

**Building a Healthy Learning Organization
at the NASA Goddard Space Flight Center**

by

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Knowledge Management Systems as Human Systems

Managing the interface between humans and machines has taken on new challenges in organizations as transactional efficiencies of electronic connectedness offer greater potential for information dissemination. Many knowledge management efforts are focused solely on this transactional efficiency aspect of the problem. Less well understood and certainly not accounted for in most attempts at knowledge management are the human factors that make sharing both possible and worthwhile. However, to build a sustainable learning culture these human factors must be addressed in the architecture of organizational system design to enable learning and sharing.

It is important to state two assumptions fundamental to this paper. First, 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. It does so because its systems (human and technical) interact in meaningful and healthy ways. Information is represented in ways meaningful and useful to humans (Novak, 1977). The organization learns because its human members interact with each other in ways that stimulate sharing and reapplication of organizational knowledge (Argyris, 1991). Second, the core of an organization's knowledge resides in the work units and projects where it is being generated, not in a central repository. The key to managing knowledge is not to extract it from its origins but to facilitate its use both at the source and within communities of practice across the organization (Wegner, 1998; Rogers, 2004). These two premises will not be argued here but are essential to this paper.

To be effective then, knowledge management must go beyond 'first generation KM characterized by single loop learning (Argyris, 1992). McElroy (1999) concludes that "conventional knowledge management practice boils down to little more than getting the *right information to the right people at the right time*. Think *single-loop learning*." [italics in original]. Shukla and Srinivasan (2002) go further and state "The purpose of first generation KM programs is to improve operational efficiency of the employees by enhancing access to rule sets." An effective KM architecture must focus on second generation knowledge management that is clearly double-loop learning and includes the what and why (the context) of the knowledge, not just the rules and forms. KM models that are built solely on efficiency concerns will find difficulty in achieving healthy organizational learning environments.

NASA's response to the knowledge management challenge was the formation of a NASA Knowledge Management Team chartered to write a KM Strategic Plan for the Agency. Unfortunately, that plan fell short of achieving effective change primarily because it focused exclusively on IT as a KM driver with an over-emphasis on ***capturing knowledge from workers*** for the organization as opposed to ***facilitating knowledge sharing among workers***. In other words, it called for efficient deployment of tools but

accepted unintended consequences detrimental to organizational health, many of the things predicted by Argyris (1992) in his discussion of why MIS implementations so often fail. Many KM efforts similarly fail precisely because they “emphasize technology and the transfer of codified knowledge.” (Pfeffer & Sutton, 1999). McElroy (2000) put it succinctly when he stated, “As smart as a KM system may be, it will never be smart enough to fool the people expected to use it.” The Goddard Space Flight Center KM approach seeks to overcome the tendency for large organizations to focus on IT efficiency drivers and instead works towards building an effective learning organization supported by appropriate technology¹.

Functioning Like a Learning Organization

The Goddard Learning Plan has been developed in the context of the post-Columbia environment. In August of 2003, the Columbia Accident Investigation Board Report (CAIB) faulted NASA for not functioning as a learning organization. Consider these telling excerpts from the final report on the Columbia accident: [all italics added]

“We are convinced that the *management practices* overseeing the Space Shuttle Program *were as much a cause* of the accident as the foam that struck the left wing.” Synopsis, Page 11

“The Board concludes that NASA’s current organization does not provide effective checks and balances, does not have an independent safety program, and *has not demonstrated the characteristics of a learning organization.*” Synopsis, Page 12

“..the pressure of maintaining the flight schedule created a management atmosphere that increasingly accepted less-than-specification performance of various components and systems, on the grounds that such deviations had not interfered with the success of previous flights.” Section 1.4, Page 24

“With no engineering analysis, Shuttle *managers used past success as a justification for future flights*, and made no change to the External Tank configurations planned for STS-113, and, subsequently, for STS-107.” Section 6.1, Page 126

“Shuttle management declined to have the crew inspect the Orbiter for damage, declined to request on-orbit imaging, and ultimately discounted the possibility of a burn-through.” “The Board views the failure to do so as an illustration of the lack of institutional memory in the Space Shuttle Program that supports the Board’s claim... that *NASA is not functioning as a learning organization.*” Section 6.1, Page 127

¹ The Department of Navy released a Memo (October 20, 2005) outlining a strategy for KM in the DON that states sophisticated technology is not a required element of a successful KM program.

“As the autumn of 2002 began, both the Space Shuttle and Space Station Programs began to use what some employees termed ‘tricks’ to regain schedule margin. Employees expressed concern that their ability to gain schedule margin using existing measures was waning.” Section 6.2, Page 134

“The *organizational structure and hierarchy blocked effective communication* of technical problems. Signals were overlooked, *people were silenced*, and useful information and dissenting views on technical issues did not surface at higher levels. What was communicated to parts of the organization was that O-ring erosion and foam debris were not problems.” Section 8.5, Page 201

“NASA structure changed as roles and responsibilities were transferred to contractors, which increased the dependence on the private sector for safety functions and risk assessment while simultaneously reducing the in-house capability to spot safety issues.” Section 8.5, Page 202

“Changes in organizational structure should be made only with careful consideration of their effect on the system and their *possible unintended consequences*. Changes that make the organization more complex may create new ways that it can fail.” Section 8.6, Page 203

These statements indicate an organization that is not applying what it already knows to its own problems. First, such an organization accepts unintended consequences due to a lack of systems thinking (make up schedule by slacking on safety), stumbles over itself (adopts rules that inhibit communication) and fails to correct detected errors (rationalizes anomalies rather than investigating and closing them.) To be an effective learning organization NASA must overcome these deficiencies and build a learning system that is reliable and of sustainable strategic value to the organization.

Reliability and Sustainability of Organizational Systems

In general, a system may be considered healthy if it is both reliable and sustainable. Unreliable systems produce errors or spurious output causing users to lose confidence in system performance. An unsustainable system is often inefficient because of costly repair, realignment and upgrade cycles that cost more than the output value of the system, i.e. they are high maintenance systems. Reliability is primarily a function of operational effectiveness while sustainability is more an issue of efficiency of design. A high reliability system produces predictable output. A sustainable system continues to be reliable because it is designed to adapt as the environment changes. Translating these general systems concepts to organizations helps explain why so many organizations fail despite well-meaning people, lofty goals and ample resources. Organizational systems that are either unreliable or unsustainable are strategic failures sometimes in spite of heroic operational efforts.

Reliable systems that cannot adapt may be termed “learn once” systems or ‘knowing organizations’ (McGill & Slocum, 1993). Once a pattern is adopted, it is repeated reliably without change or adaptation. If the inputs or the environment are altered the reliability degrades and the organization fails. A system that is only reliable under very narrow set of environmental constraints is probably unsustainable because those constraints cannot be maintained within a value returning cost structure. Systems that are not sustainable are draining. They may use more resources than they produce in products because of the high cost of retooling, inefficient processes and high overhead. Many government agencies find themselves operating in a human capital environment that is not sustainable. Systems that are unsustainable may operate productively for periods of time but they often suffer dramatic realignments when delayed investments cause reliability to fail. NASA’s experiment with Faster, Better, Cheaper (FBC) can somewhat be explained by examining this dependency between reliability and sustainability. FBC was unsustainable and eventually proved to be unreliable as a systems approach in part at least because NASA did not pay attention to what actually worked during the FBC era (MacCormack, 2004).

To address this type of challenge, Goddard must build a learning organization that improves reliability across all projects and invests in human capital strategies that will assure sustainability in the future. To do so requires monitoring the health of teams, continuously integrating work processes and facilitating the sharing of knowledge within the organization. The approach must connect organizational system health with systems engineering, project management practices and safety in an integrated learning environment. The success of such a system must be measured over an appropriate investment time cycle and not merely on a project by project basis.

It is useful to consider reliability and sustainability as points of tension between doing what an organization already knows how to do well and being good at adapting what it can do well to what it needs to do in the future. In the consumer field this is considered being market savvy; staying abreast of customer needs, ahead of the competition and maintaining a quality production process in the midst of constantly changing product specifications. Commercial firms that do not learn how to build both a reliable and sustainable system are generally competed out of the market through various economic means such as dissolution due to loss of profit or acquisition from loss of relative capital power. Government entities do not face the same boundaries though they are constrained to be productive or risk losing credibility and resource allocations.

In the project organization, the “parts” are the team members, not the hardware or software. A project team is assembled to execute a project plan. It must have quality parts control that assures a reliable quality level for each team so that every team has the same likelihood of success. The knowledge management reliability problem is how to assure that matrixed engineers bring the line organization’s full knowledge to bear on each project and not just their own personal knowledge base. In a matrixed engineering organizational structure like NASA Goddard, project outcome should not depend on which engineer is assigned to the project. Any lack of sharing at the branch level in the line organization will result in an inability to deliver reliable expertise into the project. Anecdotal evidence within NASA indicates this is not an insignificant issue. One project

failure was explained by stating that “our best people weren’t working on that project because another larger mission was just getting underway.” Project managers relate stories of how important it is to fight to get the right people on your team acknowledging that a random assignment may be unreliable in delivering adequate knowledge and expertise into the project.

Highly technical organizations like NASA accumulate experts or individuals with significant amounts of wisdom and knowledge that is often critical for many projects. As the organization matures, the value of these individuals grows commensurate with demands for their time. If the organization is not reproducing these experts at the same rate as they are being depleted from the organization, then their value and demands for their time increase. Unfortunately, heavy reliance on ‘expert’ opinion where individuals hold final say based on their unique experience and skill can be not only unsustainable but also unreliable. The failure of NASA to obtain on-orbit images of Columbia is a case in point that was made by the CAIB Report.

For NASA it is reflected in the fact that the organization is not operating in the same way that it did when it produced its cadre of experts. The number, nature and stability of projects performed by NASA has changed dramatically. Since they are not being replaced within the system when their expertise becomes obsolete or they retire, the system faces possible failure modes. Maturing organizations in a dwindling spiral of knowledge expiration often chase efficiency gains by increasing reliance on expert opinion instead of open and conscientious debate. Since the role of the expert grows in importance during this phase, fewer new experts develop. When the expert finally leaves, there is a gaping hole in knowledge and the organization suffers. This is not a human resource failure to supply new talent. This is a learning organization design deficiency that results in a human capital crisis. In other words, this type of outcome is predictable and avoidable. That it is wide-spread across the Federal Government would suggest that the Government as a whole is not functioning like a learning organization by its own design (CAIB Report, 2003, p127).

It is noteworthy that expert based organization models may be a reaction to a shrinking availability of resources. Faster-better-cheaper (FBC) initiatives in the early 90’s forced NASA to cut corners, including increased reliance on experts and less use of community knowledge simply because community knowledge takes longer and is generally more risk averse than an individual. However, the system lost sustainability in that FBC production cycles did not produce experts the way traditional large-scale projects did. Thus NASA more or less created its own human capital problem by using up its human capital slack, outsourcing core competency areas that were production zones for experts and knowledge and generally accepting less reliable outcomes. When those unreliable outcomes (failures) were not tolerated (Mars failures in 1999-2000), the organization had trouble readjusting to the previous model.

A sustainable system should be able to build capability while using existing capacity. Clearly NASA is concerned about losing expertise as people retire, but it needs to build a system that does not continue to suffer from expertise loss: ie. one that is not dependent on the ‘expert guru’ model but instead relies on a shared knowledge

community that does not retire but evolves with time. The knowledge management challenge with human talent is not how to capture knowledge from people as they leave the organization but to build learning into all that they do while they are here so that when they are ready to leave, the majority of their knowledge is embedded in the organization, people, processes and policies that already express that expert wisdom. Such a system will be both sustainable into the future and produce more reliable results.

The Goddard Model for Building a Learning Organization

Goddard hired a Knowledge Management Architect in May of 2003 to address these challenges and to design a plan that would ‘help smart people work together.’ The Goddard model is based on two theoretical considerations. Not an IT driven issue. Not a one best practice issue but a bundle approach (Barney & Wright, 1998).

The plan for Goddard calls for developing excellence in six practices in an iterative manner. The architecture is designed to avoid short term sub-optimal solutions based on efficiency models, addressing the three characteristics of a learning organization while building a reliable and sustainable organizational system.

Figure 1 shows the six core practices of the KM Architecture at Goddard. The top three lend themselves to centralized management where review processes, lessons learned and training decisions need to be made for the good of the center. The lower three are tied to the project life cycle and need to be aligned with work-flow processes in order to be effective. Importantly, the lower half is essential for informing the upper half with valid content. Lessons learned extracted from the organization and devoid of context are often meaningless and probably useless.

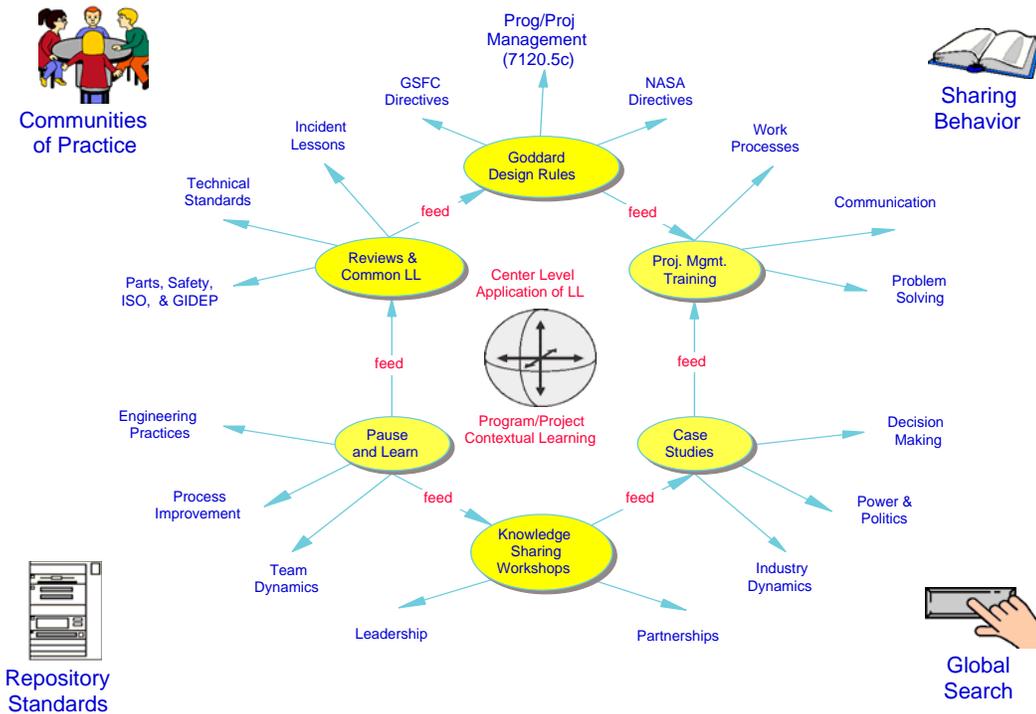


Figure 1 The Goddard Learning & Knowledge Management Architecture

The core of Goddard knowledge resides in the work units and projects where it is being generated. The key to managing knowledge is not to extract it from its origins but to facilitate its use both at the source and within communities of practice across the organization. KM should help Goddard communities (project teams, work units, domain groups etc.) behave and function like learning organizations generating, sharing, using and preserving their own knowledge. The divisions and other work units at Goddard are the primary owners and holders of their respective knowledge. Goddard's plan is designed to help put in place practices that will facilitate the flow of knowledge and help build the feedback learning loops that characterize a learning organization (Senge, 1990).

PRACTICE 1: Pause And Learn (PAL)

Goddard has embarked on a program to adopt the U.S. Army's After Action Review (AAR) concept to project management. 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 learnings in the way AAR's function.

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 (Morrison & Meliza, 1999). 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 most 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 discussion 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 these discussions may only happen after mission launch, often years after significant events when memories are clouded and outcomes bias interpretation of decisions (Dillon, Tinsley & Rogers, 2005).

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 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 time. The adaptation of the AAR process to the NASA PAL concept is presented elsewhere in Rogers and Milam (2005).

PRACTICE 2: Knowledge Sharing Workshops

A learning culture thrives on opportunities to share and learn from each other (Schein, 1993). 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 opportunity to model that kind of behavior for Goddard. 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 are attended by emerging project leaders at Goddard who want to learn the wisdom necessary to succeed as project managers.

Participants are invited to the workshops through senior management contacts and an invitation email list. The facilitator meets with the panel prior to the workshop and prepares talking notes with them for use at the workshop. The panel does not make any formal presentation but rather speaks from their personal experiences. The workshop participants discuss among themselves the issues raised and formulate questions to ask the panel in order to learn more. These sessions are not recorded to encourage more open and practical sharing; not more slides and reports and so panelists and participants are completely free to bring up issues however sensitive or unresolved they might be.

There are many science, technical and engineering seminars and lectures given at NASA Goddard as a matter of course. These are essential element of a continuous learning culture. The Knowledge Sharing Workshops are intended only to augment those type of activities with a venue to discuss the project management lessons as a whole, not the technical challenges and trades. The key difference is the individuals sharing what they learned from the experience and how they will approach future problems differently. The panel construct helps diffuse the individual focus without losing the personal story aspect of the workshop.

PRACTICE 3: Case Studies

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 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 story is the primary vehicle to do this. Documented case stories 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 provides means for developing systems thinking skills needed by a learning organization (Senge, 1990).

Case stories are best told by the key players in that story. A professional writer interviews the players and 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. Goddard is using case studies in training courses, at conferences and in Knowledge Sharing Workshops.

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 at 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, but used alone foster little organizational learning. Learning takes place within context and an effective approach to knowledge management and learning must create that context. The case studies are intended to actually drive people to dig into the lessons learned and vice versa. Someone reading a rather sterile lesson might want to know the context of the mission and understand the relevancy to their own situation. They can do so by reading the case surrounding the particular lesson that they are addressing.

PRACTICE 4: Review Processes and Common Lessons Learned

Lessons and insights that come from the project work done at Goddard need a means to be collected, analyzed and disseminated across the Center. These lessons might range from small but critical parts items to safety procedures, contract issues and physical or engineering discoveries. Many of these insights occur during or in preparation for reviews throughout the project life cycle. These reviews should and could be learning opportunities for the team and others with little marginal effort by collecting the lessons and insights that are mentioned and taking time to pause and learn from those things that have been resolved or mitigated. It is important to note that much of this type of

information has an appropriate home in a database, publication system or other reporting mechanism such as the Goddard Problem Reporting System (GPRS). Data trends and reports from GPRS and other reporting systems offer candidate material for lessons learned and potential workshop or case study content.

As the library of case studies grows at Goddard, an annual review of Common Lessons Learned from projects has been initiated. A panel of experts, mostly senior or retired program/project managers, spends a day reviewing all the cases from the past year and discussing the similarities and trends. Any patterns of behavior, risk or failure possibilities are identified. Strengths and competencies that could be further leveraged are also called out. The report is the Center Common Lessons Learned and is delivered to senior management for review and incorporation into processes, rules and training.

PRACTICE 5: Goddard Design Rules

The practice that enables project management guidance at the center level is the Goddard Design Rules owned by the Office of Mission Success. The Goddard Design Rules (also referred to as the GOLD Rules) are formulated from the best rules and practices of the different engineering divisions at the Center. These rules are considered mandatory for all projects. A waiver process exists for projects that are operating outside the intended scope of the rules or otherwise need relief from compliance. The rules are updated through a rule change process. The learning practices at Goddard inform the rules change process on at least an annual basis.

The Goddard Design Rules are meant to be a reflection of the wisdom of how Goddard executes its projects. They are in essence the best practices written down. They were derived from responsible technical unit. Links are being built from the rules to standards, lessons learned and case studies enabling users of the rules to access the context of each rule, its origin, intent and sphere of effect. This allows project personnel to more accurately assess the appropriateness and applicability of the rule to their project and how to meet the embedded wisdom of the rule, not just the sterile technical specification captured in the rule set itself. It is important that users of the rules do not stop thinking about the practice to which the rule applies. The learning context surrounding the rule enables users to continue to think creatively instead of blindly following rules with possible unintended consequences. Where waivers are sought, a hearty risk discussion can ensue with open and full context of the rule, its bearing and the implications of granting a waiver or allowing for a deviation.

PRACTICE 6: Management Training

The training of project leaders is crucial to the future success of Goddard. Goddard is taking an aggressive approach to assure that its project leaders and line managers have the fundamental skills and the collective wisdom of experienced leaders available to them. The Center has developed series of 2-day workshops called the *Road to Mission Success* that will inculcate the requisite project management skills and the Goddard wisdom embedded in cases, PALs, Common Lessons and workshops into future Goddard leaders. Senior managers will be involved in delivering course cases. The series

will become an integral component of many of the leadership training programs in across the center and will provide a common, consistent exposure to how the Center functions and achieves mission success.

Conclusion

Sharing behavior is an organization attribute that attracts bright people. Intellectually curious people often know that they have the best chance of being stimulated, creating new knowledge or participating in exciting discoveries where a team or community of like-minded thinkers are engaged in open and honest sharing of their ideas, insights and experiments (Davenport & Prusak, 1998). Goddard wants to continue to attract these people in line with the Human Capital Plan to sustain and build on the competencies that have characterized the Center for fifty years.

Goddard has made progress in building an effective learning organization and responding to the challenges facing NASA in a post-Columbia environment. It is suggested here that by clearly defining the problem of knowledge management as building a healthy organizational learning system, NASA can overcome self-defeating tendencies of large organizations to adopt short-term technical solutions that risk alienating the workforce and may even exacerbate knowledge application deficiencies. Adopting a suite of self-reinforcing practices can provide a pathway towards identifying technical requirements for support systems and build awareness of systemic challenges. It is also recognized that change of this type will take years, not months to achieve. Building a learning organization and managing organizational knowledge are long term engagements which means smart organizational leaders will duck under the low-hanging fruit and work on the real challenge of building a learning organization that manages knowledge efficiently and applies it effectively to achieve mission success.

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