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Knowledge Reapplication:
Enhancing Organization Learning at NASA

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ABSTRACT

This paper lays out a descriptive model of knowledge reapplication at NASA to help frame Agency approaches to knowledge management and organizational learning. An 3-part integrated model of experience, networks and references is explained in the context of NASA's project focus of organization. The principles of local knowledge management and distributed ownership are suggested as important design considerations. Six existing practices that aid organizational learning are discussed as examples of knowledge reapplication at NASA.

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The Challenge to Learn

A learning organization knows how to process knowledge, appreciates the value of shared collective knowledge and grows stronger and more knowledgeable with each activity it performs. The question is how exactly does an organization like NASA do that and what changes can be made to improve the way NASA learns? Even though NASA is a unique organization it faces knowledge management challenges similar to other organizations involved in complex technical work. In order to meet these challenges NASA needs to make a strong commitment to becoming the best learning organization it can be. Fulfilling this commitment to be a better learning organization entails facilitating meaningful learning at the individual, group and organization levels. It also means improving the way NASA manages knowledge so it is useful to a broader range of people, developing new ways of sharing and transferring wisdom, and putting in place the tools, practices and structures that will move NASA toward becoming a better learning organization. This document focuses on framing the nature of this challenge in a manner so that as activities are undertaken towards meeting it, NASA leaders will be guided by a clear understanding of the parameters, constraints and opportunities that surround sustaining a healthy learning organization at NASA.

> *"The Board concludes that NASA's current organization ... has not demonstrated the characteristics of a learning organization." (p 12)*

Columbia Accident Investigation Board (CAIB) Report Aug. 2003

Initial responses to the CAIB report statements tended to focus on building systems to support collaboration tools, collections of lessons learned in databases and policies directing people to use these systems. Like many other organizations, NASA pursued ways to capture knowledge into systems assuming knowledge can be managed best when it's captured in a system for later retrieval. This response is not without precedence as many organizations in the 80s and 90s faced increased global competition based on knowledge resources. The answer seemed to be knowledge management systems that could track and manage knowledge much like enterprise data systems enabled Wal-Mart to track inventory and supply giving it a competitive advantage through efficient information management. Many millions of dollars were spent on such systems by big firms with dismal results. What worked for WalMart may not be the answer for knowledge management at organizations like NASA. The main lesson[1] to learn from these early attempts at managing knowledge seems to be that knowledge systems are necessary only as much as they enable people to share their knowledge more effectively or more efficiently with others rather than sharing with (contributing to) the system itself.

[1] WalMart was primarily interested in transactions and inventory management. It used the information to manage its supply chain and respond more rapidly to customers while minimizing system (stocking) costs. Other large organizations like NASA that have a very different business model than WalMart obviously need to think about knowledge management differently.

To approach this problem in a meaningful way at NASA it will be necessary to consider how people at NASA actually reapply knowledge prior to designing any enhancing support systems. Jens Rasmussen[2] argues that there are three means of knowledge application common to organizations: skill-based, rule-based and knowledge-based. Skill-based knowledge is that learned from training and subsequently internalized. Rule-based knowledge remains external and is utilized by reference to manuals, processes and procedural dictates. Knowledge-based implies thinking and reasoning through problems by recognizing that there are new facets and challenges that do not fit a previous solution rubric. James Reason[3] uses this model in attempting to explain organizational accidents but his expansion of the model helps clarify that organization learning takes place by updating either the rules or the skills in use within an organization. This seems to validate the focus of organization on documenting 'known-to-work' routines and institutionalizing continuous training based on lessons garnered from on-going experiences. NASA does use lessons from mishaps to update rules and training though in some areas the linkage could probably be more explicitly managed.

The difficulty for NASA may be in the third area of knowledge-based learning that often characterizes the nature of much of NASA's work. Most organizations use rules to eliminate thinking on the part of employees. To quote Alfred North Whitehead: "Civilization advances by extending the number of important operations which we can perform without thinking about them."[4] Using rules is necessary but not sufficient for an organization like NASA to learn effectively in order to assure mission success. NASA must foster learning that updates rules but also enhances skills and builds capacity for knowledge-based problem solving. Knowledge reapplication does not necessarily imply a lesser degree of thinking in the space business but more informed thinking and broader application of proximate knowledge domains.

How does NASA reapply knowledge?

Much of the core and unique NASA knowledge is embedded in the experiences of NASA people—people who have worked through challenges and problems and gained their own personal experience along the way. When that person moves to a different project or job, they take along their personal experiences and the associated knowledge and reapply it in the new situation. Getting the right (experienced) people assigned to new missions, projects or departments is a critical task within NASA that reflects this knowledge embeddedness. To get the necessary experience: get the person with the experience. The natural life cycle of projects (they begin, perform, and die) forces people to tackle new assignments every few years within NASA. This inherent job migration process moves and reapplies NASA embedded wisdom.

Closely related to personal experience is personal network. If I don't know what I need to address the problem in front of me I consider who I do know who might know how to solve it or could at least help me think through it. I draw on what others know through the network of who I know. Clearly, the experiences of several projects helps me grow my network so that I know

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[2] "Skills, rules, knowledge: signals, signs, symbols and other distinctions in human performance models." (1983). Jens Rasmussen, *IEEE Transactions: Systems, Man and Cybernetics*, SMC-13, pp257-267.
[3] Managing the Risks of Organizational Accidents, (1997). James Reason, Ashgate Publishing, Burlington, VT.
[4] *Introduction to Mathematics,* (1911). Alfred North Whitehead.

many people who know things that can augment my own ability to design, craft and problem-solve. This extended network greatly enhances the reapplication of NASA knowledge by extending the reach of each one to many. A network helps me draw upon what other people know but to do so I have to know them and know what they might know. It is interesting to note that many knowledge management systems (ASKME being a popular example) attempt to replicate this process anonymously by setting up a system whereby a person can get answers without having to know either the person or what they already know. People use this type of inquiry daily on the internet to answer questions. Organization have struggled to make this process value-added because the anonymity removes the *personal* network aspect. Gaining knowledge off an internet site does not enhance my network of who I know—it just answers the one question of the moment.

Much wisdom has been gained and accumulated in the knowledge domains relevant to NASA in textbooks, manuals, guides and policy documents. These references represent a means to find information of a more specific nature (how to design or build a particular assembly) and also principles on the management level such as margin allowances, team building tips or how to conduct a review. This kind of knowledge can be referred to as what everybody knows or common knowledge. Common knowledge though useful, often lacks sufficient context to reapply it effectively unless it can be integrated with personal or network knowledge.

These three systems of knowledge reapplication really work in an almost seamless fashion on a daily basis and clearly support each other. (See figure 1.) In some cases the primary path may be through job migration: people move from job to job or assignment to assignment and simply take their knowledge and experience from job 1 to job 2 and apply it there. This continuous mixing and matching of employees in teams, missions and assignments results in a great deal of exposure to new thinking and subsequent reapplication of knowledge to new situations. NASA is not unique in this regard but perhaps it is more critical for us because of NASA's projectization of missions, its matrix structure of disciplines and the decentralized distribution of workforce across multiple centers, partners and industry.

People rely heavily in NASA on their personal networks to help them reapply knowledge. Clearly, a persons network is largely contingent on the successful job migration path and whom they have worked with during their career. The network may be considered the second tier of learning that enables someone to quickly call a trusted known source to get an answer, a second opinion, a reference or question which helps them solve a particular problem.

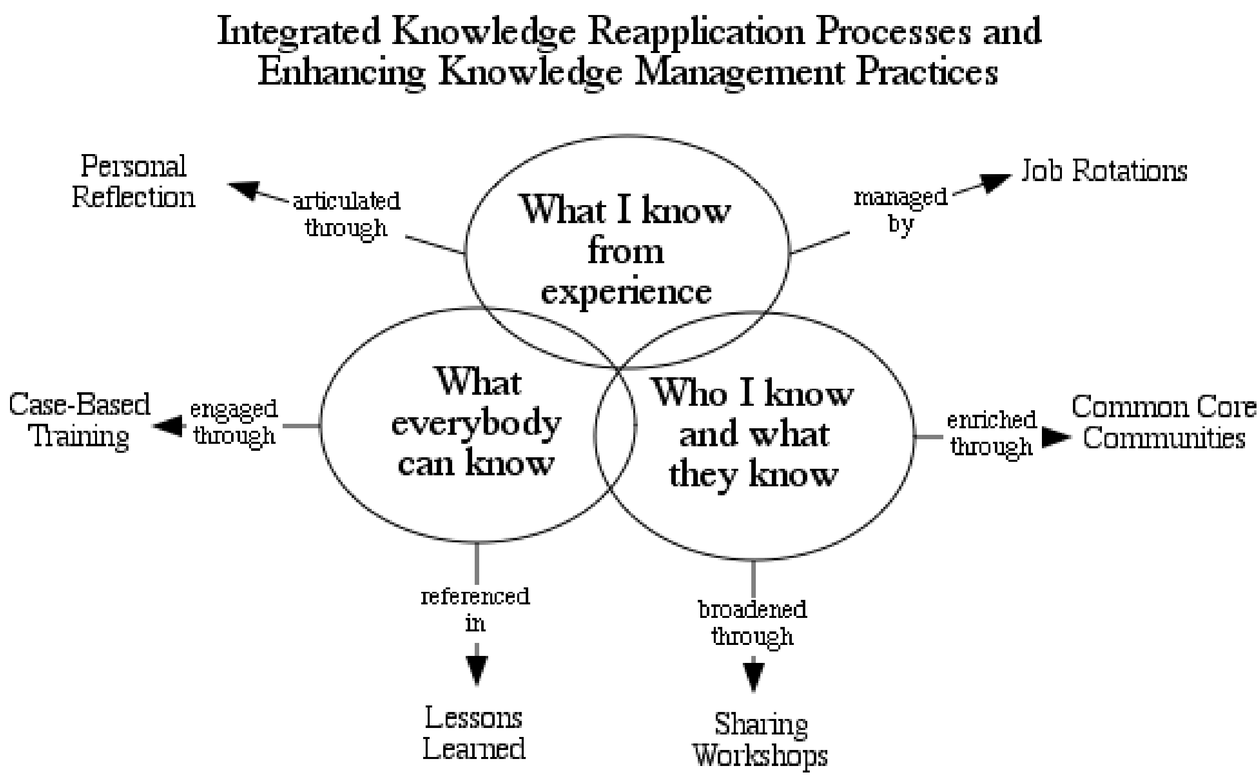
> Knowledge management does not substitute for individual learning capacity. Our systems must augment the human capacity to learn, not seek to replace human thinking with rules and procedures.

If someone doesn't know the answer *and* doesn't know someone who probably knows the answer, *then* they might look for it in a stored system to find someone who does know something about the subject at hand. Alternatively, they may *start* with the repository if they already have a clearly defined question. Experience and networks are necessary to frame questions and challenge assumptions. Documents provide evidence but it is difficult to quickly reapply thinking from documents without the context.

Curious thinkers almost always want to know the context to understand the knowledge they are considering. Experience or networks are essential in this regard. For example, a colleague may suggest a lesson from another mission he's heard about. The seeker may look up the lesson and find out who the system engineer was and call them to discuss a design question or risk element. In this way the systems all work in an integrated fashion in practice within the daily flow of work.

Understanding this three level system of knowledge reapplication at NASA can help guide interventions to improve the way the Agency learns and avoids repeating mistakes. At the start, interventions should not hinder the way people are learning but instead should enhance their ability to learn from all three paths in an integrated fashion. This model of learning may also help explain why people so routinely perceive a low value-add of database approaches to knowledge management. If the Agency talks about Lessons Learned Databases as a *primary* learning vehicle when the workforce actually uses such systems in a tertiary manner then users have a gap in promise versus expected value. This gap can feed the perception that Lessons Learned databases are not useful when they clearly have an important role to play. The Agency could address this perception problem by approaching knowledge management in a larger way that includes all three modes of reapplication in an integrated model closer to what people perceive as reality.

FIGURE 1: KNOWLEDGE REAPPLICATION MODEL



Enhancing Existing NASA Practices to Increase Learning

The NASA learning model is useful because it points to where intervention can help. Specifically, there are six intervention points that can enhance organization learning at NASA: 1) effective job rotation, 2) personal reflection, 3) knowledge sharing forums, 4) common core communities, 5) case-based training and 6) lessons learned. Each of these can be thought of as an organizational practice that individually may not seem tremendously effective but when combined add up to a powerful learning energy for the organization.

To enhance the benefits of job migration careers need to be proactively managed to assure that people are getting challenging, stimulating and relevant experience to build their personal knowledge. A robust and well-managed job rotation program can be significant step to getting people the right experiences.

The second key to learning from job migration is making sure there is adequate time for reflection at each job assignment.[5] Teams need time and focus to learn from what they are doing before they move on. Making reflective learning a routine process for all teams and work groups can greatly enhance the quality and depth of experiential learning. Reflective learning can achieve two things: 1) the team can process their experiences into more articulate insights and lessons; and 2) the individuals will gain knowledge and experience beyond their own by sharing insights with those they worked closely with while on the team.

A good series of job experiences will obviously enhance a personal network of contacts but there are other ways to enhance networks. Interactive workshops, seminars and knowledge sharing events bring people together from various groups to share lessons and experiences. These events can have a long-term effect by building relationships and establishing broad networks of experts.

The second network enhancing practice is that of facilitating the operation of quasi-formal communities, on-going discussion groups and digital forums. These "Common Core Communities" [6] or CCC often need only simple sharing, networking and collaboration tools to facilitate their operation. Allowing and even encouraging such groups to form across NASA will enhance personal networks and the extended reapplication of knowledge through expert communities often outside of formal lines of organizational structure.

Whether mishaps, close calls or successes, the case study is a proven means to get people to engage with a situation, learn the larger lessons and begin to see connections to their current work. Cases stimulate deep thinking and learning beyond simply providing answers.[7] In this way cases augment traditional lessons learned systems. A case study discussion may also help an

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[5] Reflective learning often happens on its own. It can also be encouraged through simple activities such as the PaL process (Pause and Learn) developed at Goddard to facilitate time for reflection and learning within teams.

[6] Common core communities (CCC) is a term for communities of practice, professional discussion groups, digital societies etc. in other words professional who share some knowledge domain in common and can relate to each other by discussing, sharing and interacting around and within that knowledge domain.

[7] There are actually many ways to use case studies. The Office of Chief Engineer uses case studies extensively in technical training. The Safety and Mission Assurance Office uses System Failure Case Studies derived from mishaps. The project management community uses cases of successful and failed missions to illustrate project management principles. The point is to use the case study as a tool not just rely on hearsay and anecdotes.

individual identify where to go or who to contact for further insight. Case-based training brings practitioners into contact with others specifically to discuss their experiences. Involving case studies in NASA training programs not only integrates experience and thinking skills into training but creates a meaningful context for experienced persons to share their stories, insights and lessons with others. To enhance learning from documents and records the knowledge embedded in them can be made more attractive and relevant when presented in the context of a case study.

Lessons learned both in narrative documents and summarized report form a reference foundation of learning. Documented lessons should be linked to policies, handbooks and standards so that the context of the lesson is apparent and the application is relevant. Lessons learned systems by themselves struggle with credibility because reapplication is often below the expectations of those managing the system. The key to making them effective and worth the time collecting is the connection to work processes and linking them back through case studies into training. This awareness and relevance of lessons makes them alive and active rather than passive. Lessons learned can also be connected through corrective action systems for timely consideration across the organization.

> Knowledge should be organized as closely as possible to the work processes that it impacts.

Principles to Keep in Mind

The key to managing knowledge is not necessarily to extract it from its origins but to facilitate its use both at the source and within communities across the organization. KM systems don't so much create communities as they facilitate their existence and function. The communities are defined by function, task or interest. KM should help NASA communities (project teams, work units, domain groups etc.) behave and function like learning organizations generating, sharing, using and preserving their knowledge. The divisions and other work units at NASA will still be the primary owners and holders of their respective knowledge. Knowledge should be organized as closely as possible to the work processes that it impacts to retain its relevance and authenticity. Knowledge management then is helping the organization utilize its knowledge and benefit from the learning pathways in operation. Knowledge that is close to the action is more likely to be reused. Centralizing knowledge repositories for IT efficiencies may decrease knowledge utilization rates by reducing relevance, access and context all of which help knowledge flow to new challenges. Locally owned and sustained knowledge is more up-to-date, more contextual and richer in connections (links to origins, owners and operators) that enhance the ability of people to grasp and apply the knowledge to their own situations.

> We must resist deskilling solutions that remove human creativity from the workplace.

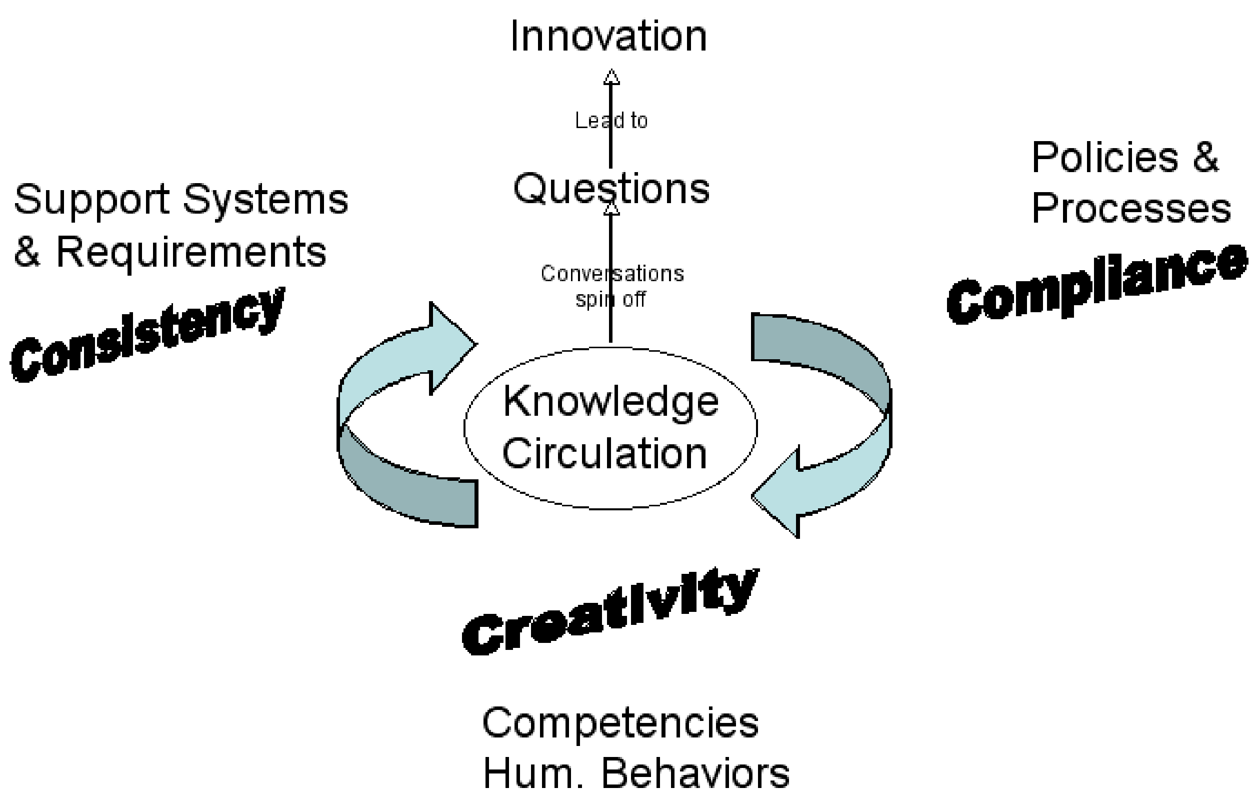
To really function like a learning organizaton, learning behavior must be modeled by organizational leaders.[8] Members of a learning organization take time to reflect, learn and share. They take time to comment on insights of

[8] Leader modeling is a catch-phrase but the principle derives substance from Argyris *Teaching Smart People How to Learn,* Harvard Business Review (1991) double loop learning concept that old methods cannot be used to introduce new methods. In this sense leaders must model new learning behavior if they expect that behavior to be adopted within the organization—or more bluntly: command and control will not foster commitment and caring!

others. They share incomplete ideas hoping others will fill in gaps or point out omissions. This type of behavior generates the cross-domain innovation necessary to solve unique challenges such as those adopted in NASA's mission. People will behave this way particularly when they observe that such behavior is valued and demonstrated by their leaders. An open decision-making process and the frequent sharing of stories, cases and challenges help communicate and reinforce positive learning behaviors.

Valuing collective knowledge means rewarding, celebrating and pursuing activities that help NASA to know more. To build systems that enhance human potential means we must resist deskilling solutions that remove human creativity from the workplace. Knowledge management is not about automating human thinking processes but augmenting them to be more productive. KM should enhance creativity and innovation at NASA.

FIGURE 2: MODEL OF KNOWLEDGE CIRCULATION

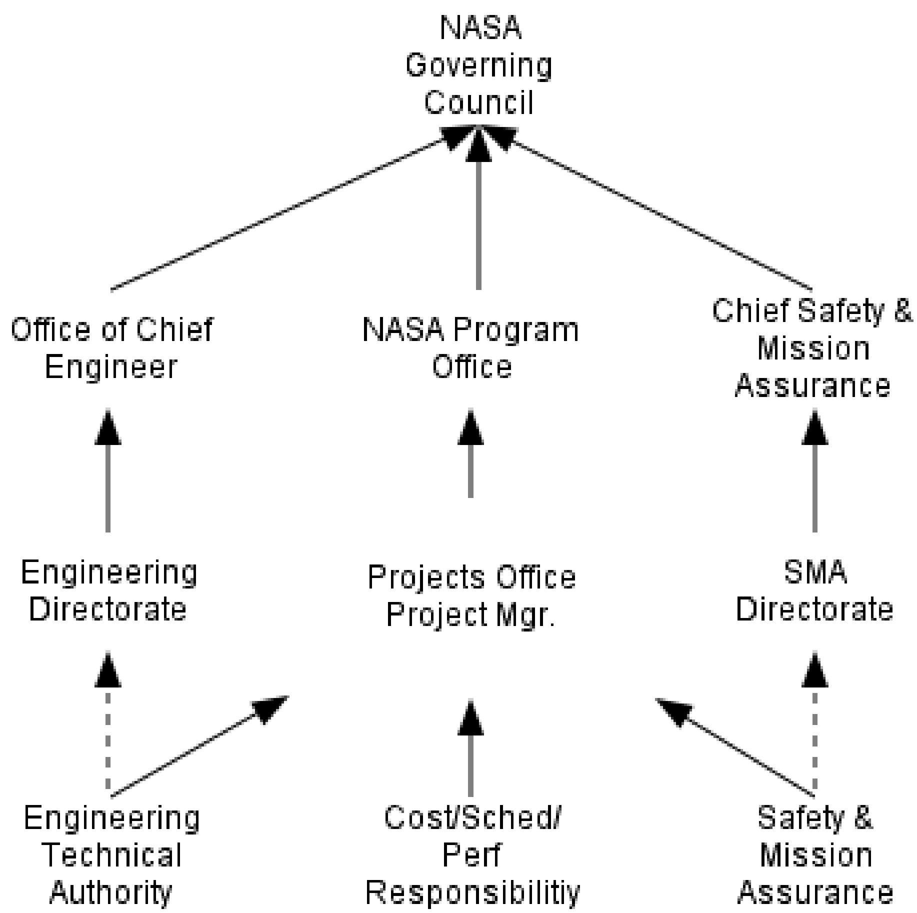


Sustaining Learning Capability

To sustain this capability in the future NASA needs to recognize specifically why it has been successful in the past. Examining mishaps is necessary but policy decisions need to also be driven by understanding successes. Success motivates people far better than failure but it is often more difficult to understand. Success does not have a 'point of success' to single out as cause. All the more reason for NASA leaders to continue to champion the attributes of the NASA system that contribute to mission success. One model for understanding NASA's success is that of Knowledge Circulation (see figure 2).

Knowledge circulation occurs with the right balance among these three elements – a healthy tension in the organizational structure – that maintains focus on purpose but allows room for creativity and innovation to occur. This model of tension is reflected further in the matrix structure of the NASA approach to project management and the governance model of independent checks and balances between project management, technical authority and safety. (See figure 3).Success is bred in adequate creativity focused on solving relevant challenges in safe (with acceptable risk) and well-understood ways.

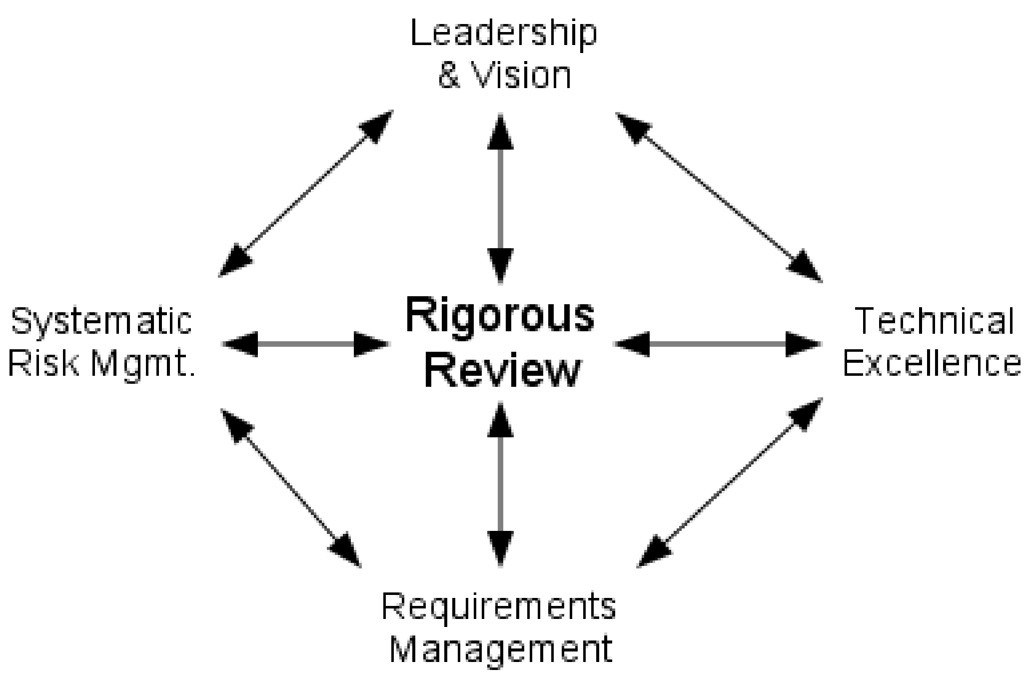
FIGURE 3 NASA GOVERNANCE MODEL (SIMPLIFIED) OF INDEPENDENT LINES OF AUTHORITY



As important as this matrix structure and independent reporting lines are to keeping NASA healthy there is another aspect to consider: how a project functions within this framework. It is worth noting (see figure 4) that the four critical areas of success: 1) leadership towards a vision, 2) requirements management 3) risk management, and 4) excellent engineering –still hinge on the center box of a healthy internal discussion and an open review process. NASA has worked hard to maintain this open learning environment that both assures mission success and also helps attract a vibrant and intellectually engaged workforce. In this NASA is on a solid foundation of freedom of inquiry going back to John Stuart Mill in 1859: "Complete liberty of contradicting and disapproving our opinion is the very condition which justifies us in assuming its truth for purposes of action and on no other terms can a being with human faculties have any rational assurance of being right."[9]

The practices outlined above that NASA uses help the organization to function like a learning organization. An effective knowledge management approach for NASA needs to build on this success model and the three learning modes that exist within the organization. A clear and meaningful commitment to leaning can be motivating and liberating to the workforce to share and learn while they are engaged in their demanding and critical NASA work.

Figure 4 NASA Project Management Success Model



Conclusion

The principles and insights shared in this paper come to have meaning within this NASA culture of open decision-making, the free-flow of information and the welcoming of dissent, debate and discussion around decisions concerning design, development, deployment and decommissioning of missions. How KM can work for NASA may not be the same as how it works for other

[9] *On Liberty,* (1859). John Stuart Mill.

organizations. NASA is already a tremendous learning organization that has accomplished tasks people only dreamed about just decades ago. This paper has attempted to layout a description of how NASA learns and how those processes can be enhanced through a meaningful approach to knowledge management as a means to improve organizational learning. NASA has been faulted in some its high visibility accidents for not learning from past mistakes. Not learning is itself a mistake that sometimes manifests in accidents. The way to avoid such mishaps is to continue to build the most robust learning organization possible. The cause of future accidents cannot be accurately predicted but a smart and healthy learning organization has a much better chance of avoiding future mistakes because it reapplies its own best knowledge effectively.

Six Fundamental Learning Practices

Pause And Learn (PaL)[10]

While many teams and groups at NASA meet and discuss events after they happen, NASA has no formal process to guide the meaningful collection of lessons in the way AAR's function. The Goddard Office of Chief Knowledge Officer (OCKO) adapted the U.S. Army's After Action Review (AAR) concept to project management.

> An AAR is "…a professional discussion of an event, focused on performance standards, that enables ***soldiers to discover for themselves*** what happened, why it happened, and how to sustain strengths and improve on weaknesses" [italics added]
>
> A Leader's Guide to After-Action Reviews, 1993 p 1.

The Army learned from years of experience with After Action Reviews (AAR) that much of the value in the AAR exercise comes from several key design parameters. First, the focus of the AAR is specific to 1) What happened (events), 2) Why did it happen (cause), 3) How can we improve (action). Second, the AAR is a participant discussion. AAR's replaced traditional top down lecture critiques. What was valuable about AAR's was the voice of the team members themselves offering up their views and ideas. Third, the AAR is close to the action in time, space and personnel. Fourth, the AAR does not function as a career review. It is a non-attribution team review of what happened. The team members participate because they feel free to speak. Finally, the AAR is part of the overall process whether it is a training exercise, a simulation or a field operation. The action is not complete until the AAR has been conducted. The AAR is a fundamental part of the process built into the project. The AAR method replaced sterile lecture type critiques delivered by judges often some time after the end of the events. The participants were not energized and sometimes defensive about these reviews.

At NASA the process is called "Pause and Learn" because the exercise is not just performed at the end of a mission but at an event, milestone or review step. Before going on to the next task, the team is brought together to pause and reflect on learning from what they have just accomplished. The concept PaL can be described as a 3-step process outlined below. Key is having knowledgeable facilitators that are familiar with the topic, the people and process.

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[10] See White Paper on *Pausing For Learning: Adapting the After Action Review Process to NASA* and a brochure explaining the PaL process at: http://www.nasa.gov/centers/goddard/about/organizations/OCKO/index.html

Step 1

- Identify when PaLs will occur
- Determine who will attend PALs
- Select Moderators, Rapporteurs
- Select potential PaL sites
- Review the PaL plan

Step 2

- Review what was supposed to happen
- Establish what happened (esp. dissenting points of view)
- Determine what worked well and what didn't go so well
- Determine how the task could/should be done differently next time

Step 3

- Review objectives, tasks, and common procedures
- Identify key events
- Rapporteurs collect *ALL* observations
- Organize observations (identify key discussion or teaching points)

The PaL process is the critical foundation for learning from the project lifecycle. PaLs should occur after major events, milestones and reviews. The material generated first and foremost belongs to and is meant for the team. Out of their notes and lessons there is a potential for important lessons, insights and wisdom to flow to other projects through the other practices. Without this foundational practice in place, the architecture for learning has little chance of being highly successful. If learning is done at this level throughout the project life, gathering lessons learned after launch, or post mission will mainly be a review of the PaL data. In addition, the bias of hindsight will be removed by using data collected close to the event in time.

Job Rotations[11]

Job rotation is in some ways a fact of life at NASA simply because of the project orientation of the work. In the normal life cycle of projects, people are moved to new assignments. However, some people manage themselves and those who report to them better than others. What is needed is to recognize that it is every supervisor's responsibility to proactively manage work rotations to enhance learning. NASA depends on it. Likewise, the ability to move between jobs and assignments, especially those horizontal moves that broaden experience needs to be encouraged and facilitated with appropriate support from the Office of Human Capital (OHCM). Then what is a characteristic of NASA by the nature of the work also becomes a strength for the building of a sound learning organization. It is not enough to have an OHCM practice but also an attitude of every employee that seeks out a broad and rich experience base throughout their NASA career.

Knowledge Sharing Workshops[12]

A learning culture thrives on opportunities to share and learn from each other. It attracts those interested in learning together because they know that they will be personally challenged only if they are active participants in the learning culture. Knowledge Sharing Workshops are an

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[11] For information on job rotations see OHCM at: http://ohcm.gsfc.nasa.gov/

[12] For information on how the OCKO runs the KSWs at Goddard see the OCKO website at: http://www.nasa.gov/centers/goddard/about/organizations/OCKO/index.html

opportunity to model that kind of behavior for NASA. At each workshop, senior project leaders share their insights, what they learned and what they might do differently based on their recent project experience. These workshops may also include emerging leaders who want to learn the wisdom necessary to succeed. APPEL[13] has been the Agency's proponent of learning forums through its many courses and workshops, the best known being the Master's Forum held twice a year. Experienced project leaders come together to share their stories and lessons with each other in an open exchange format while simultaneously building their networks.

Knowledge Sharing Workshops are also held at centers ranging from a few hours to a full day. A typical Knowledge Sharing Workshop is about two hours in length. The first 30 minutes the panel briefly tells their role in the project and their most memorable experiences. Then for 30-40 minutes the participants discuss in groups what those lessons mean to them sometimes with the aid of a short case study, timeline or other material about the mission. During the second hour, the panel responds to questions from the groups. The session is facilitated to keep on topic and time. The panel is made up of senior project personnel who were directly involved in the project. It is primarily individuals telling their own story of what happened and what they learned. Usually the workshop is focused on a project that is in operations or has experienced a significant event (could be failure, cancellation or success). The main point of the workshop is to allow people to hear the 'rest of the story' and to make connections with their own work for immediate reapplication of lessons from the experiences shared. Like the APPEL forums, people also build their own personal networks through the interactive learning process.

Common Core Communities[14]

Communities at NASA exist in many shapes and sizes. There are semi-formal groups formed as project teams, review teams and investigative teams and there are ad hoc groups formed just to discuss specific issues. Groups exist on PBMA with the Safety and Mission Assurance Office as well as within the Office of the Chief Engineer (NASA Engineering Network) and with the Exploration Systems Mission Directorate under Risk Management. All of these groups and others that exist try to facilitate interaction and sharing along a common knowledge domain.

The tool and breadth of the group is not as important as the vibrancy of the interactions. Getting everyone who has a similar sounding title assigned to a group is not what makes a group function well. Sometimes less facilitation (light touch) is needed to allow discussion and interaction to flow. Natural curiosity and intellectual inquisitiveness are much stronger drivers than organizational charts and titles. It is important to not confuse a tool that supports groups from a tool that requires or mandates group formation. Support is needed. Assignment is rarely valuable.

NASA Case Studies[15]

Organizational learning takes place when knowledge is shared in usable ways among organization members. Knowledge is most usable when it is contextual. NASA has processes for recording and sharing parts, safety and routine process knowledge across disciplines through training, lessons learned and information databases. What is less well developed is the sharing of

[13] APPEL: The NASA Academy of Program/Project and Engineering Leadership see: http://appel.nasa.gov
[14] See the PBMA for more information on NASA on-line communities at: https://secureworkgroups.grc.nasa.gov/
[15] Case studies are available at both the OCKO and APPEL websites listed in the previous footnotes.

contextual project management knowledge. To build organizational learning capacity around project management, the context of the project stories must be brought into the knowledge management system. A case study is an effective vehicle to do this.

Documented case studies provide a context for key players to present material, reflect on project management insights and share contextual knowledge in a meaningful way. The case teaching method is a means for developing systems thinking skills needed by a learning organization. While case learning is not as common in engineering and scientific fields as it is in policy or business, project management wisdom is really an ideal subject for the case learning method. Some resistance to case learning with its inherent ambiguity can be expected from technical professionals more accustomed to finding ‘the right answer’ than wrestling with multiple outcome paths.

The case study is written to allow one or more key players from the case to tell their story and interact with participants in a learning environment.

Case stories are best told by the key players in that story. Case stories are written by interviewing the key players on a project in addition to collecting historical documents and reports. A professional writer produces a written case story incorporating human elements, technical aspects and lessons learned. From the case stories one or more case studies are then extracted. The case study is written to allow one or more key players from the case to tell their story and interact with participants in a learning environment.

A case study for teaching focuses on a specific aspect, event or time horizon in the life of the project. Each study has one or more learning objectives that can be used in a discussion, presentation or self-reflection. The case study also provides links (on-line) to the sources, referenced competencies or technical details (such as designs, test results, or configuration management documents) to enable the reader to probe further questions that arise in the reading of the case. Case studies are used in training courses, at conferences and in Knowledge Sharing Workshops across NASA.

Case studies are another form of a knowledge transfer channel. They are constructed opportunities for conversations to happen. They allow learning to happen at several levels. Participants often learn details of other projects or events that they did not know of beyond headlines. They also get to meet the people who were intimately involved with those events. They are placed in a position to think through the decisions those people had to make a the time. Thus, they get the benefit of learning from the decision making process itself, what they will experience in their work, rather than just hearing filtered after-the-fact explanations. Finally, hearing the rest of the story directly builds trust, opens relationships and fosters a sharing environment. All of these benefits are lost with traditional captured lessons learned that are devoid of context. Lessons learned systems are good for information management, keeping track of things we know but by themselves foster little organizational learning. Learning takes place within context. The case learning approach to knowledge management helps create that context.

Case studies as used in academic settings also help get out the story of NASA. Unless we actively tell the story of how NASA works, college students will learn about NASA only from press accounts of mistakes and accidents. Goddard is working to make its case studies suitable and available for use in aerospace, engineering, and management programs.

Lessons Learned

Lessons learned are collected by many projects and institutional groups across NASA. Most are shared locally within the group where most of the learning is applied. Some of these lessons, especially if they are well-articulated and broadly applicable may be shared in various NASA systems for lessons. The Office of Chief Engineer operates a NASA Engineering Network for technical lessons. The Academy of Program/Project and Engineering Leadership (APPEL) holds numerous training events incorporating lessons and case studies. The Safety and Mission Assurance Office operates the Process Based Mission Assurance (PBMA) site which houses lessons and video nuggets. The NASA Safety and Engineering Center (NESC) has a collection of reports and video courses on lessons from experts. Many other examples exist within NASA of lessons from the very local level to the highest levels.

The Exploration Systems Mission Directorate (ESMD) has chosen to integrate Knowledge Mangement with Risk Management functionally. In part this is due to the unique combination of risks facing ESMD. As ESMD moves through the early stages of risk identification and mitigation planning, it has developed a sound Risk Management Plan (RMP) that uniquely incorporates Knowledge Management. ESMD understands that many of the challenges of exploration systems development are due to the complexity arising from interactions among hardware and software systems, management processes, organizational cultures, and transitions from past or existing programs to new programs. These interactions require systems thinking and constant diligence to achieve acceptable levels of risk. . The following is from the ESMD Risk Management Plan:

> *ESMD risk management shall include the integration of knowledge management and risk management processes into the program/project life cycle. Designing a complex architecture of hardware, software, ground and space-based assets to return to the Moon and then on to Mars will require an effective strategy to generate, capture and distribute knowledge. Risk Management Officers, who already use lessons learned as a source of information for risk identification, are in a unique position within the organization to effectively perform these functions.*
>
> ESMD RM Plan, Sec 2.2

Capturing existing knowledge and then applying that knowledge is critical to mitigating risk. Where the knowledge does not exist, ESMD must produce it through technology development, robotic flight precursors, and verified modeling and simulation. The knowledge must be effectively transitioned to the development and operating programs. This is the shared goal across NASA: to reapply knowledge effectively and efficiently to achieve mission success.

References:

Argyris, C. (1991). *Teaching Smart People How to Learn*, Harvard Business Review, May-June 1991, pp. 99-109.

Davenport, T. & Prusak, L. (1998). Working Knowledge, Harvard Business School Press, Boston, MA.

Dixon, Nancy, et.al. (2005). Company Command: Unleashing the power of the Army Profession, Center for the Advancement of Leader Development and Organizational Learning, West Point, NY.

Lengyel, D. & Rogers, E. (2006). *Strategy for Exploration Systems Mission Directorate (ESMD) Integrated Risk Management, Knowledge Management and Organizational Learning*, Internal NASA White Paper.

Morrison, J. & Meliza, L. (1999). *Foundations of the After Action Review Process,* United States Army Research Institute for the Behavioral and Social Sciences, Institute for Defense Analyses, Alexandria, VA.

McElroy, M.W. (1999). Double-Loop Knowledge Management, MacroInnovation Inc. Available from www.macroinnovation.com

Perrow, Charles, (1984). *Normal Accidents: Living with High-Risk Technologies*, Basic Books, New York.

Pfeffer, J. & Sutton, R. (1999). The Knowing-Doing Gap: How smart companies turn knowledge into action. Harvard Business School Press.

Rasmussen, Jens, (1983). "Skills, rules, knowledge: signals, signs, symbols and other distinctions in human performance models." *IEEE Transactions: Systems, Man and Cybernetics*, SMC-13, pp257-267.

Reason, James, (1997). Managing the Risks of Organizational Accidents, Ashgate Publishing, Burlington, Vermont.

Rogers, E. & Milam, J. (2005). *Pausing for Learning.* IEEE Aerospace Conference Proceedings, March 7-12, 2005, Big Sky Montana.

Rogers, E. W. (2004). *The role of perceptions of reciprocity in achieving cooperative knowledge behavior in high tech firms.* Journal of High Technology Management Research. Vol. 15/1 pp. 17-36.

Rogers, E. (1998) *Enabling innovative thinking: Fostering the art of knowledge crafting*. International Journal of Technology Innovation, 16(1/2/3) pp. 11-22.

Schein, E. (1993). *On Dialogue, Culture, and Organizational Learning,* Organizational Dynamics, Autumn 1993, pp 40-51.

Starbuck, W. H. & Farjoun, M.(eds.) (2005). *Organization at the Limit: Lessons from the Columbia Disaster*, Blackwell Publishing, Malden, MA.

U.S. Army Combined Command, (1993). *A Leader's Guide to After-Action Reviews*, Training Circular (TC) 25-20.

Wenger, Etienne (1998). *Communities of Practice: Learning, Meaning and Identity,* Cambridge University Press, Cambridge, UK