and peers are critical for exchanging ideas, sharing experiences, and soliciting advice or opinions. Alliances also play a role in obtaining assignments: professional networks and recognition by superiors can open doors for challenging or high profile work. Expert practitioners create alliances as they progress through their careers, and their success in turn attracts others seeking alliances. Perceptions are central to alliances—a reputation for being a good person to work with is critical to the successful cultivation of constructive relationships. Given the growing importance of "smart networks" that enable project teams to leverage expertise from around the world (see chapter 6), alliances are becoming more critical by the day.

Ability and attitude are intrinsically personal qualities—nobody can give another person a better attitude or a greater ability to do a job. Alliances and assignments, on the other hand, are interpersonal by definition. In an organization like NASA, cultivation of both the personal and interpersonal dimensions is necessary to be effective, though the balance differs for each individual and area of expertise.

The Academy promotes individual professional development that addresses these "4 A's" through multiple channels, including:

- Identifying a career development framework and an integrated competency model for project management and systems engineering.
- Offering a curriculum that includes both core and in-depth courses in areas ranging from Mars mission design to green engineering.
- Sponsoring developmental assignments and hands-on opportunities to help individual practitioners develop their skills.

> **"Experience may possibly be the best teacher, but it is not a particularly good teacher."**
>
> — James March, *The Ambiguity of Experience*

INTEGRATED COMPETENCY MODEL AND CAREER DEVELOPMENT FRAMEWORK

The Academy's approach to developing individual capability begins with its integrated competency model and career development framework. These tools emerged as the Academy's precursor, the Program/Project Management Initiative (PPMI), matured beyond its initial course offerings in project management. In the early 1990s, Lieutenant General Sam Armstrong (ret.), then NASA's Associate Administrator of the Office of Human Resources and Education, pushed for the development of competencies so that practitioners would know what was expected of them.

The Academy developed its competency model through a multi-step collaborative process. It first derived its requirements based on extensive interviews with highly successful NASA project managers and systems engineers. It then incorporated input gathered through the DACUM (Developing a Curriculum) methodology and practitioner focus groups. After devising a draft competency model, the Academy validated it with internal and external organizations that reviewed it for both thoroughness and accuracy. Validation also included aligning it with NASA policies and procedures as well as existing project manager competency models at NASA field centers and leading external organizations. Once validation was complete, the Academy created performance-level descriptions to guide the overall development of individuals through each phase of their careers.

The development of the systems engineering competencies followed the same methodology. By 2009, after extensive collaboration with stakeholders in both disciplines, the Academy reviewed and consolidated its existing competency models for project management and systems engineering into an integrated competency model consisting of five project management competency areas, three systems engineering competency areas, and five competency areas common to both disciplines. (See Figure 3-2.)

INTEGRATED COMPETENCY MODEL

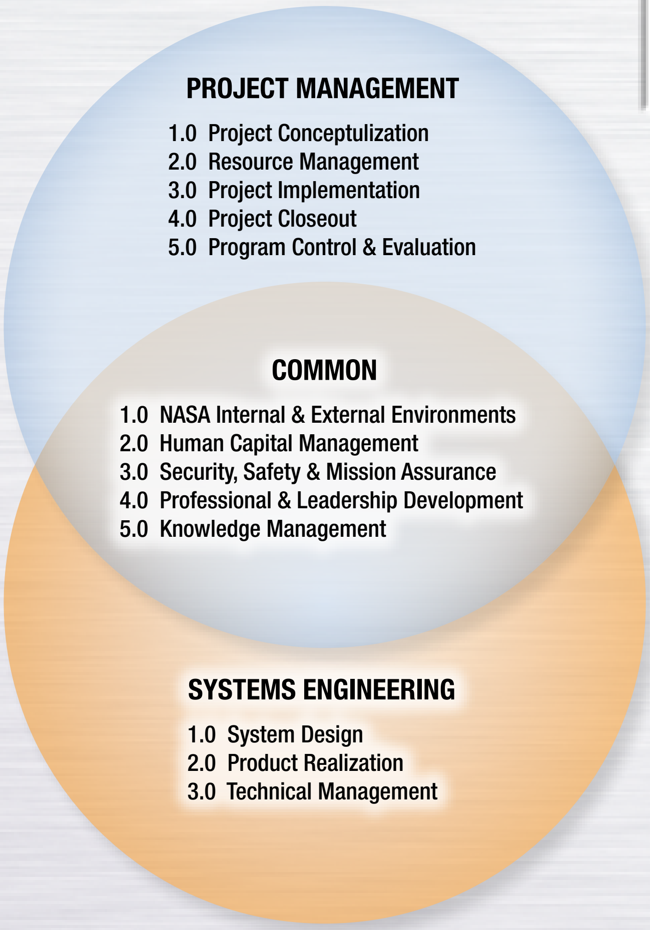


Figure 3-2 The Academy employs an integrated competency model that addresses project management, systems engineering, and shared competencies. See Appendix X for a full list of all competencies and sub-competencies. See Appendix A for a more detailed breakdown of the competency model.

Today every Academy training course, team intervention, or knowledge sharing activity has a direct relationship to at least one NASA competency. The competency model undergoes regular reviews to ensure that it remains relevant to the needs of NASA's practitioners.

The career development framework represents a progression through four levels of increasing responsibility over the course of an individual's career. It identifies the blend of formal training, on-the-job learning, knowledge sharing, mentoring, and coaching that should happen at each level as well as the exit criteria for moving to the next level. (See Figure 3-3 for a high-level overview.)

Together, the competency model and the career development framework provide the foundation of the Academy's approach to developing individual capability. Both have been vetted extensively

CAREER DEVELOPMENT FRAMEWORK

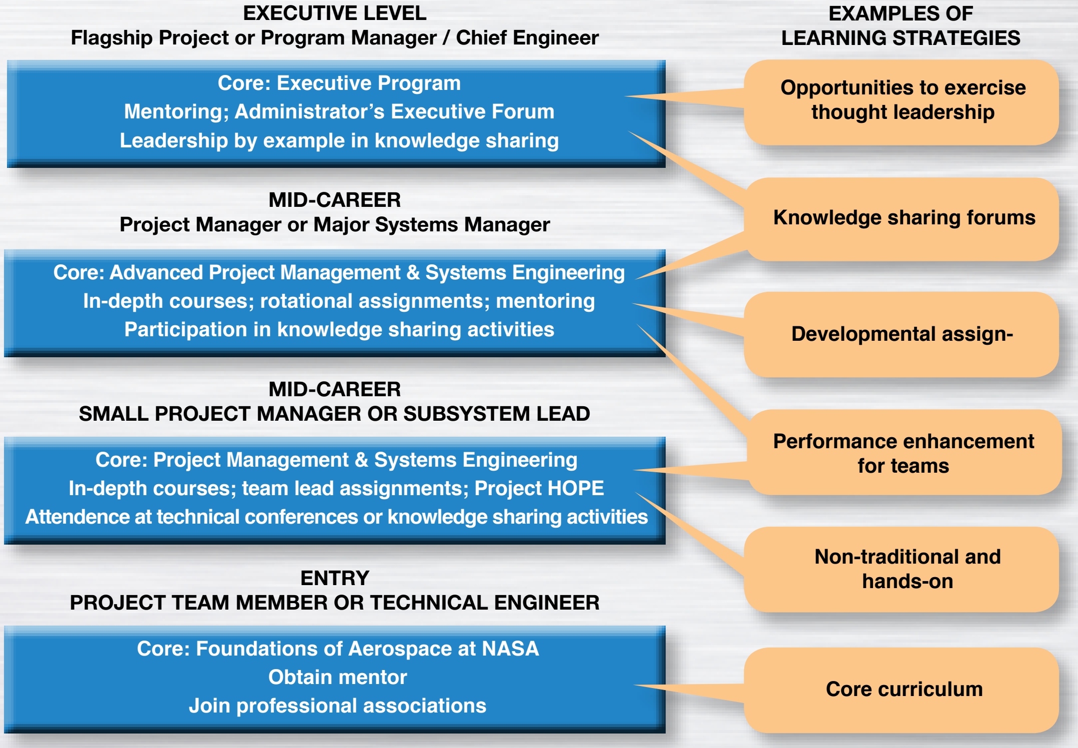


Figure 3-3. The career development framework identifies key learning experiences at four career levels. A more detailed version provides specific guidance about courses, on-the-job learning, and other activities.

by practitioners over the past two decades and reflect our best understanding of the combination of knowledge, skills, and experiences necessary to thrive within NASA.

> **"For learning from experience to be effective, the learner must be self-aware and have a degree of humility that may be missing in some practitioners especially if they believe and have certifications to attest to their "competence" as project managers. The use of personal experience as a resource in adult learning is well established but we need ways to "animate" useful learning from experience that will translate into the mastery required to manage challenging projects."**
>
> Lynn Crawford, "Beyond Competence: Developing Managers of Complex Projects"[23]

[23] L.H. Crawford, "Beyond Competence: Developing Managers of Complex Projects," Proceedings of AIPM National Conference, Darwin, October, (Sydney: Australian Institute of Project Management, 2010), p. 6.

CURRICULUM

As with the competency model and career development framework, the starting point for the training curriculum has always been the community of practitioners at NASA. In the period before the development of the first competency model for project management, the content for PPMI's first courses, "Project Management" and "Advanced Project Management," came from the recommendations of a program/project management working group. The experts who participated in this group, many of whom had begun their careers with Apollo, Viking, Voyager, and other early NASA successes, used this as an opportunity to codify their own experiences as senior practitioners.

Core curriculum. The core curriculum focuses on building NASA-specific expertise and capability in project management and systems engineering. It is intended to supplement an individual's academic and professional work experience, and is sequenced according to career level.

All core courses are based on the integrated competency model, and course designers regularly update the content to reflect the latest developments in project management and systems engineering. NASA subject matter experts often serve as instructors since they can speak from first-hand experience about the relevance of the content to their own work.

CORE CURRICULUM

The Academy's core curriculum consists of the following four courses:

Foundations of Aerospace at NASA is designed for employees who began work at NASA within the last five years. The learning objective of this course is to give participants a solid understanding of the NASA organization and its principles of technical excellence. Topics include NASA's strategic direction, governance model, organizational structure, technical guidelines, and history.

Project Management and Systems Engineering is designed for NASA project practitioners and systems engineers prior to or in the first year of entry into project, systems engineering or supervisory positions. The learning objective is to enhance proficiency in applying project management and systems engineering processes and practices over the project life cycle. It places a strong emphasis on the integration of project management and systems engineering principles.

continued ▶

Advanced Project Management and Advanced Systems Engineering is designed for technical professionals who have had prior supervisory experience with projects or systems. The learning objective is to give experienced practitioners a deep understanding of the challenges of leading and managing programs and projects in a complex and dynamic environment. Topics include the formulation and implementation of integrated systems and organization architectures, advanced acquisition strategy, review and oversight, and approaches to identifying and mitigating risks such as changing requirements and unanticipated budget reductions.

International Project Management is designed for project managers, systems managers, systems engineers and program managers who work on international projects. Since all of NASA's human spaceflight program and 70% of its science missions involve international partners, the ability to work effectively with international partners is critical. Topics include cultural challenges, legal concerns, and teaming issues that are likely to be encountered working with international partners.

The course development or redesign process is a rigorous one involving extensive input from a wide range of practitioners. In early November 2010, for example, 15 NASA stakeholders—including representatives from six different centers and multiple NASA Headquarters offices—gathered at Kennedy Space Center to evaluate a redesign of "Project Management and Systems Engineering." (See above description.) This meeting was just one aspect of the collaborative effort that the Academy undertakes in this four-phase process. (See Figure 3-4.)

The redesign of this course was prompted by systems engineering stakeholders, including the Systems Engineering Working Group, and confirmed by the project management stakeholder community. Other input considered in curriculum development and redesign includes the Academy's annual data call for training requirements from the centers, NASA's State of the Agency Report, feedback from formal Academy surveys of NASA stakeholder communities, and ongoing identification of emerging and evolving needs from key stakeholder groups (including NASA's mission directorates, center training offices, practitioners and mission support offices). Changes in policy—both internal and external—create unique and time-sensitive challenges for the Academy to keep up with key policy revisions and updates. Ongoing communication with the stakeholder community is a key factor in meeting this challenge.

CURRICULUM DEVELOPMENT AND REDESIGN PROCESS

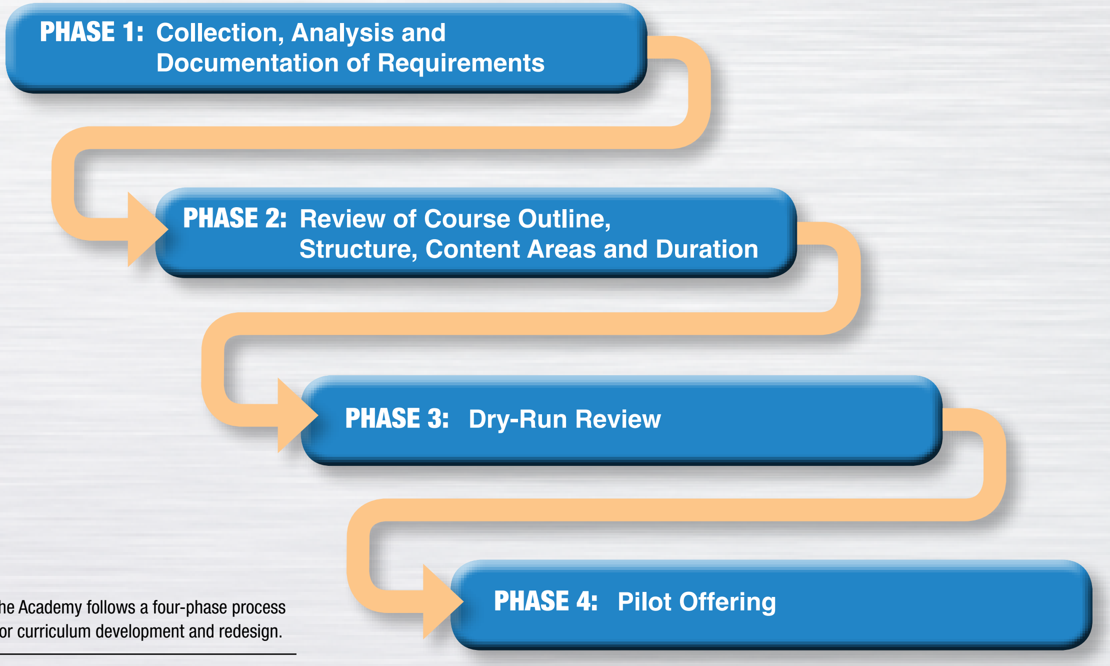


Figure 3-4. The Academy follows a four-phase process for curriculum development and redesign.

In-depth courses. In-depth courses address topics beyond the core curriculum that have specific relevance for NASA's project and engineering workforce. These continually evolve in response to the changing needs and requirements of the practitioner community. In 2010, for example, the Academy debuted "Orbital Debris Mitigation and Reentry Risk Management," which addresses the critical issue of ensuring that spacecraft and their payloads do not create debris that can pose hazards to other spacecraft operating in low-Earth orbit. Since then, the White House Office of Science and Technology Policy (OSTP) has issued a new National Space Policy that calls for the use of these same practices, and the subsequent NASA Strategic Plan has reinforced this message.

In-depth courses also sometimes emerge from cross-pollination with the Academy's knowledge sharing activities. (These will be detailed in chapter 5.) For example, the Academy worked with NASA's Environmental Management Division in late 2009 to hold the agency's first-ever "green engineering" forum to explore sustainable practices across all phases of the project lifecycle. This dovetailed with a Presidential Executive Order that set sustainability goals for the federal government. Over the next year, the Academy consulted with the Environmental Management Division and decided that a green engineering training course would now be appropriate to address emerging requirements, lessons learned and best practices across NASA, and perspectives from academia and industry.

In short, in-depth courses offer a means of adapting rapidly to the changing requirements that our practitioners face and providing them with the explicit knowledge and skills they need to succeed at the individual level.

DEVELOPMENTAL ASSIGNMENTS AND HANDS-ON OPPORTUNITIES

Training courses offer one means for building individual capability, but there are clear limits to what can be achieved in a classroom setting. (Would you trust a surgeon whose only preparation was medical school?) Practitioners have told us over the years that 90% of learning takes place on the job. (The earlier discussion of the "4 A's" reflects the importance that practitioners place on development experiences other than traditional training.) Formal development programs and hands-on learning provide early and mid-career professionals with on-the-job learning experiences that accelerate their professional development and readiness to lead.

The ***Systems Engineering Leadership Development Program*** (SELDP) grew out of a need identified by NASA leadership and the Office of the Chief Engineer for an agency-wide leadership development program that would help identify and accelerate the development of high-potential system engineers, with a focus on specific leadership behaviors and technical capabilities that are critical to success in the NASA context. The program aims to develop and improve systems engineering leadership skills and technical capabilities within the agency. SELDP graduated its first class of systems engineers in June 2009. Tom Simon, a systems engineer from Johnson Space Center who spent eight years in the Space Shuttle Program, reflected on the importance of his developmental assignment working on the **Fast, Affordable, Science and Technology SATellite (FASTSAT),** a microsatellite designed to carry six small experiments into space: "I don't think they (the SELDP team) could have picked a better assignment, team, or organization for me," he said. "If the first 10 years (of my career) are any sign, I'll be learning every day until I retire."[24]

Project HOPE (Hands-On Project Experience) is a cooperative workforce development program sponsored by the Academy and the NASA Science Mission Directorate. It provides an opportunity for a team of early entry NASA managers and engineers to propose, design, develop, build, and launch a suborbital flight project over the course of a year. The purpose of the program is to enable practitioners in the early years of their careers to gain the knowledge and skills necessary to manage NASA's future flight projects. The first project team selected, the Jet Propulsion Laboratory's (JPL) Terrain-Relative Navigation and Employee Development (TRaiNED), kicked off in May 2009 and launched in December 2010 from the White Sands Missile Range in New Mexico. (A series of weather-related delays postponed the launch for six months.) In the Spring 2011 issue of ASK Magazine, TRaiNED project manager Don Heyer described the growth that he witnessed on the day of the launch:[25]

> *As the launch window nears its end, most people are beginning to resign themselves to another weather cancellation when, with just a*

[24] "Academy Brief: The SELDP Year from Three Perspectives," ASK the Academy Vol. 4 Issue 1, January 31, 2011. Accessed 13 July 2011 at http://www.nasa.gov/offices/oce/appel/ask-academy/issues/volume4/AA_4-1_SF_brief.html

[25] Don Heyer, "Reflecting on HOPE," ASK Magazine, Issue 42, Spring 2011. Accessed 13 July 2011 at: http://www.nasa.gov/offices/oce/appel/ask/issues/42/42s_reflecting_hope.html

few minutes remaining, Dr. Martin Heyne (the TRaiNED principal investigator) announces that there's been just enough of a clearing in the weather to go for the launch.

If an argument ever had to be made in support of Project HOPE, it was exemplified by the following fifteen minutes. The calm, composed manner in which each member of the project team quickly transitioned from a weather-induced limbo to efficiently executing the final steps of the launch countdown was rewarding to watch and special to be a part of. The collective poise exhibited by the team as the rocket left the rail didn't exist in 2008. It was poise that could not have come from attending classroom lectures or from reading a stack of books. It came from experience.

The Academy has also supported hands-on opportunities and developmental assignments by providing support to professional development programs at various NASA centers that address "local" needs. This enables the centers to leverage the Academy's agency-wide resources while tailoring project manager and systems engineering development programs to their specific situations.

LESSONS ABOUT DEVELOPING INDIVIDUALS

Individual development can build competence, capability, and confidence. It does not guarantee optimal performance at the team level.

Professional development does *not* equal training. Blended learning includes courses, developmental assignments, support in a team context, mentoring, coaching, and participation in knowledge sharing activities such as forums and publications. Fully 90% of an individual's development comes from work experience.

The 4 A's (ability, attitude, assignments, and alliances) determine ultimate individual success. Build an integrated development program that incorporates all four factors.

The competency model is the basis for all training and development. It must link directly to the organization's policies and standards and serve as the starting point for determining learning objectives and outcomes.

A career development framework allows practitioners to visualize the career path and identifies career-specific knowledge and experiences. As a rule of thumb, career models should focus on entry-level, mid-career, and executives.

Primary stakeholders should be involved in the development of the competency model and the design of core training courses. Establish working groups of practitioners to hear their thoughts and implement their guidance.

continued ▶

A strong practitioner connection will build institutional support for the program.

Core and in-depth training courses should be separated. Core represents a limited number of critical learning experiences tied to career transitions (e.g., from entry level to mid-career). In-depth courses address specific needs of a discipline or domain. This distinction allows for growth and contraction based on need and available funding.

Respected leaders and practitioners within the organization are a valuable asset. Use them as core faculty members and/or storytellers. This will establish the relevance, credibility, and influence of training and development activities.

Measures help tell a story about the development of individual capability. The measurement approach should be based on the requirements that are most important to the organization's senior leadership. The ultimate measures are project success and a satisfied practitioner base.

CODA: REX'S DILEMMA

Against the advice of his GP-B Chief Engineer at Marshall and his prime contractor's Program Manager at Stanford, Geveden decided to scrub the launch and pull the ECU off the spacecraft. It was a difficult decision. Early estimates were that the total cost of the decision would be $20 million.

Once the cover came off the ECU, the teams from Stanford and Lockheed found more problems than they expected. "When we pulled the box... we actually found three other problems in the design," said Bill Bencze of Stanford. "Once you popped open the box and found these other issues that weren't apparent from the schematics, you were able to fix those (as well)."

The Lockheed team that examined the box found that the power supply cases were not grounded, and that due to a design flaw the box employed the wrong filter pin connectors for the box's switching converters, which handled very high power density at very fast switching times.

At that point, Bill Reeve of Lockheed had very little confidence in the ECU. "I asked for an independent audit of all the circuits in the box, and I brought in electronics experts from around the country to come and have a review of every single circuit in the box. And I think they found 20-some issues—I don't remember the (exact) number of issues," he said. "We went through every single one, to determine whether or not they need to be repaired, need to be fixed, to make sure that all the proper analyses were performed to make sure the box was healthy."

The box was repaired and returned to the spacecraft. The total cost of the stand-down was close to $11 million. The teams from Stanford and Lockheed reintegrated the spacecraft and prepared it for launch. Five and a half months after the decision to scrub the launch, Gravity Probe B lifted off successfully from Vandenberg on April 20, 2004.

Chapter Four

BUILDING HIGH-PERFORMANCE TEAM CAPABILITY

You will unite, or you will fail.

— J.R.R. Tolkien

In May 2006, a team at Glenn Research Center led by project manager Vince Bilardo received provisional authority to proceed with designing, developing, and building an upper stage mass simulator for the Ares I-X test vehicle as an in-house project. This test flight called for a vehicle with an unpowered upper stage (i.e., no engine) that would have the same mass and physical characteristics as an actual upper stage. The team at Glenn would develop the hardware in its own facilities using its own technical workforce, rather than contracting the job out to private industry.

The selected design required manufacturing eleven segments of half-inch thick steel that stretched 18 feet in diameter and nine and a half feet tall. The job would incorporate all the basic hardware manufacturing functions: cutting, rolling, welding, inspecting, sandblasting, painting, drilling and tapping for instrumentation.

Preparing for a fabrication job of the size and scope of the Upper Stage Simulator demanded a wholesale renovation of a facility: new cranes, new assembly platforms, and a new sheet metal roller. This meant retrofitting an older manufacturing shop floor that was large enough to accommodate the hardware. The facility modification had to be done quickly—in about three or four months—so the project could begin work as scheduled on its first "pathfinder" segments.

Since the project team was beginning with limited in-house expertise in large-scale fabrication or manufacturing, it required an entirely new set of procedures that documented each step of the building and assembly process. An additional challenge was demonstrating compliance with AS 9100, an aerospace manufacturing quality standard. Glenn's management team was making a center-wide effort to achieve AS 9100 certification. For the upper stage simulator (USS), this meant putting in place rigorously documented procedures that met with the approval of both the Safety and Mission Assurance organization and the technicians doing the work. The AS 9100 standard added another level of rigor to the process of designing and building the hardware.

Management of the USS project called for constant interaction with the other three NASA field centers responsible for Ares I-X and its integrated product teams (IPT): Langley Research Center (systems engineering & integration office and the crew module/launch-abort system simulator IPT), Marshall Space Flight Center (first stage, avionics, and roll control system IPTs), and Kennedy Space Center (integration and test functions as well as the launch itself). Bilardo spent a significant amount of time traveling or otherwise coordinating with his counterparts at these centers. With his focus increasingly on these "up-and-out" management duties, he needed a deputy who could handle the "down-and-in" details of running the project on a daily basis.

He turned to Bill Foster, his lead systems engineer, who had project management experience from his years on microgravity science projects where he'd served as both the project manager and systems engineer. With Foster moving over to project management, the team needed a new lead systems engineer. They brought in Tom Doehne, who was just finishing up a trade study for the Upper Stage Thrust Vector Control (TVC) System of the Ares I vehicle.

Doehne's primary focus was on managing the design integration of the simulator hardware, documenting the design in the Design Definition Memorandum (DDM), and developing the project requirements. The design evolved and the requirements database kept expanding as the larger Ares I-X management team kept adding more requirements for the Upper Stage Simulator. He realized he needed more systems engineers to support the project. "Initially, I was the only systems engineer as we were developing this task, and we had a lot of work up front that we were trying to do in the early July-November (2006) timeframe," he said.

As the systems engineering workload increased leading up to a Systems Requirement Review (SRR), Doehne had trouble finding qualified systems engineers. The new Orion and Ares I projects at Glenn had been ramping up over the past year. Eventually he was able to transition two civil servants who were in Glenn's Space Mission Excellence Program (SMEP), a professional development initiative, as well as some experienced contractor support. "We took qualified engineers from other areas of the center who were in training as systems engineers. They received real project experience, and we were able to complete the large volume of work that was in front of us," Doehne said.

In addition to knowledge and experience, Doehne valued team members who could remain engaged and be flexible on a project with an aggressive schedule and a rapidly changing context. "Team dynamics is also a very important key to building a successful project team and shouldn't be mistaken for something that isn't needed," he said. "In today's projects with limited budgets and aggressive schedules, we need to work as a cohesive team unit and have the ability to adapt to a dynamic work environment to achieve our common goal."

Figure 4.1. The Ares I-X Upper Stage Simulator consisted of eleven "tuna can" segments.

The scale of the USS demanded a manufacturing capability that didn't exist at Glenn. The recent focus of the center's manufacturing efforts had been on microgravity payloads that called for the highly intricate machining of sophisticated instruments, not on the rough fabrication skills needed to roll, weld, and attach large segments of a launch vehicle. This fundamental reorientation toward heavy manufacturing posed challenges both in terms of the workforce and the organization. Glenn had several highly skilled machinists among its civil service workforce, but it had few fabricators and a critical shortage of welders. There was also a need to reconfigure the manufacturing organization.

Building a project team with the right competencies to undertake this new work would prove to be the greatest project management challenge.

★ ★ ★

How does an organization build the team capability necessary to do something it has never done before? Or something no organization has ever done?

Project performance happens at the team level. Perhaps no lesson is as important as that one. While individual competence is critical, there is no way that a complex project can achieve success without a high-performance team.

The Academy began its work supporting project and engineering teams in response to the back-to-back failures of the Mars Climate Orbiter and the Mars Polar Lander in the late 1990s. In the immediate aftermath of those failures, Dan Goldin, then the NASA Administrator, made it clear that he expected the Academy to find a way to help develop teams, not just individuals. He wanted to ensure that no project would fail due to a lack of support for team development. This mandate was reinforced by the NASA Integrated Action Team (NIAT) report of December 2000, which wrote that, "NASA must invest in enabling team competency."[26]

The assertion that project performance happens at the team level may seem obvious, but at the time it was a wake-up call that helped set us on our present course. Team support is our most requested service today, and our activities in this area have attracted the attention of organizations ranging from the American Society of Training and Development to the Central Intelligence Agency.

[26] "Enhancing Mission Success: A Framework for the Future," NASA Chief Engineer and the NASA Integrated Action Team, December 21, 2000, p. 16. Accessed 13 July 2011 at: history.nasa.gov/niat.pdf

The Academy's work with teams has included activities such as: workshops focusing on team effectiveness; online assessments measuring team performance; technical support; and intensive coaching, mentoring, and consulting with expert practitioners. While it might seem that technical support would be the most sought-after service in an engineering organization like NASA, the reality is the reverse. The demand has been far greater for team building services, which validates our working assumption that *projects are first and foremost about people.*

Our approach to team building, begins with a powerful force that can play a crucial role in determining its success: its storyline.

What exactly do we mean by a project's story? In short, it's the ongoing conversation we have about a project. How can it have any impact on mission success? Imagine the following:

A new project starts up, and the excitement is palpable. The core team consists of smart, highly dedicated professionals who come to work early and stay late. Even so, there are question marks about ambiguous requirements and technology readiness for a key component. As the project moves from one phase to the next, the question marks become fault lines, and eventually cracks begin to appear. Requirements creep kicks in from outside the project. A teammate who seemed highly driven turns out to be inflexible in the face of the changing environment. The project becomes a source of constant anxiety for you and a few colleagues who "get it." A milestone review determines that you're approaching the red zone. Rumors begin to circulate about your cancellation.

We all know the feeling of a project storyline that gets away from us. A project's negative story, or its context, can become a self-fulfilling prophecy. Likewise, a positive storyline can reinforce the things that are going right and help steer a project toward a successful outcome.

Responsibility for the project's storyline begins with the project manager. Ultimately he or she plays a key role in helping to shape the story for the team on a daily basis as well as for others outside the project. A project manager who understands the power of the story knows how to incorporate both the positive and negative developments into the storyline in a way that is constructive and honest. Managing the negative or challenging elements of the story is critical. Denying the negative is a surefire way of destroying the credibility of the story and the storyteller. At the same time, setbacks have to be framed in an appropriate context in order to prevent them from taking on lives of their own that can be destructive.

Responsibility for the storyline does not end with the project manager, though. Every team member owns a part and contributes to it every day through meetings, conversations, emails, and any other form of communication. The story we tell others becomes our story. We need to be aware of the power of that story to shape the perceptions of others, ranging from our teammates to senior leaders.

The stories of our projects are not simply instruments that we manipulate to further our own ends; that is the definition of propaganda. Though we can play a central role in shaping our stories, they respond to multiple dynamics that are not fully under our control. Ultimately our stories simply reflect the truth as we understand and convey it — nothing more and nothing less. As the political theorist Hannah Arendt once said, "Storytelling reveals meaning without committing the error of defining it."

Another synonym for the project storyline is its context. This is a useful way to think of project teams because they always exist within multiple contexts—divisions, centers, mission directorates, NASA, and even the global scientific, engineering, and aerospace communities. The team building methodology employed by the Academy, which has been developed by Dr. Charles Pellerin, former director of the astrophysics division at NASA, places a heavy emphasis on understanding the project team context.[27] Pellerin has drawn heavily from the "broken windows" theory of sociologists George L. Kelling and James Q. Wilson, which looked at the connection between untended minor vandalism in city neighborhoods and more serious urban decay. In a seminal article in the March 1982 issue of the *Atlantic Monthly*, Kelling and Wilson wrote, "…one unrepaired broken window is a signal that no one cares, and so breaking more windows costs nothing."[28]

[27] For an in-depth look at Pellerin's methodology, see Charles J. Pellerin, *How NASA Builds Teams: Mission Critical Soft Skills for Scientists, Engineers, and Project Teams* (Hoboken, NJ: John Wiley & Sons, Inc,) 2009. Much of this information is also freely available at: http://www.4-dsystems.com/

[28] George L. Kellering and James Q. Wilson, "Broken Windows," *Atlantic Monthly,* March 1982. Accessed April 7, 2011 at: http://www.theatlantic.com/magazine/archive/1982/03/broken-windows/4465/2/

In other words, tolerance for small instances of unacceptable behavior initiates a larger deterioration of norms. In a project setting this can manifest itself in any number of ways. One person always arrives late to team meetings, and eventually others do as well. A single bad attitude leads to a culture of complaint, spreading like a virus among the team. A toxic personality pits individuals or groups against each other. The list can go on and on.

The broken windows theory bears some similarity to Diane Vaughan's concept of the normalization of deviance, which she developed after analyzing the decision-making that preceded the *Challenger* accident:

> *"The explanation of the* Challenger *launch is a story of how people worked together developed patterns that blinded them to the consequences of their actions. It is not only about the development of norms but about the incremental expansion of normative boundaries: how small changes—new behaviors that were slight deviations from the normal course of events—gradually became the norm, providing a basis for accepting additional deviance."*[29]

While the broken windows theory focuses on evident flaws, Diane Vaughn's concept of the normalization of deviance addresses flaws in thinking and behavior that develop invisibly in project teams over time. These can include incremental changes that

[29] Diane Vaughan, *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA* (Chicago: University of Chicago Press, 1986), p. 409.

stem from phenomena such as groupthink, in which group members may not be wholly cognizant that they have moved away from previous norms.[30]

The foundation of this approach to interpreting a team's context is a survey-based assessment tool. The current version asks each member of a project team to answer eight questions in an online survey. Once the data from all team members are aggregated, a profile of the team's context emerges. Team members also provide anonymous assessments of their colleagues, facilitating honest discussions about personal strengths and weaknesses in the team setting. Post-assessment services typically include a combination of team workshops, personal coaching, and consultations with experienced practitioners. Like Charlie Pellerin, many of the experts working directly with the teams are retired NASA and aerospace industry veterans who understand the workings and culture of the agency. This translates into credibility with practitioners, many of whom have had little or no exposure to this type of professional skills development.

Since beginning this work, the Academy has supported approximately 500 NASA teams and 2,000 individual practitioners. This has provided sufficient data to yield reliable a baseline against which new team assessments can be compared. While there is an inherent methodological limitation to this approach (since the universe consists solely of NASA teams, it only defines excellent and poor performance in terms of what's normal for NASA), we can also draw qualitative inferences that help validate these findings. For instance, the vast majority of NASA space flight projects achieve at least their minimum goals for mission success, and a great many far exceed expectations. (To cite just one example, the Mars Exploration rovers Spirit and Opportunity were slated to last 90 days when they were launched in 2004; Spirit completed its mission in May 2011, and as of this writing, Opportunity is still alive.) This suggests that the data collected about high-performing teams at NASA corresponds to the reality of project performance.

The team building approach focuses on developing the behaviors found in high-performing teams and eliminating those found in teams with bad storylines.

EIGHT BEHAVIORS MEASURED IN TEAM AND INDIVIDUAL ASSESSMENTS

1. Express authentic appreciation
2. Address shared interests
3. Appropriately include others
4. Keep all your agreements
5. Express reality-based optimism
6. Be 100% committed
7. Avoid blaming and complaining
8. Clarify roles, accountability, and authority

(Source: Charles J. Pellerin, How NASA Builds Teams)

The assessments measure how often teams and individuals say that they fully meet the behaviors listed above. As straightforward as it sounds, this approach has yielded measurable results for NASA teams over a period of several years. The gains are particularly dramatic for teams that score in the bottom quintile (i.e., the lowest 20 percent). After interventions and re-assessments, the vast majority of poorly performing teams show marked improvement, moving into the second-highest quintile by the time of their fourth assessments.

TEAM PERFORMANCE BEFORE AND AFTER INTERVENTIONS

Figure 4.2. Teams in the bottom quintile show marked improvement with each successive re-assessment. (Adapted from Charlie Pellerin, 4-D Systems)

[30] Vaughan references Irving L. Janis's *Groupthink: Psychological Studies of Policy Decisions and Fiascoes.*

NEW CONCEPTIONS OF TEAMS

There are also new frontiers for working with teams in project-based organizations like NASA. Recall the Cassini team that we mentioned in chapter 2, with 260 scientists in 17 countries spanning 10 time zones. Similarly, the International Space Station provides an analogue in terms of human spaceflight. (See Figure 4.3.) Today's teams are virtual and distributed in ways that were unimaginable a generation ago.

The challenge of successfully managing virtual teams remains unsolved. Despite significant research in this area (and tremendous incentives to find solutions), there are no clear answers about best practices for getting optimal performance from a distributed team or a virtual workforce. Many organizations have done interesting studies about problems such as maintaining consistent levels of awareness among remotely located team members,[31] but none have cracked the code.

THINKING DIFFERENTLY: THE IMPORTANCE OF DIVERSITY

Some of the most compelling research in recent years has looked at the importance of cognitive diversity—bringing together people who think differently than each other. Professor Scott E. Page of the University of Michigan has identified four "frameworks" for cognitive diversity:

- **Diverse perspectives** – ways of representing the world
- **Diverse interpretations** – ways of creating categories
- **Diverse heuristics** – techniques and tools for making improvements
- **Diverse predictive models** – inferences about correlation and cause and effect

Through a rigorous logic exercise, Page demonstrates that diverse groups get better outcomes than homogeneous ones.[32] The implications for complex project teams are clear—in a world where knowledge is the only competitive advantage, cognitive diversity is critical for bringing the best ideas to the table. This insight suggests that the trend toward employing global, distributed teams to tackle complex projects—as we've seen with the International Space Station, the Large Hadron Collider, and the ITER nuclear fusion reactor, among others—will only increase in the years to come. We don't collaborate solely in the interest of sharing financial burdens; we also work together because there is strength in the diversity of talent.

In a time when expertise can come from any corner world, we're beginning to see an emerging model

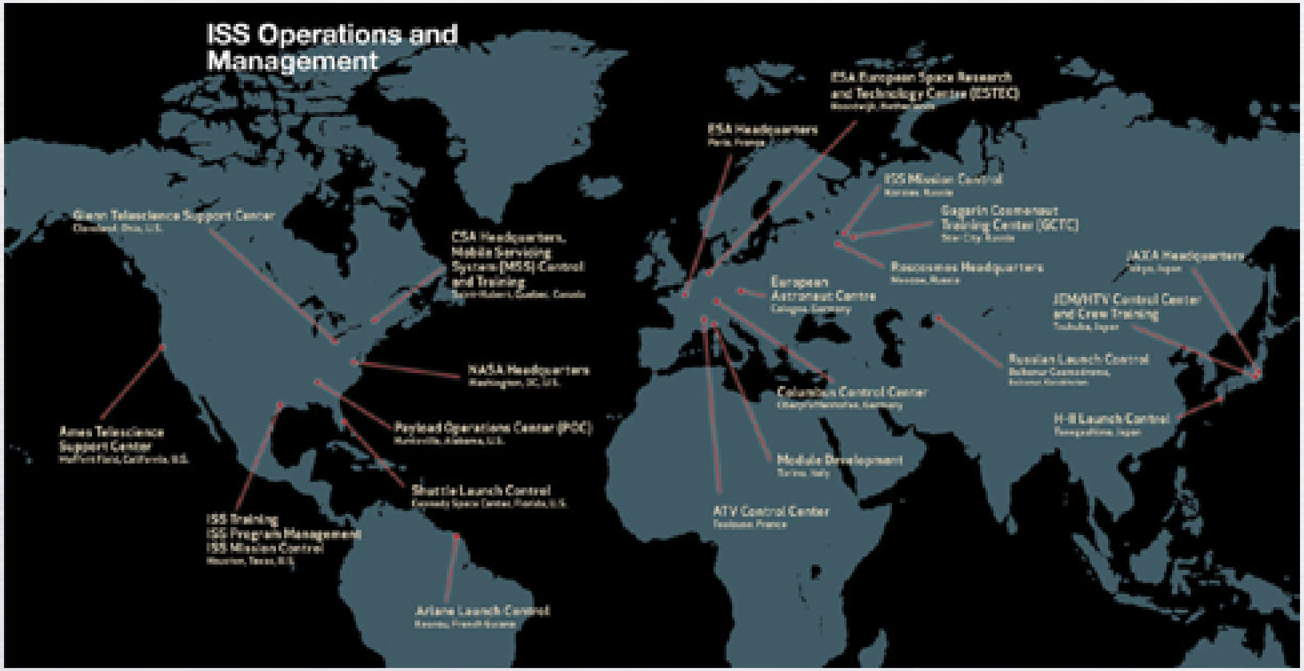


Figure 4.3. The International Space Station operations and management team spans four continents. (Source: *International Space Station Guide,* ISS International Facilities and Operations, nasa.gov)

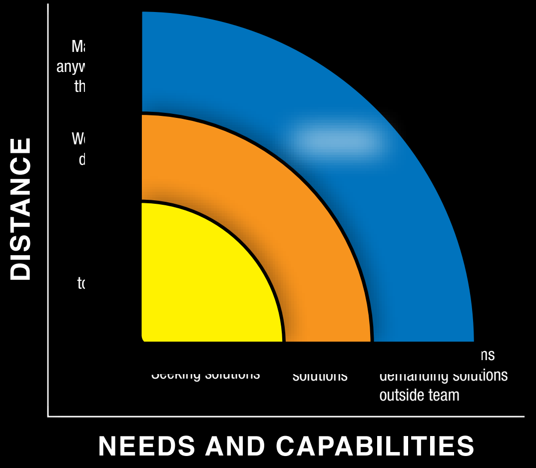
[31] See, for example, A.J. Bernheim Brush, Brian R. Meyers, James Scott, and Gina Venolia, "Exploring Awareness Needs and Information Display Preferences Between Coworkers," Microsoft Research, April 2009. Accessed 10 May 2011 at: http://research.microsoft.com/apps/pubs/?id=79361

[32] Scott E. Page, *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies* (Princeton, NJ: Princeton University Press, 2007).

of a team that goes far beyond the traditional conception. In the last five decades we've seen an evolution from distributed teams (Apollo and Space Shuttle) to global distributed teams (International Space Station) to the present day, where the *potential team*—the most inclusive collection of talent that can be harnessed around the world, regardless of national boundaries—offers the greatest possible cognitive diversity.

LOCAL, VIRTUAL AND POTENTIAL TEAM MEMBERS

- **Local** – Team members are specifically connected and identified as part of a project. Usually have at least occasional in-person contact.
- **Virtual** – Team members are specifically connected and identified as part of a project, but are geographically dispersed.
- **Potential** – Individuals who are not connected or identified with a project at the outset, but who have expertise or influence that can contribute to project success.



There's little doubt that we have yet to see the true power of the potential team, but we already have some idea of the possibilities. Software projects such as the Linux operating system and Mozilla's Firefox browser offer one indication. The aerospace world has also generated its own examples. The winner of NASA's 2007 Astronaut Glove Challenge was Peter Homer, a resident of Southwest Harbor, Maine who had no previous expertise in human spaceflight or glove design and discovered the competition by accident while surfing the Internet. "I had to make it up, because there is no book you can buy about this. There is no pattern," Homer told the *New York Times* after winning the prize.[33] As he later recounted in *ASK Magazine*:

> *One of the things that interested me was that competitors had to build the hardware; this wasn't just a design competition. At the time, I was heading up a medium-sized nonprofit and had been away from aerospace engineering for a while, so this was to be strictly a personal challenge, a "science project" to pursue in my spare time. Creating a better astronaut glove appealed to me because it would be a good test of my skills and was a small enough project to do in my garage. As it turned out, the bulk of the fabrication took place on my dining room table.*[34]

Whether he realized it or not, Peter Homer was part of the potential team that was helping the next generation of astronauts. We are likely to see more Peter Homers play a part in designing solutions to the problems that accompany every complex project. For the time being, there are obvious limits to the uses of the potential team—we're not suggesting that a heavy-lift launch vehicle can be built in the backyard. But we've only just begun to understand the power of the potential team and the full impact it can have on project-based organizations.

[33] Jack Hitt, "The Amateur Future of Space Travel," *New York Times Magazine*, July 1, 2007.

[34] Peter Homer, "The Astronaut Glove Challenge: Big Innovation from a (Very) Small Team," *ASK Magazine* Issue 29, Winter 2008.

Chapter Five

KNOWLEDGE SERVICES: BUILDING ORGANIZATIONAL CAPABILITY

"I will reveal unto thee, O Gilgamesh, the mysterious story, and the mystery of the gods I will tell thee."

— The Epic of Gilgamesh

On November 14, 2008, as *Endeavour* rocketed skyward on STS-126, flight controllers monitoring data noted an unexpected hydrogen-flow increase from one of the shuttle's three main engines.[35] Despite this in-flight anomaly, the launch went smoothly—since the flow control valves for each engine work in concert to maintain proper pressure in the hydrogen tank, one of the other valves reduced flow to compensate for the greater flow from the valve that malfunctioned. The likely causes of the problem were either an electrical failure or a mechanical failure, which might have resulted from a broken valve. This would require immediate attention as soon as STS-126 landed safely.

[35] We are indebted to Don Cohen, Managing Editor of *ASK Magazine*, who served as co-writer of the full-length version of the case study featured in this chapter.

"We knew at least on paper the consequences could be really, really bad, and this could have significant implications for the orbiter fleet and, most urgently, the next vehicle in line. Depending on where the vehicle landed, we wanted to get these inspections done and some X-rays done as quickly as we could," said John McManamen, chief engineer of the Space Shuttle Program.

Shuttle and ISS program managers preferred launching STS-119 prior to mid-March so it would not interfere with the March 26 mission of the Russian Soyuz to transport the Expedition 19 crew to the ISS. If the launch were delayed until after the Soyuz flight, interdependencies in the schedule would require a reevaluation of other future launches.

STS-126 touched down at Edwards Air Force Base on November 30 after unfavorable weather conditions at Kennedy Space Center led flight controllers to divert the landing to California. This delayed work until December 12, when the shuttle was ferried back to Kennedy aboard a specially equipped 747.

A December 19 X-ray showed evidence of a problem with a poppet, a kind of tapered plug that moves up and down in the valve to regulate flow. Inspection determined that a fragment had broken off, the first time such a problem had occurred during flight, although there had been two similar failures in the early 1990s during testing of a new set of flow control valves for *Endeavour*. "We knew we had a pretty significant problem well outside our experience base at that point," said Orbiter Project Manager Steve Stich.

There were a total of twelve flight-certified valves in existence: three in each shuttle, and three spares. Simply buying more was not an option—these custom parts had not been manufactured in years, and NASA had shut down its flow control valve acceptance-testing capability.

Understanding the causes and implications of the failure was essential to the safety of future shuttle missions. Management would have to promote and ensure open communication among the multiple organizations involved in the shuttle program so that all relevant information would be available to decision makers with the responsibility to approve or delay future shuttle flights.

THE FLIGHT READINESS REVIEW

With the launch scheduled for February 19, the program scheduled a Flight Readiness Review for February 3. At that review, it quickly became clear that the engineering and safety organizations felt that significant work needed to be done before a sound flight rationale could be established. Steve Altemus, director of Engineering at Johnson Space Center, summarized the knowledge gap from the Johnson engineering community's point of view: "We showed up at the first FRR and we're saying, 'We don't have a clear understanding of the flow environment; therefore, we can't tell you what the likelihood of having this poppet piece come off will be. We have to get a better handle on the consequences of a particle release.'" The most important outcome of the meeting was the establishment of new lines of inquiry that could lead to better understanding. Three days after the review, the launch was delayed until February 22.

TECHNICAL ANALYSIS

Analysis of the cracked valve showed that the failure resulted from high-cycle fatigue (in which a material is damaged by numerous cycles of stress). This raised several questions. Had STS-126 presented an unusual environment, or was another valve likely to break in normal flight? What would be the worst-case consequences of a break? Engineers needed to determine the probable size and the maximum size of a loose particle, understand how it would move through the propulsion system, and what the system could tolerate without experiencing a potentially catastrophic rupture in its lines.

Teams worked on the problem from multiple angles, including materials, structural dynamics, computational fluid dynamics (CFD), and fracture mechanics. Initial efforts relied on visual inspection and nondestructive evaluation (NDE) techniques. One NDE technique that was initially dismissed was an eddy-current system, because the size of the probe head was too large for the valve. Another NDE technique was scanning electron microscopy. The microscopes could see small cracks only after the poppet was polished, however, and polishing invalidated the flight certification of the hardware. "A polished poppet could upset the flow balance of the valve, rendering it unusable for flow management. In this case the valve could get stuck in the high-or low-flow positions, which could cause a serious issue in flight," said Steve Stich, the orbiter project manager. "In order to ensure that a polished poppet was properly balanced required testing using the system that had been shut down at the White Sands Test Facility in the late nineties. So we were in a bit of Catch-22 situation with respect to performing the best possible NDE."

The Orbiter Project authorized impact testing at Glenn Research Center, Stennis Space Center, and the White Sands Test Facility to learn more about whether a fragment of a broken poppet would puncture the pressurization lines downstream of the valve. The data from these tests and other analyses contributed to a probabilistic risk assessment of the entire flow control valve hydrogen-repress system. At the same time, the CFD analysts figured out the velocity and spin of a given-sized particle as well as the probable path it would travel through the elbow-joint turns in the pipe.

As data began to come in from these tests, the program decided to convene a second FRR on February 20. Some members of the engineering and safety organizations expressed doubts about the timing of the review.

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CAN PROJECT ORGANIZATIONS LEARN?

Remember where we began with the *Challenger* case in chapter one. The issue twenty-three years later was in some respects the same: how can a large, distributed organization that depends on the fluid exchange of expertise between government and industry solve complex problems and share knowledge effectively? In the case of *Challenger*, the knowledge was available; engineers at Thiokol understood the potential problem the day before the launch. The barriers that kept the knowledge from the decision makers proved to be organizational and cultural—among other things, they were a product of hierarchy (management stifling dissenting opinions from subject matter experts within the vendor organization), vendor-customer dynamics (the vendor not wanting to tell the customer what the customer did not want to hear), and the normalization of deviance, as we pointed out in chapter 4.

The flow control valve issue was in some ways more challenging: nobody understood the technical problem. Knowledge would have to be acquired, validated, and shared effectively in a context of intense schedule pressure. How does an organization build a culture that generates new solutions, facilitates open dialogue, welcomes dissenting opinions in a constructive context, and works across boundaries (bureaucratic, geographic, and otherwise)?

This is more than a hypothetical question. In research that contrasted a project-based division of a firm with a functional matrix division, Michael Hobday of the University of Sussex found that the project division suffered from a lack of ability to share knowledge. "Lessons learned from particular projects were not shared formally because there were no structures or incentives for cross-project learning or communications." [36]

[36] Michael Hobday, "The project-based organisation: an ideal form for managing complex products and systems?" *Research Policy* 29 (2000), p. 885.

This is a perennial challenge. As we mentioned in chapter 1, after the 1999 failures of the Mars Climate Orbiter and the Mars Polar Lander, the General Accounting Office (now the General Accountability Office, or GAO) did a survey of NASA's lessons learned process and issued a report that called for a comprehensive knowledge sharing effort at NASA, which found that, "NASA's processes, procedures, and systems do not effectively capture and share lessons learned and therefore, NASA has no assurance that lessons are being applied towards future missions." [37]

To begin addressing this issue, it's important to recognize that in a project environment, knowledge is not just a matter of *what* you know.

Knowledge plays a different role in a project-based organization than it does in the world of high finance. On Wall Street, Sir Francis Bacon's axiom holds true: knowledge is power. Timing and secrecy are paramount. For example, understanding the specifics of a firm's breakthrough innovation before others have access to the same information can make you rich. Who you know is everything. Insider trading is illegal for a reason.

At NASA, the relationship to knowledge is shaped by different incentives. Knowledge is only valuable to the extent that it helps teams succeed at complex projects and missions. Given the nature of working for a government space agency, the lack of a traditional market-based profit motive, and the fact that

[37] General Accounting Office, "Survey of NASA's Lessons Learned Process" (GAO-01-1015R), September 5, 2001. http://www.gao.gov/new.items/d011015r.pdf See also: General Accounting Office, "NASA: Better Mechanisms Needed for Sharing Lessons Learned" (GAO-02-195), January 2002. http://www.gao.gov/new.items/d02195.pdf

most missions are one of a kind, we generally don't benefit from hoarding what we know.

Acquiring knowledge is different than mastering information—otherwise, brain surgeons, auto mechanics, foreign language translators, and computer programmers would become experts through rote memorization. Knowledge doesn't work that way.

The need for highly specialized knowledge leads us to *who* we know: talent. Getting the right people with the right knowledge at the right time in a project's lifecycle is one of a project manager's critical roles. Building a team that has the necessary knowledge or the means of accessing it is as important as getting the requirements right; one without the other is useless.

As NASA designs and develops systems of increasing complexity, it faces a critical need to transfer knowledge and expertise from those who have done this kind of work before to those who are doing it now.

PRINCIPLES AND EARLY EFFORTS

Even before GAO issued its report, the Academy had begun to develop practices for knowledge sharing that would fulfill this recommendation. The Academy developed its approach to knowledge sharing based on the following guiding principles:

1. The practitioner knows best—knowledge exists primarily in the minds of the people who do the work.

2. Stories are a powerful means of conveying knowledge because they stimulate curiosity and are memorable.

3. Project managers should be encouraged to share their knowledge through stories.

4. Storytelling could serve as a tool to create a community of reflective practitioners.

These principles blended a practical knowledge about how work gets done at NASA with a theoretical understanding of organizational learning. With NASA's field centers spread from coast to coast, there are very few built-in opportunities for cross-pollination among the project workforce. For example, an electrical engineer working on the space shuttle at Johnson Space Center may have no opportunities to interact with an electrical engineer working on Earth science missions at Goddard Space Flight Center, even though both work in the same discipline and potentially have valuable knowledge and experience to share with each other. On the theory side, a growing body of literature supported the hypothesis that stories serve as a highly effective mechanism for sharing organizational knowledge. With these principles in mind, the Academy invested in strategies that emphasize the power of telling stories through forums and publications in order to help create a community of practitioners who are reflective and geared toward sharing. (This approach anticipated the recommendations of the GAO's report, which recommended "that the NASA administrator strengthen the agency's lessons learning processes and systems by…developing ways to broaden and implement mentoring and "storytelling" as additional mechanisms for lessons learning."[38])

The first comprehensive effort in this area was the "Excellence through Stories" project. Ed Hoffman collaborated with Dr. Alex Laufer on an anthology titled *Project Management Success Stories: Lessons of Project Leaders*, which gathered 36 practitioner stories from NASA, the Department of Defense, and other federal government organizations.[39] In the introduction to *Project Management Success Stories,* Laufer and Hoffman explained the reason for focusing on stories, quoting Roger Schank, an artificial intelligence researcher at Northwestern University: "'Human memory is story-based. Not all memories, however, are stories. Rather, stories are especially interesting prior experiences, ones from which we learn…Not every experience makes a good story, but if it does, the experience will be easier to remember.'"[40]

The following year, the Academy published the first issue of *ASK Magazine*, with the tag line "By practitioners for practitioners." (ASK stands for Academy Sharing Knowledge.) Practitioner ownership of *ASK* was a key to its credibility and ultimately its popularity. Featuring practitioner stories in their own words built grassroots support that prevented *ASK* from becoming a "Headquarters publication." As with *Project Management Success Stories*, the Academy had to take a very proactive approach to soliciting

[38] Ibid.

[39] Alexander Laufer and Edward J. Hoffman, *Project Management Success Stories: Lessons of Project Leaders* (New York: John Wiley & Sons, 2000).

[40] Ibid, p. xvi.

stories for the early issues of the magazine. Over time, though, practitioners began contacting the Academy independently and suggesting their own stories. At that point, the idea had taken root.

ASK collected practitioner stories, but it could not create a community. This would require bringing people together in the same room. The Academy began to host Masters Forums that would gather master practitioners from across the agency to share their stories and experience. These "campfire events" were held away from NASA centers so they would function as mini-retreats that would allow time for reflection and networking outside the distractions of the office. The Academy solicited nominations from NASA Center Directors for attendees to ensure that these events attracted highly talented individuals who would be intrinsically motivated to exchange ideas with a small group of like-minded peers.

A second, smaller effort was a series called Transfer of Wisdom workshops. These were held at NASA centers, and they used *ASK* articles as a starting point for discussion and sharing, which helped ensure that the content from *ASK* circulated through the agency and stimulated conversations.

The Masters Forum format became very popular, with demand almost immediately outstripping supply in terms of attendance. The Academy held two forums per year and adopted timely themes to shape the events, such as the fiftieth anniversary of NASA, or Passing the Torch, a series that focused on transferring lessons from the Space Shuttle, International Space Station, and Constellation programs. The Academy videotaped the forums and made them available on its website (and later its YouTube and iTunes University channels).

The Academy also adapted the concept to develop custom forums, including:

- ***Principal Investigator (PI) Team Forums.*** This partnership with the Science Mission Directorate brought together PI teams applying for mission opportunities to learn from past master PIs, project scientists, and project managers.
- ***Green Engineering Forum.*** This partnership with the Office of Strategic Infrastructure was NASA's first-ever agency-wide event focused on exploring green engineering methods and practices that can be used to reduce the environmental impact and associated health risks of NASA's systems, processes, and hardware.

While the Masters Forum concept helped create a network of master practitioners, there was also a growing recognition across NASA of the need to bring together the larger project management community. This led to the establishment of the Project Management Challenge, a training event that serves as an agency-wide gathering of the project community. First held in 2005 near Goddard Space Flight Center, the PM Challenge grew into an annual event for practitioners from government, industry, and academia, with regular participation by senior NASA leaders.

KNOWLEDGE AND COMMUNICATIONS

Both the Masters Forums and PM Challenge faced practical limitations in terms of the number of people who could attend. As the combination of the Internet and multimedia technology made it possible to reach many people with a single event, the Academy began to pursue technology-enabled learning through informal channels. It introduced Masters with Masters, a series that brings together a small number of expert practitioners in a talk show interview format with Ed Hoffman serving as the moderator. The live audiences are small, but the end products are high-quality videos that are distributed through the Academy's multiple web-based channels. The Academy also began revisiting its rich back catalog of videos from previous Masters Forums to identify short, engaging clips that it could post on YouTube and iTunes University. (These uses of social media brought the Academy's content to much larger audiences than it reached through its own website or even YouTube: for example, in the first five weeks on iTunesU, users around the world downloaded the Academy's content 58,000 times.)

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."[41] Part of the Academy's response to this was to focus more directly on communications. It began a new effort to develop case studies that would illustrate lessons learned and capture knowledge from NASA projects. Unlike earlier cases developed by the Academy in the mid-1990s, these followed a model popularized by Harvard Business School, which emphasized on-the-record interviews with multiple practitioners to explore differing points

[41] Columbia Accident Investigation Board, *Report Volume 1* (Washington, D.C.: Government Printing Office, August 2003), p. 12.

of view about the same event. Building on the trust that the Academy began to establish among the community with *ASK Magazine*, these case studies provided an opportunity for practitioners to share divergent opinions and explain how leaders made critical decisions with the best available knowledge and data.

In addition to *ASK Magazine*, it developed *ASK OCE*, an e-newsletter published by the Office of the Chief Engineer, that would serve 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. This enabled the Academy to communicate with practitioners about "news they could use," ranging from changes in NASA procedural requirements documents to global trends in project management. This also provided an opportunity to bring content such as *ASK Magazine* stories to a wider and different audience. In January 2008 ASK OCE was rebranded as *ASK the Academy*, a monthly e-newsletter.

Around same time that it began publishing ASK the Academy, it also established a presence on social media channels such as Facebook, Twitter, Flickr, and the content sharing sites mentioned above. This made it easier than ever to engage with audiences such as students and representatives from international partners, and to initiate two-way conversations rather than simply pushing information out.

BUILDING KNOWLEDGE NETWORKS

One consistent aspect of the Academy's knowledge sharing activities has been a focus on building broader networks. From the beginning, there was a conscious effort to bring in practitioners from industry, academia, and other government agencies to share knowledge about how they addressed common issues. The *Project Management Success Stories* anthology from 2000 included stories by representatives from a half-dozen federal organizations ranging from the FBI to the Department of the Interior.

In recognition of the increasing importance of international collaboration in space, in 2010 the Academy undertook new efforts in close collaboration with the Office of International and Interagency Relations to learn from and with NASA's international partners. The animating principle behind these efforts could be summarized as "learn together, work together." With all of NASA's human spaceflight activities focused on international collaboration and fully 70 percent of its science missions involving international partners, the ability to work successfully in this arena had become a critical part of project management at NASA.

As a first step, the Academy sponsored an International Forum at PM Challenge 2010 in partnership with the Project Management Institute. Over a half-dozen of NASA's international partners attended or participated. (Given the success of this debut offering, the International Forum has become a regular part of PM Challenge.)

After the event, Ed Hoffman convened a meeting with colleagues from international partners to discuss the establishment of a standing group. Based on the strong interest expressed at that meeting, the initial participants decided to organize as the International Project/Program Management Committee (IPMC), a technical committee under the auspices of the International Astronautical Federation (IAF). The first formal meeting was held in March 2010 at the IAF Spring Meeting in Paris. The goal of the IPMC is to establish a means to share experiences and best practices with space project/program management practitioners at the global level, which it pursues through the following objectives:

- Exchanging information on program/project management, technical workforce development, best practices, and other activities of mutual interest.
- Organizing specialized symposia/events on topics of interest to the international space project management community.
- Cooperating with other organizations interested in the enhancement of space project management practices.
- Undertaking studies, reports and projects that contribute to the improvement of space project management at the global level.
- Facilitating opportunities for collaboration among members.

Since the founding of the IPMC, the Academy has held three Masters with Masters events with leaders from international partner agencies. NASA Administrator Charles Bolden appeared with Jean-Jacques Dordain, Director-General of the European Space Agency (ESA), at a Masters with Masters held at the International Astronautical Congress in Prague in September 2010. Two months later, Bolden participated in an event at NASA Headquarters with Johann-Dietrich Wörner, Chairman of the German Aerospace Center (DLR) Executive Board. The Academy also held Masters with Masters events on Mars exploration with Rob Manning of the Jet Propulsion Laboratory and Rudi Schmidt of ESA, and on collaboration in human spaceflight with Bill Gerstenmaier, NASA Associate Administrator for Space Operations, and Dr. Kuniaki Shiraki, Executive Director of the Human Space Systems and Utilization Mission Directorate at the Japan Aerospace Exploration Agency (JAXA).

The Academy drew on the expertise of the IPMC members to review the course materials for its "International Project Management" course, with a view toward identifying common principles and practices that could be incorporated into the curriculum. Based on that feedback, the Academy revised the curriculum and invited international partners to participate in the next offering of IPM, which took place January 31 – February 4, 2011 at Kennedy Space Center. Participants came from all NASA centers and Headquarters as well as the Canadian Space Agency (CSA), European Space Agency (ESA), German Aerospace Center (DLR), Japanese Aerospace Exploration Agency (JAXA), Korea Aerospace Research Institute (KARI) and four IPMC industry partners (Astrium, Thales Alenia, INVAP, and Comau). The course also featured partners serving as instructors, with Andreas Diekmann of ESA and Takayuki Imoto of JAXA offering perspectives from their respective agencies.

AN UNANTICIPATED OUTCOME

The unanticipated outcome of all these activities has been to give practitioners involved in NASA projects and missions a feeling of belonging to a larger community as well as a sense of dignity. Immanuel Kant wrote that everything has either a price or dignity. In traditional project management we've developed sophisticated tools to measure the price of work (i.e. its cost), but we've tended to overlook the other side of Kant's equation. This is a mistake. Project success ultimately depends on the efforts of individuals whose worth cannot be understood strictly in terms of value; they also have dignity. Storytelling brings a sense of inclusion and focuses on the human dimension of projects, which is all too often overlooked. It helps us construct a sense of dignity, meaning, and purpose for our work, which fulfills a critical human need. If we derive a sense of meaning and purpose from our work, we'll do anything to succeed.

The ability to share knowledge effectively at NASA ensures the long-term sustainability of the agency. Great designs live on through heritage hardware for generations, but as they get passed down, the context and rationale for decisions and design choices tends to get lost. This is why the personal stories of practitioners are essential. As the political theorist Hannah Arendt once said, "Storytelling reveals meaning without committing the error of defining it." We cannot anticipate when these stories will be critically relevant, but we do know that without them, the knowledge is gone. In a world where NASA practitioners are increasingly asked to do more with fewer resources, these are losses we cannot afford.

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CODA: GETTING TO YES THE RIGHT WAY

The second FRR for STS-119 lasted nearly fourteen long hours, and the outcome was not clear until the end. "It was much more of a technical review than typical Flight Readiness Reviews. There was a lot of new data placed on the table that hadn't been fully vetted through the entire system. That made for the long meeting," said FRR Chairman Bill Gerstenmaier.

Well over a hundred people were in the Operations Support Building II at Kennedy Space Center, seated around the room in groups with their respective organizations as technical teams made presentations to the senior leaders on the FRR board. Some participants believed that the analysis done on the potential risk of a valve fragment puncturing the tubing that flowed hydrogen from the external tank to the shuttle main engines showed that the risk was low enough to justify a decision to fly. Others remained concerned throughout that long day about the fidelity of the data, and that they didn't know enough about the causes of the valve failure and the likelihood and risk of its occurring again.

Despite the tremendous amount of analysis and testing that had been done, technical presentations on the causes of the broken valve on STS-126 and the likelihood of recurrence were incomplete and inconclusive. Unlike at most FRRs, new data, such as computations of loads margins that couldn't be completed in advance, streamed in during the review and informed the conversation. A chart reporting margins of safety included "TBD" (to be determined) notations.

Doubts about some test data arose when Gene Grush received a phone call from Stennis informing him that the test program there had used the wrong material. "I had to stand up in front of that huge room and say, 'Well there's a little problem with our testing. Yes, we did very well, but the hardness of the particle wasn't as hard as it should have been.' That was very critical because that means that your test is no longer conservative. You've got good results, but you didn't test with the right particle," he said.

NASA Chief Safety and Mission Assurance Officer Bryan O'Connor remarked, "Gerst [Gerstenmaier] was absolutely open. He never tried to shut them [the participants] down. Even though he could probably tell this was going to take a long time, he never let the clock appear to be something that he was worried about."

Toward the end of the meeting, Gerstenmaier spoke about the risks to the ISS program and to the shuttle schedule of not approving *Discovery's* launch. A few participants perceived his comments as pressure to approve the flight. Others saw it as appropriate context-setting, making clear the broader issues that affect a launch decision. After he spoke, he gave the groups forty minutes to "caucus," to discuss what they had heard during the day and decide on their recommendations. When they came back, he polled the groups. The engineering and safety organizations and some center directors in attendance made it clear that they did not find adequate flight rationale.

Bill McArthur, safety and mission assurance manager for the space shuttle at the time, said, "The fact that people were willing to stand up and say, 'We just aren't ready yet,' is a real testament to the fact that our culture has evolved so that we weren't overwhelmed with launch fever, and people were willing to tell Bill Gerstenmaier, 'No, we're no-go for launch.'"

As the participants filed out of the meeting, Joyce Seriale-Grush said to Mike Ryschkewitsch, "This was really hard and I'm disappointed that we didn't have the data today, but it feels so much better than it used to feel, because we had to say that we weren't ready and people listened to us. It didn't always used to be that way."

NEW INFORMATION

Engineers across NASA continued to work on finding new solutions. Charles Bryson, an engineer at Marshall Space Flight Center, used eddy-current probe equipment with a relatively large probe head to inspect a poppet. His inspection, confirmed by other analysis, indicated that the eddy-current inspection technique showed promise in finding flaws. Propulsion Systems Engineering and Integration Chief Engineer at Marshall Rene Ortega told colleagues from the Materials and Processes Problem Resolution Team about Bryson's eddy-current inspection results. Ortega helped arrange for Bryson to examine several poppets at Boeing's Huntington Beach facility. Bryson then worked collaboratively with a team from Johnson led by Ajay Koshti, an NDE specialist with expertise in eddy-current investigations. Koshti brought an eddy-current setup with a better response than Bryson's, and together they arrived at a consistent inspection technique.

"Once we were able to screen flaws with the eddy current and there wasn't a need to polish poppets with the process," Ortega explained, "we had a method by which we could say that we … thought we're pretty good at screening for non-polished poppets."

Engineers had found that some of the smaller flaws identified in the poppets didn't seem to be growing very fast. "Through that exercise, we came up with the suggestion that, 'Hey, it doesn't look like these flaws are growing out very rapidly in the flight program, and with the screening of the eddy current we can probably arrive at a flight rationale that would seem to indicate that those flaws being screened by the eddy current wouldn't grow to failure in one flight," Ortega said. The eddy-current technique was not a silver bullet, but in conjunction with the other techniques and test data, it provided critical information that would form the basis for sound flight rationale.

THE FINAL FRR

With the results from the test programs all now supporting a shared understanding of the technical problem, there was wide consensus among the community that the third Flight Readiness Review, on March 6, would result in a "go" vote.

"By the time we eventually all got together on the last FRR the comfort level was very high," said O'Connor. "For one thing, everybody understood this topic so well. You couldn't say, 'I'm uncomfortable because I don't understand.' We had a great deal of understanding of not only what we knew about, but what we didn't know about. We had a good understanding of the limits of our knowledge as much as possible, whereas before we didn't know what those were."

The FRR board agreed and STS-119 was approved for launch on March 11. After delays due to an unrelated leak in a liquid hydrogen vent line, *Discovery* lifted off on March 15, 2009, and safely and successfully completed its mission.

Two months after the completion of the mission, Bill Gerstenmaier spoke to students at Massachusetts Institute of Technology (MIT) about the flow control valve issue. In an email to shuttle team members, he shared a video of the lecture and wrote, "I am in 'continue-to-learn' mode. There is always room to improve."

Chapter Six

REFLECTIONS AND FUTURE DIRECTIONS

"Your task is not to foresee the future but to enable it."

— Antoine de Saint-Exupery

Twenty-two years is a long time in the life of an organization. When the Program/Project Management Initiative (PPMI) first began life in 1989 as a series of training courses in project management, there was no way to anticipate that it would grow into what is now, the NASA Academy of Program/Project & Engineering Leadership.

The question that frequently comes up from colleagues in other organizations is, "How did you survive?" We've talked about how the Academy developed its current approach to learning in response to events and changing organizational needs, but we haven't given much attention to the inside game: how does a project-based organization set up an internal project academy that's a sustainable, long-term entity?

With the caveat that every situation poses its own unique context and challenges, we will offer some reflections on practices that have helped at NASA. In conversations with peers at other organizations, we've learned that many have had similar experiences, though the sample size is too small to draw rigorous conclusions.

Align with organizational strategy; focus on practitioners. We talked in chapter 2 and elsewhere about the importance of understanding what practitioners need and serving as an advocate for those needs. The project academy also has to ensure that everything it does—from training courses to forums to publications—aligns with the organization's strategy and builds a critical link between that strategy and the practitioner community. For example, we were both deeply involved in the 2005 rewrite of NASA Policy Document (NPD) 1000.0, which was then called the Strategic Management and Governance Handbook. This is the highest-level policy document in the agency. In addition to communicating with practitioners about the changes in NASA's governance model, the Academy also developed a case study about the Pluto New Horizons mission that served as a test of the new governance model. This served as an example for practitioners of the connection between high-level strategic decisions and projects. Illustrating this linkage through a project story that includes diverse personal perspectives is a more powerful way of reaching practitioners than simply broadcasting changes to the governance model, though that is also a necessary mode of communicating with the practitioner community. (Think of it as the difference between showing and telling.)

Understand the political and leadership landscape. While the Academy's direct customers are the project and engineering management communities across NASA's centers, support for it as an agency-wide resource ultimately depends on the buy-in of senior leaders at the headquarters level. This demands an understanding of the political and leadership landscape within the organization. Over the last 22 years, NASA has had five Administrators appointed by four U.S. Presidents. These top leadership changes have been accompanied by numerous changes in the agency's mission and the way it does business. The Academy's survival and growth during that time resulted in large part from building relations with senior leaders, maintaining an awareness of the political environment, and adapting quickly to meet shifting organizational needs.

Demonstrate value to the organization through a comprehensive set of measures. One of the most common questions about a project academy is, "How does your organization measure return on investment?" Since there is no way to demonstrate definitive causality between the project academy and overall project performance—the sheer number of variables involved in even a single project's performance make this impossible—we focus on a more fundamental question: how can we tell if we're doing the right things well? The Academy measures the effectiveness of all of its learning activities, both to ensure that we're meeting our learning objectives and to assess the quality of our products and services. We use five primary yardsticks to gauge how we're doing.

- ***Accreditation.*** The Academy holds accreditations from several professional organizations that have assessed its work and offered objective, third-party validation of its quality:
  - The Project Management Institute (PMI) recognizes the Academy as a registered provider of professional development units. It has also formally recognized NASA's process for meeting the standards set by the Office of Management and Budget (OMB) for federal project managers, and it allows NASA-certified project managers to sit for PMI's Project Management Professional (PMP) exam without further review of their education or experience.
  - The American Council on Education recommends graduate credit for a dozen Academy courses. (More will be submitted for approval in the future.) This recognition is available to international participants in the courses as well as NASA civil servants.
  - The International Association for Continuing Education and Training (IACET) has awarded the Academy its authorized provider status. IACET is the only organization with a continuing education and training standard approved by the American National Standards Institute (ANSI).

- ***Customer feedback.*** The Academy collects a variety of customer feedback. One of the most basic indicators is utilization of training courses, team support, and knowledge services (such as forums and the PM Challenge). In all three areas, demand has consistently outstripped supply. The Academy also conducts user surveys for every activity it holds and reviews this feedback in after-action meetings as part of its efforts to practice continuous improvement. Finally, in his capacity as the Academy director, Ed Hoffman holds regular meetings with senior leaders at NASA's centers and mission directorates to ensure that their organizations' learning needs are being addressed.

- ***Assessment and testing.*** Like most educational institutions, the Academy makes extensive use of assessments in its team support activities and tests in its training courses to track individual and team learning. (See chapter 4 for more about the use of assessments in teambuilding.) The Academy has also supported the development of online knowledge testing tools for use with updates to key NASA documents, such as the agency's procedural requirements for project management.[41]

- ***Benchmarking with external organizations.*** The Academy has participated in several benchmarking activities with organizations including Aerospace Corporation, Perot Systems, and Massachusetts Institute of Technology (MIT). In 2009, Human Systems, a global consulting firm specializing in project management, conducted a first-of-its-kind benchmarking study of project academies around the world, and it ranked the Academy first among its peers.

- ***Alignment with NASA strategy and external requirements.*** The Academy regularly updates its curriculum to ensure alignment with changing policies and requirements. It also works hard to satisfy requirements from external stakeholders such as the Office of Management and Budget (OMB) and the General Accountability Office (GAO). In 2007, for instance, OMB released new requirements for the certification of federal project managers on projects over $250 million. Since the Academy already had a very mature competency model and career development framework for project managers, the process the Academy developed for certifying NASA's project managers focused on showing that NASA project managers already met the new requirement.

THE ACADEMY'S MEASUREMENT APPROACH USES FIVE PRIMARY YARDSTICKS:

- Accreditation
- Customer feedback
- Assessment and testing
- Benchmarking with external organizations
- Alignment with internal and external requirements

Communicate in terms of risk mitigation. Project success is a shared goal, and, conversely, project failure is something everyone wants to avoid. It is expensive, demoralizing, and ultimately corrosive to the organization. While the presence of a project academy is in no way a vaccine that prevents project failure, it is a low-cost investment that reduces risks related to individual competence, team performance, and organizational knowledge.

Establish the project academy in a management or technical organization, not in human resources. The Academy moved into the NASA Office of the Chief Engineer in 2004, which strengthened its connection with the project management and engineering communities that it served. Colleagues at other project academies have reported coming to the same conclusion within their organizations. Some have housed their project academies within a project management office (PMO) or systems management office. While there is no one-size-fits-answer for where a project academy should live within an organization, the common denominator has been keeping it as close as possible to where the work gets done. By all accounts so far, this is never in human resources.

FUTURE DIRECTIONS: TRENDS IN PROJECT MANAGEMENT

From our vantage point, the most interesting story is the one we don't know yet—the challenge ahead. Just as the Academy evolved over the past 20 years in response to changes in NASA's mission and organizational context, continuous learning and adaptation is critical to remaining relevant.

[41] NASA Procedural Requirements (NPR) 7120.5, "NASA Space Flight Program and Project Management Requirements."

FIVE SUGGESTED PRACTICES FOR PROJECT ACADEMIES

- Align with organizational strategy; focus on practitioners.
- Understand the political and leadership landscape.
- Demonstrate value to the organization through a comprehensive set of measures.
- Communicate in terms of risk mitigation.
- Establish the project academy in a management or technical organization, not in human resources.

As part of our efforts to anticipate future needs, in 2008 we began tracking trends in project management. This effort included an extensive literature search[42] as well as personal conversations with practitioners and thought leaders around the world affiliated with organizations such as the Project Management Institute (PMI), the UK-based Association for Project Management (APM), the International Project Management Association (IPMA), and the International Centre for Complex Project Management (ICCPM). We presented our first-year findings at the NASA PM Challenge in February 2009, and this became an annual activity.

After three years, we assembled a master list of the eleven trends we had identified to date:

- Talent management
- Complexity
- Project management certification
- Project academies
- Team diversity
- Sustainability
- Portfolio management
- Virtual work
- Transparency
- Frugal innovation
- Smart networks

When we looked closely at the list for patterns, we noticed that the trends fell into three broad categories of change: the global business environment, the priorities of project-based organizations, and the work environment for project practitioners.

TRENDS IN PROJECT MANAGEMENT

Figure 5.1. The Academy's research into trends in project management over a three-year period led to the identification of three broad categories of change.

THE WORLD AROUND US

There are four big-picture trends shaping the global business environment for project-based organizations.

- ***Complexity.*** As we discussed in chapter 2, complexity means different things to different people, but just about all spaceflight projects at NASA meet any definition. As projects become larger and involve more international and cross-sector partnerships, the project manager has to play a more active role in developing and maintaining support from a wide range of stakeholders. Since complex projects often have long time horizons, leaders need to sustain their projects through changing political, social, and economic circumstances. The skills required to succeed in

[42] The literature search draws on up to two dozen journals per year, including leading publications such as: Academy of Management Journal, Acta Astronautica, Aviation Week and Space Technology, California Management Review, Harvard Business Review, Harvard Business School working papers, International Journal of Project Management, PM World Today, PM Network, Sloan Management Review (MIT), and Strategy + Business. For the past two years, our colleague Haley Stephenson has been a tireless researcher and thought partner on this initiative.

this environment go beyond the traditional project management domains of cost, schedule, and technical performance. Organizations have to find new ways to give their project managers the knowledge and skills to deal with this dynamic environment. Our own framework for thinking about complexity in terms of technical, organizational, and strategic dimensions suggests that project-based organizations often underestimate the effects of organizational and strategic complexity. NASA engineers are world-class experts at finding ingenious solutions for technical problems. It is less clear how to work effectively with other organizations or stakeholders to achieve mission success.

- ***Sustainability.*** Sustainability has arrived as a permanent feature of the landscape for project-based organizations. While some use sustainability as a synonym for "environmentally friendly," others 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 aerospace project managers to think about life-cycle costs. Sustainability tackles questions of life-cycle impact, which can extend far beyond the duration of a project. In 2009, the Academy partnered with the Office of Strategic Infrastructure to hold NASA's first Green Engineering Masters Forum. This coincided with President Obama signing an Executive Order that set sustainability goals for all federal agencies. Based on the success of the forum, the Academy went on to develop a full-length training course on green engineering and hold a Masters with Masters event on sustainability in government organizations.

- ***Transparency.*** Projects exist in a more transparent, networked environment than in the past. President Obama's open government directive initiated a shift toward government transparency. Thirty-nine government agencies, including NASA, have developed open government initiatives. World Wide Web pioneer Tim Berners-Lee highlighted the work of Data.gov, introducing the possibilities (and controversy) that open data and ideas can offer, from new uses of satellite data to provide relief to earthquake victims in Haiti to WikiLeaks. Managers and leaders are expected to be open about their work. Information and decisions are no longer easily hidden.

- ***Frugal Innovation.*** The growing demand for breakthrough technologies in engineering and management has led to the emergence of innovation grounded by cost. The watchwords of this practice are "reuse, repurpose, redesign." Cost-conscious innovators make use of existing hardware or technologies in novel ways that allow them to achieve ambitious goals with limited resources. Associated with products like the Nokia 1100 and the Tata Nano, this innovation paradigm can be seen in aerospace projects like the Lunar CRater Observation and Sensing Satellite (LCROSS), CubeSats, and Johnson Space Center's Project M, which sought to put a humanoid robot on the moon.

ORGANIZATIONAL CAPABILITY

Project-based organizations are also dealing with new trends in management.

- ***Portfolio Management.*** Portfolio management reflects the context in which project-based organizations operate today. No project exists in a vacuum, and 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. Portfolio management is an executive function that calls for decision making about programs and projects based on a strong understanding of the organization's mission, goals, and strategy. (In NASA's case, the mission directorates function as its portfolio management organizations.) These decisions involve resource allocation (e.g., talent, funding, and physical capital) in the context of maintaining a balance among portfolios that aligns with organizational needs. The consequences of the success or failure of a project in one portfolio depend on its relative weight, which can be gauged in terms of resources, visibility, and importance to the overall organizational mission. As project-based organizations continue to grow around the world, portfolio management will increase in importance.

- ***Talent Management.*** As technology, globalization, and system requirements drive us toward ever-greater complexity, there is an increasing worldwide demand for professionals who are highly skilled in the integration of complex systems. These skills cannot be taught in a training course or even a graduate program; they are the result of experience acquired on the job. This means the talent pool of successful, experienced practitioners is limited. Since demand for these skills is high in a global economy, talent is an international commodity that does not sit still. A skilled knowledge worker may have opportunities in Dubai, Shanghai, and Seattle. Talent also crosses sectors more fluidly than ever before: people hopscotch between government and the private sector in search of the best opportunities for growth. Talent management is a shared responsibility. In a project-based environment, both project leaders and senior executives have to address the needs of knowledge workers in order to compete in the global battle for talent.

- ***Project Manager Certification.*** Project-based organizations are under pressure to demonstrate that their project management professionals are qualified to run highly complex and expensive projects. In the federal government, the White House Office of Management set out new project management certification requirements in April 2007. The Academy spearheaded NASA's response to this requirement by developing a process for certifying NASA project managers. (As we mentioned earlier in this chapter, the Project Management Institute found this process sufficiently rigorous to allow NASA-certified project managers to sit for their Project Management Professional (PMP) exam without other prerequisites.) Certification is likely to grow in importance as project complexity continues to increase around the globe.

- ***Project Academies.*** This book itself is a response to the rise of project academies and the interest others have expressed in what NASA has done. As we mentioned in chapter 2, Ed Hoffman participated in a meeting in the fall of 2008 with representatives from other organizations that have started their own project academies. At this point, the total numbers are small, but the attention from other organizations since that event has been strong and growing.

THE WAY WE WORK

Project-based work is also changing at the practitioner level.

- ***Smart Networks.*** Complex projects are about collaboration, alliances, and teaming—you're only as good as your network. In 1965, the world's first communications satellite introduced the "frightening prospect" of man being able to communicate anything anywhere in the world. Now wikis, Facebook, Twitter, and other platforms are rapidly spreading and transforming the way practitioners connect. Cultivating "smart networks" that provide broad streams of information, a global perspective, and sophisticated tools to manage information overload is integral to success.

- ***Team Diversity.*** Diversity has multiple dimensions in a project management context, including cultural, cognitive, and geographic. As projects become more complex, technically challenging, and costly, they also become more globalized, compelling project managers to learn how to lead diverse teams. Skillful management of cultural diversity in teams is crucial to project-based organizations. The future of space exploration hinges upon the ability to collaborate with government space agencies, industry, academic institutions, and nonprofit organizations. Research also shows that project teams thrive on cognitive diversity, which can result from varying levels of education, experience, age, training, and professional background. Geographic diversity poses challenges in developing an environment that facilitates meaningful communication and productivity when team members are not collocated. Once considered a hindrance to effective team productivity, great distances among team members can be managed more effectively than before thanks to advances in technology.

- ***Virtual Work.*** The success of geographically diverse teams is closely tied to a project manager's ability to support a virtual work environment. With a boom in collaborative technologies, the means of communication are no longer an obstacle. While contacting people is no longer a problem, connecting with them is. Virtual work offers project managers the ability to attract and recruit talent from anywhere in the world and decreases project cost. On the other hand, it also threatens effective knowledge transfer, eliminates "water cooler" conversations, isolates workers, cuts down on managerial support and oversight, and blurs the line between one's work and personal life. Despite a mountain of research, there aren't yet definitive answers about virtual work. For now, project managers must take care to document best practices and lessons learned on virtual projects to increase understanding of this type of work.

CONCLUDING THOUGHTS

Our story began in 1986 with the *Challenger* accident. That was a different world—a world before the Earth Observing System changed the way we view our home planet, and the Hubble Space Telescope changed our understanding of the universe. We didn't know then that the Soviet Union would collapse in five years, or that China would become the third nation to achieve independent human spaceflight. Among many other things, the World Wide Web, ubiquitous public use of the Global Positioning System, and pocket-sized mobile phones that could check on the status of orbiting satellites were all ahead of us.

We have tried to document the evolution of the NASA Academy of Program/Project & Engineering Leadership from its post-*Challenger* beginnings as a project management training initiative to its current state as a project academy that addresses individual competence, team performance, and organizational knowledge. In doing so, we have been keenly aware that the ground beneath us is shifting even as we write this. The project academy itself is a structure that enables an organization to respond dynamically to a changing world. We already see that the project academy's work is evolving in dramatic and unexpected ways, and we fully anticipate that this will continue for the foreseeable future. Change is the one constant we have come to expect.

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The Academy of Program/Project & Engineering Leadership (APPEL) supports NASA's mission by promoting individual, team, and organizational excellence in program/project management and engineering.

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