Knowledge Management at the Jet Propulsion Laboratory: History, Potential, and Challenges

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Abstract

At the close of the 20th century, Information Technology (IT) revolutionized the way we live, forcing us to meet challenges like security and privacy issues while enjoying increased productivity, collaboration, and efficiencies. Knowledge Management (KM) has emerged from the proliferation of IT solutions, combining the efficiencies of technology with the open sharing of thoughts, experiences and ideas for the sake of learning. NASA's Jet Propulsion Laboratory (JPL) developed a KM initiative in order to increase project success and ameliorate the effect of a looming human capital crisis. While the KM effort at JPL is well planned, it faces obstacles in regard to changing the culture within the agency. We find that new technologies disappoint those who expect quick fixes to process problems that existed before the technology itself. Such will be the case if JPL's KM rests solely on the use of IT. Normally, emerging technologies are not fodder for public administrative thought, however, they be should studied as would be any other function that delivers public goods.

Why is KM Relevant?

Utilizing innovations in Information Technology (IT) to address age-old organizational problems in the public sector is no small challenge. Often, IT experts lack an understanding of the intricacies of public administration, while those who study public administration are reluctant to embrace forward-thinking technology based solutions. Bridging the communications gap between these two divides is important not only because all levels of government invest significantly in IT, but also because IT is as relevant and worthy of study as any other public sector problem solving tool. The research presented in this paper hopes to be an example of how to bridge that gap by explaining the public sector applications of a trend in technology, Knowledge Management, in a way that is easily grasped by those with little background in IT.

Knowledge Management (KM) is seen by some as one of the latest in a long line of IT buzzwords that begin with great promise, yet in the long run, fail to provide a noticeable improvement in productivity, communication or cooperation. Often with IT-based "business solutions," the true cause of failure is the expectation that technology alone, without human effort, will magically solve all workplace woes. Like many large organizations, NASA realizes the need for a comprehensive KM program, as evidenced by their development of a 25-year strategic KM plan. NASA isn't the only organization banking on this recent trend; the surge in combined public and private KM investments has been estimated to be between $5 to $12 billion by the start of this year (Williams 2001). The two critical issues NASA is hoping their KM plan will address are the anticipated human capital crisis and higher-than-acceptable project failure rates.

Like NASA, many federal agencies are turning to KM initiatives as a way to offset dire projections of human capital losses. "Doomsayers of the human capital crisis warn that government soon will lack sufficient experienced staff to perform important missions such as protecting the country, preventing illness, curing disease and exploring the universe" (Friel, 2003). At NASA, project failure due to the lack of knowledge sharing is just as large a concern, if not more so, than an impending "brain drain." Specifically, this essay will focus on a division of NASA-the Jet Propulsion Laboratory (JPL), their KM initiative, its potential for success, and areas of concern that it must address in order to reach its goals. A good portion of the background knowledge of JPL and its knowledge sharing culture and KM strategies found in this paper are based on a case study written by Dorothy Leonard and David Kiron. The case study, *Managing Knowledge and Learning at NASA and the Jet Propulsion Laboratory* was written in 2002 for the Harvard Business School Press.

What is KM?

KM is a tool of systems theory-based management. Organizations invest in KM initiatives when they want to transform into learning organizations and create an organizational memory. "Whether public or private…learning organizations nurture new patterns of thinking so that members learn together to improve the organization... all organizations are capable of learning and growing…from their interactions with their environments" (LeMay 2002, 129).

It is important to understand the difference between KM and general information management. Instead of merely organizing data, KM's goal is the "leveraging of an organization's collective wisdom to increase responsiveness and innovation" (Koulopoulos in Williams 2004). Well-planned KM initiatives will use a combination of IT tools as well as encourage "water cooler" exchanges that facilitate collaboration and the free exchange of ideas, experiences and information.

Larger, more complex KM initiatives can support teams that are scattered around the world and are simultaneously working on the same problems. These systems rely heavily on technology-based tools such as videoconferencing to ensure employees have the information they need to be more productive and proactive. For example, large research and development projects can be worked on 24 hours a day by having three different offices in three time zones—eight hours apart. At the close of business in one office, another office will be starting their day by picking up where the last office left off, because they all share the same databases and information.

At JPL the KM goals are to capture, organize and distribute knowledge in a way that transforms JPL into a learning organization, creates an explicit organizational memory, and meets short-term information sharing needs throughout the process (Leonard and Kiron, 2002). The KM team has established "three prongs": processes, services, and systems that work together to deliver products such as document management, mentor support systems, and expert directories.[1] The goal is to facilitate the creation of new knowledge by making it easier for employees to share what they know beyond their current assignment or work team (Holm in Bran 2002). To accomplish this, the KM team will have to do more than simply codify information; they need to find systems and processes to make pertinent information available to employees when they need it.

JPL Recent History

Being simultaneously accountable to several interests internally, externally, and politically has been a major contributor to the chain of events that lead to project failure throughout NASA's history (Romzek and Dubnick 1987). JPL is a prime example of this. As NASA's lead center for robotic exploration, JPL is responsible to many stakeholders beyond the U.S. government—including other NASA departments, the U.S. military, corporations, research laboratories, other countries, and of course, the American people.

In 1992, Daniel Goldin took over the leadership of NASA after the well-publicized failures of the Challenger Shuttle explosion and Hubble Telescope. Goldin instituted a new project strategy that became know as Faster, Better, Cheaper (FBC), reduced the workforce by 28 percent, decentralized the organization, and increasingly used outside contractors. The hope was that NASA would produce several more innovative and lower budget projects rather than a few long-term expensive projects, like they had in the past (Leonard and Kiron 2002).

Because morale at NASA was very low when FBC was implemented, the program sought to turn the momentum around by tapping into creativity and ingenuity that had been stifled in the past. Being that projects were smaller and more numerous, failure was supposed to be acceptable, therefore allowing employees to be more innovative and less inhibited. One of the first FBC projects, the Mars Pathfinder Mission, benefited by having some of JPL's best project managers, and the project had a lower profile than other projects in development, which resulted in less oversight and pressure to deliver. Early success in the FBC program, such as Pathfinder, provided good publicity for NASA, and improved the confidence of its employees.

That confidence was short lived; because of the increase in number of projects and expectations, the ideal conditions under which the Pathfinder was developed could not replicated with following projects. Soon, the JPL operated much like a university with independent departments, competing for talent among project teams. A major intent of FBC was to save money through the re-use of technology and the building upon the successful components of previous missions. Unfortunately, this resulted in a "not-invented-here" attitude because project components developed outside of one's project team were considered inferior and not trusted. This often led to duplication of work since personnel preferred to create rather than capture and re-use knowledge, essentially the opposite effect FBC was designed to produce (Leonard and Kiron, 2002).

FBC and Knowledge Hoarding

Due to the budget cuts, pressure for success, and the FBC process, employee development and knowledge sharing slowed. Project managers were more concerned with individual project success than total program success, and placed more importance on short term rather than on long-term goals. Since projects competed for talent, employees were informally ranked; this created a culture that rewarded those who hoarded valuable information (Leonard and Kiron, 2002). The end result at JPL, as is the case in many organizations, is that knowledge became power.

Because managers were allowed more leeway in implementing projects under FBC, one of the first problems they encountered was pinpointing exactly what "better" meant. They soon found that "cheaper" threatened the existence of projects that found themselves over budget. However, it was the combination of the emphasis on "faster" and the decentralization of projects that had several negative results on knowledge sharing. Because the number of projects at JPL increased tenfold, the decentralization of decision-making placed unproven mangers in charge of projects and overburdened those managers with experience. Many JPL employees began to subscribe to a "pick any two" mentality. In other words, they felt it would be impossible to have all three-faster, better and cheaper-simultaneously, so they would settle for two (McCurdy in Chaiken 2000).

The pressure to succeed had personnel working over 60 hours a week. Many could not recheck their work, much less mentor junior staff. The result was that knowledge was not passed along like it had been in the past. Moreover, the time constraints did not allow people the opportunity to reflect on and learn from mistakes, and then apply those lessons to new projects. Another result was that project reviews were not as thorough as in the past and errors that would have normally been detected through systems-management safety measures were not caught. (McCurdy in Chaiken 2000) The result was a project failure rate that was higher than NASA anticipated, and increased negative publicity. Many of NASA's technical and managerial problems resulted from efforts to respond to institutional demands for success under tight time and budgetary constraints. Additionally, it is probable that the pursuit of political and bureaucratic accountability distracted NASA from its strength-professional standards and mechanisms of accountability (Romzek and Dubnik 1987).

<u>Development of KM at JPL</u>

KM practices began at JPL around 1998, when management saw that web-based technologies could deliver integrated decision-making capabilities and would allow dispersed teams to collaborate at any time and any place (Bran 2002). Although it was a minimally funded experimental project, JPL hoped that KM would help prevent the loss of collective knowledge as a result of approximately 40 percent of JPL's staff being eligible for retirement (Leonard and Kiron, 2002). Encouraged by the progress the KM team made with limited resources, Congress issued a directive to expand the effort in 2000. It was then that the formal KM initiative was born, primarily because of concern over project failures and in hopes of reducing the effects of the impending retirements.

Theoretically, NASA and JPL's strategy for KM has the potential for success, and follows a typical implementation roadmap similar to the one outlined in The Knowledge Management Toolkit by Amrit Tiwana. A leader in the field of KM, Tiwana provides a standard example of a KM program with four main phases, 1) infrastructure evaluation; 2) KM system analysis, design, and development; 3) system deployment; and 4) performance evaluation (2002). Even with a solid framework, a problem many organizations face after a KM rollout is that they did not realize what they needed to change until their KM investment failed to provide it (Davenport and Prusak 1998). Fortunately, the KM team at JPL seems to be aware of what changes are necessary; now the larger issue will be acquiring the resources and support to accomplish their goals. It has been repeatedly shown that one of the most basic necessities for a successful KM project is strong support of the initiative from the top down (Davenport and Prusak 1998).

By 2002, technology based solutions were being put in place, and within the same year NASA received a new Chief Information Officer (CIO), Paul Strassmann, whose office administers the KM initiative. Strassmann began his tenure with a program he has called "One NASA." The goal is to get everyone to work as one cohesive agency, instead of in competing departments. Immediately he noted that NASA spent only 7 percent of its $2.2 billion IT budget on programs that help departments communicate with one another (Cowing 2002). After perusing his website[2] and reading materials supporting the solutions he planned to bring to NASA, it was clear that Strassmann was mostly concerned with IT development, and creating a transparent computer network, rather than focusing on a culture change in which collaborative relationships are encouraged and knowledge is shared.

Centering the KM initiative around IT solutions would create hardware and software dilemmas for the JPL KM team because of the nature of JPL users- scientists and engineers. Typically, they are accustomed to acting independently, using technology in a manner that best suits their individual project regardless of what other teams in the JPL are doing. Additionally, technologically minded people are bound to resist the added responsibility of recording the conception, development, decision rationales, and afterthoughts of a project especially under time and budgetary constraints (Leonard and Kiron, 2002). Imposing a universal KM infrastructure that is too unwieldy to learn quickly and demands uniformity of end-user hardware and software will virtually ensure that few people will go out of their way to use it. To achieve a complete KM program, Strassmann should have set aside resources for culture change objectives and hire a KM specialist. It has been shown that the most successful KM initiatives are carried out by Chief Knowledge Officers, not CIOs, who have large enough budgets to go beyond IT solutions (Tiwana 2002).

As many organizations have learned, IT products are integral tools for KM, but even the most well-developed (and expensive) software will not magically cause employees in a knowledge hoarding culture to begin sharing. "New information technology is only the pipeline and storage system for knowledge exchange. It does not create knowledge nor can it guarantee or even promote knowledge generation or sharing in a culture that doesn't favor those activities" (Davenport and Prusak, 1998, 18).

Unfortunately, JPL's KM initiative has quite a challenge to surmount in bringing about a culture change within JPL. This will prove difficult for two reasons; first, much of the prevalent culture is a direct result of time and budgetary constraints, and there is little the KM team can do alleviate those conditions. Second, many engineers and scientists simply develop a "feel" for their work through years of observation, experience, and the synthesis of principles from other fields (Schmidt 1993). Normally, such experience is rarely verbalized, and it is difficult to document, let alone with the proper context for future use.

JPL KM Projects

Before Strassmann's arrival, the initiative began with an effective strategy of making small inroads and building on early wins. To accomplish this, JPL instituted *Inside JPL,* an internal web-based portal that is customizable to aid with information searches and project development; it includes a *Technical Questions Database*.

An important realization of the KM team is that it is more effective to have a small number of willing participants rather than an entire staff reluctantly complying with the initiative. For example, many KM initiatives begin with the creation of a database of employees and their expertise, assuming this will automatically cause people with common interests to contact one another. This is a popular concept because it is fairly simple to implement, but not always effective. Instead, recognizing that not everyone is willing or available to answer questions and share experiences, JPL's experts' directory allows people to voluntarily post their profiles on the system, and change their availability status as their workload fluctuates (Bran 2002).

The initiative recognizes and rewards examples of knowledge sharing, and they are trying to gain grassroots support by encouraging communities of practice, storytelling and collaborative environments. This falls in line with industry-best practices as other government agencies have found that one of the best ways to encourage knowledge sharing and gain visibility for their KM programs is to publicly acknowledge those who have taken the lead to form partnerships and work on cross-functional solutions (Onley 2003).

While competitiveness has some value in organizations, in many ways it runs contrary to knowledge sharing at JPL. The "not invented here" culture has lead to the use of a dozen or more document management systems on the same projects. An early JPL pilot, *Project Libraries,* introduced a Xerox program called DocuShare to organize project specific documents and create a freer flow of information. The greatest improvement a software program like DocuShare can bring to JPL is a movement toward adopting project research standardization and a consistent way of encoding document meta-data. Additionally, most JPL employees required little to no training to use DocuShare's basic features (Borsook 1999). Now, they need to be encouraged and trained to move beyond the basic functions in order to fully take advantage of all DocuShare's collaborative uses. Still, hardware and software solutions, however effective, can only be part of the answer.

One of JPL's KM pilot programs calls for the creation of *Legacy Reviews* in which a "decision tree" is created that documents why decisions were made and why other options were ruled out. This type of program is ideal for an organization like JPL, because the intricacies and length of projects often make it impossible to re-trace steps that were taken. On the other hand, a program like this is a gamble, because the political and interpersonal results of such program can be more harmful than beneficial if attempted in an organization without a high-trust culture (Davenport and Prusak, 1998).

One of the goals of FBC was to make the fear of failure less of prevalent, and this has yet to be fully realized. The KM team is hoping to improve upon a *Lessons Learned Information System (LLIS)* that was already in place before they began, but not widely used. As with the *Legacy Reviews,* the KM team will have to find a way to make people comfortable with not only sharing failures but also information that potentially gives them a competitive advantage. JPL's projects are unique in that they require such a high level of precision that even the smallest miscalculation can have catastrophic results.

When missions fail, the blame is often squarely placed on the shoulders of the project manager (McCurdy 2000). The KM team is making inroads on this front and the number of negative lessons learned available on this site is steadily increasing.[3] The *LLIS* provides information on projects worked on by different departments or organizations across all of NASA, not just JPL. It is available to the entire organization and accessible via NASA's web site therefore employees and the public can connect to this system from either a NASA portal or non-NASA portal. While this amount of transparency is important for public sector agencies, it may also hinder sharing.

The *Academy of Program and Project Leadership (APPL)* is web-based as well. *APPL* provides professional development to teams as well as individuals through performance enhancement, knowledge sharing, courses, career development, university partnerships, and advanced technology tools.[4] So far, the *APPL* has developed into a human capital management system, including critical concerns for mentoring and knowledge sharing. This is helping to overcome issues of people not having enough time to mentor others.[5]

What Still Needs To Be Done

Thus far, NASA's KM success is measured in the areas of system design and deployment, which is apparent from the *LLIS, APPL* and web-based portal systems like *Inside JPL*. Much more needs to be done as an internal survey revealed that many working level people continue to think that knowledge loss is not "a big issue." To garner more support, the KM team should continue efforts to increase visibility and help project managers understand how supporting the initiative can contribute to their mission's success. According to project reports, inadequate risk assessment and planning and insufficient review processes were a major factor in six out of seven mission failures under FBC (Leonard and Kiron, 2002). Apparently, the lessons learned from project failure have not been applied sufficiently. Reports on the recent Columbia disaster indicate that while some improvements have been made, many experts feel as though JPL's and NASA's culture still has a way to go before taking on projects like resuming the space shuttle program. (*U.S. News and World Report,* 2004)

The President's fiscal year 2004 budget proposal statement before the House Committee on Science hinted at an increased interest in learning organization ideals. This statement provides a summary of accomplishments during the prior fiscal year and budget requests for the following fiscal year. The Aerospace Technology Enterprise proposal under Innovative Technology Transfer Partnerships outlines a proposal to develop partnerships with industry and academia that support technology transfers from NASA to these groups in order to maximize benefits to NASA, industry, academia and the taxpayer. Also, there is an Education Enterprise proposal to work with academia and with NASA's engineers to establish what it takes to develop the new technology required to continue keeping NASA at the forefront of space technology. Prior educational initiatives did not include mentoring and knowledge transfer, merely encouraging experimental curiosity. These proposals provide evidence that there may be an increase in awareness of and funding for programs like KM (Leonard and Kiron, 2002).

NASA's image is closely tied to very public failures and successes as marked by the recent space shuttle Columbia disaster and successful Mars Rover landings. Now that NASA and JPL have a long term KM system in place, more improvements should be forthcoming in the development of appropriate metrics and benchmarking; and hopefully the inclusion of these results in the annual report for public disclosure. Disclosing aggregate level metrics would provide the public with a historical record of the efficiency and, hopefully, success at NASA. Therefore, when and if another disaster or failed mission occurs, public opinion and, more importantly, U.S. Congressional opinion of

NASA may not be contingent on a recent incident.

Conclusion

Culture change at JPL through KM is crucial to NASA's future success. Because it is the world leader in aerospace and robotics research, no one can do what the JPL does. Practically any large organization could benefit from a KM program, but NASA and JPL are unique because the impact of pending retirements could be devastating. More so than in other industries, retaining knowledge from project to project is critical to NASA's success, because their missions have a near-zero margin for error, making concerns of quality control and safety paramount. Additionally, JPL works on projects that are very long-term and intricate, without an efficient data capture system it is difficult to re-trace steps and decisions that were made years ago, more so by people who have since retired.

In addition to the typical challenges facing any large scale KM initiative and the difficulties of affecting cultural change, the KM team has the added documentation and reporting burdens necessitated by being a federally funded research and development center as well as the added responsibility of national security and special data-sensitivity issues. Lastly, unlike many organizations, NASA and JPL are accountable on many levels; their very existence is threatened by repeated failure, which would result in decreased funding and lost widespread public support.

In the KM community, the JPL knowledge management initiative has drawn praise for several reasons. Instead of forcing cooperation, they began by making an effort to get employees on board, knowing that this would be the best way to make sure that the initiative endures. While developing universal solutions, they kept more specific issues and solutions in mind, therefore, keeping pace with the needs of the individual employee. Also, they worked to keep short-term needs satisfied, while staying focused on long-term goals. However, only explicit, widespread support from the top down will create the type of culture where knowledge sharing is commonplace. This type of universal encouragement has begun but has yet to fully emerge, largely because many of the NASA and JPL managers are not yet certain that knowledge loss is a grave enough problem.

Endnotes

1. Basic information regarding the strategic plan for Knowledge Management at NASA was found on NASA's KM page. Please see http://km.nasa.gov for additional information.

2. The bulk of Strassmann's writings and work, while impressive, have centered around IT investment and how to improve return on investment. He stepped down from his position at

NASA in 2003 after one year of service. The bulk of his improvements at NASA were centered on improving IT architecture, security, and services. Please see http://strassman.com for more information.

3. Basic information regarding this program was derived from the LLIS page on NASA's website. For more information see http://llis.nasa.gov

4. Basic information regarding this program was derived from the APPL page on NASA's website. For more information see http://appl.nasa.gov

5. This statement was derived from information pertaining to this program on the APPL page on NASA's website. For more information see http://appl.nasa.gov/about/about_home.htm

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