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APPLYING KNOWLEDGE MANAGEMENT TO AN ORGANIZATION'S TRANSFORMATION

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ABSTRACT

Although workers in the information age have more information at their fingertips than ever before, the ability to effectively capture and reuse actual knowledge is still a surmounting challenge for many organizations. As high tech organizations transform from providing complex products and services in an established domain to providing them in new domains, knowledge remains an increasingly valuable commodity. This paper explores the supply and demand elements of the "knowledge market" within the International Space Station and Spacecraft Processing Directorate (ISSSPD) of NASA's Kennedy Space Center (KSC). It examines how knowledge supply and knowledge demand determine the success of an organization's knowledge management (KM) activities, and how the elements of a KM infrastructure (tools, culture, and training), can be used to create and sustain knowledge supply and demand.

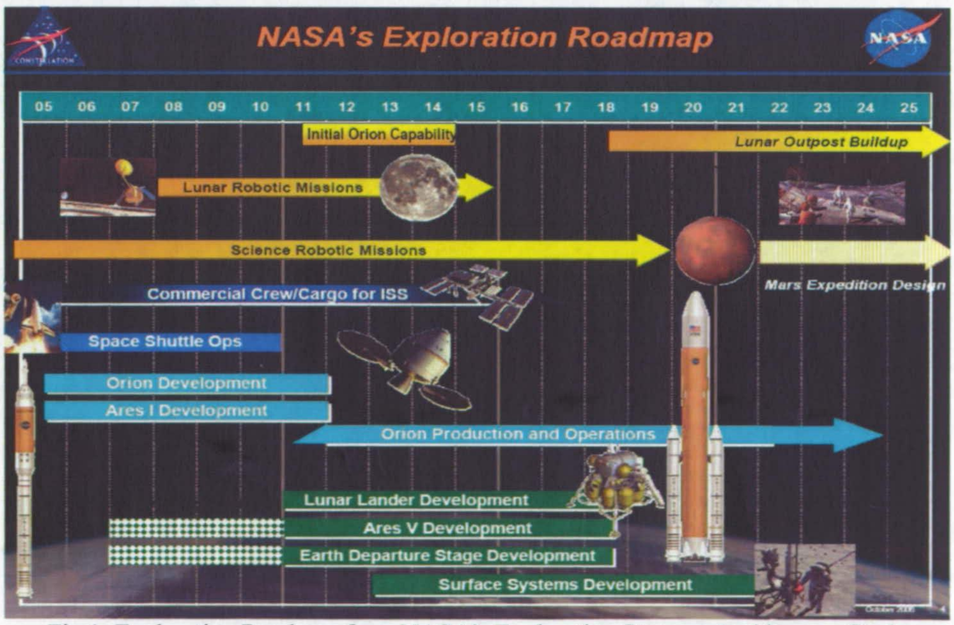


Fig 1: Exploration Roadmap from NASA's Exploration Systems Architecture Study

BACKGROUND

As NASA's primary site for launch and landing operations, the most significant foundational element in the Kennedy Space Center's (KSC) framework is the Space Shuttle Program (SSP). The Shuttle Program's planned retirement in 2010 produces far-reaching consequences throughout KSC's infrastructure and workforce. The SSP occupies 640 facilities valued at approximately \$5.7billion, and uses over 900,000 pieces of equipment valued over \$12 billion. (1, p2)

KSC is undergoing a massive transformation required to support NASA's new Constellation Program (CxP) in the post-Shuttle era. The CxP encompasses NASA's journey to return humans to exploration beyond low earth orbit, establishing a Lunar outpost, and going on to Mars. (2) (3) The amount of work required for the transformation causes a 4-5 year gap in NASA's human space flight missions. The gap and transformation present huge challenges to KSC.

Today, KSC employs over 16,000 people. NASA Civil Servants comprise nearly 14% of the workforce, with the remainder employed by various KSC Contractors. Currently, 10% of KSC's Civil Servants are eligible to retire. In 2010, eligibility increases to 13%. By the time NASA resumes its post-Shuttle human space flight missions using the CxP's Orion spacecraft, nearly 30% of KSC's Civil Servants will be eligible for retirement. (4) Additionally, KSC workforce projections for the post-Shuttle retirement era show a 20%-45% reduction (future requirements are still in development) in KSC's Contractor workforce. (5) In three years, 50-75% of the KSC workforce will be performing a different function.

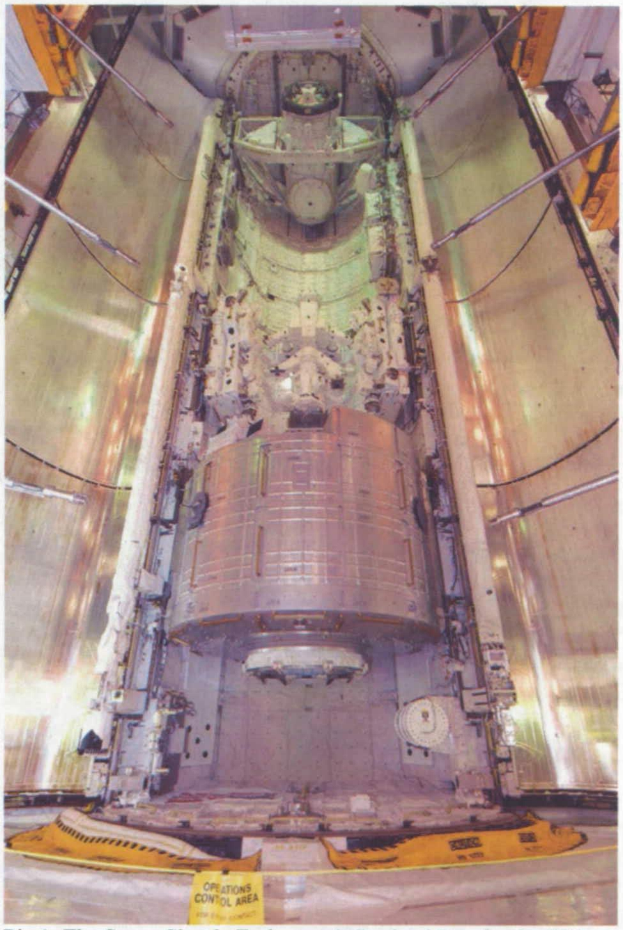
KSC is using Knowledge Management (KM) practices to help manage its enormous transformation and prevent the critical "brain drain" that could occur in light of the impending workforce changes.

INTRODUCTION TO THE ISSSPD ORGANIZATION

The International Space Station and Spacecraft Processing Directorate (ISSSPD) is one of many KSC organizations effected by KSC's ongoing transformation. It is a microcosm of the change that is occurring across KSC and other NASA centers involved in human spaceflight missions. The transformation permeates the ISSSPD's facilities, systems, processes, and personnel. NASA will conduct a series of complex ISS assembly and Hubble servicing missions using the Shuttle while simultaneously exploring and developing future transportation alternatives. (1, p27)

Function

The ISSSPD currently performs the ground processing tasks required to prepare Space Shuttle and International Space Station (ISS) payloads and experiments for flight. Upon retirement of the Space Shuttle fleet in 2010, the directorate's roles will undergo a major change as it assumes the responsibility for ground processing of the Constellation Program's Crew Exploration Vehicle, Orion, and Lunar Lander, Altair.



Pic 1: The Space Shuttle Endeavour's Payload Bay for the STS-123/1JA Mission (Mar '08), Canada's DEXTRE and the Japanese Experiment Module – Pressurized Section

ISSSPD directs and manages the launch site support, ground processing, and integration of Space Shuttle payloads, payload carriers, and Space Station components, including assembly elements, re-supply cargo, and utilization experiments. It manages the site facilities, ground support equipment, checkout systems, logistics support, and ground transportation systems. The directorate acts as the ISS Program's agent for managing and integrating the overall ground processing for all United States launched Space Station elements from manufacture and assembly through verification, launch, and landing. Its experts also support on-orbit operations during assembly and operation of the ISS. (6)

The ISSSPD's contractor partner for ISS element ground operations and for planning spacecraft ground operations is the Boeing Corporation under the Checkout, Assembly & Payload Processing Services (CAPPS) contract.

<u>History</u>

Nearly two years after the commencement of ISS on-orbit assembly in 1998, KSC combined the Space Shuttle Payload Processing directorate with the Space Station Hardware Integration Office (SSHIO) to form ISSSPD. This merger enabled KSC to mix personnel having nearly two decades of Shuttle payload operations experience with those who had five years team-building with the ISS Program Office and personnel at each of NASA's ISS element factory sites. Throughout the ISS element design and development phases, SSHIO personnel spent time in factories across the United States, Canada and Europe ensuring the requirements for ground processing and operations were incorporated into designs as early and effectively as possible.

Pic 2: Preparing Neurolab Spacelab payload for flight aboard Space Shuttle Columbia on STS-90 (Apr 1998)

The merger yielded an extremely effective organization to service the remaining ISS assembly and utilization missions. The decision to use the skills and experience of the Space Shuttle payload processing team to service and integrate the various International Space Station elements as another form of payload, while leveraging the working relationships established throughout the ISS Program by SSHIO personnel, proved a winning combination.
Today, the ISSSPD is recognized as one of NASA's nine model organizations based on the 2007 NASA Culture Survey encompassing all ten centers. (7)

The Constellation Program will further leverage the ISSSPD's payload processing expertise. The directorate has been designated the responsibility for processing the Orion and the Altair systems, which are effectively payloads for the Ares I and Ares V launch vehicles, respectively. The ISSSPD's successful legacy of incorporating requirements for operations engineering into design and development phases of spacecraft and support systems will also contribute to the CxP's early and sustained successes.

The ISSSPD's organizational history has yielded a rich diversity of people with a depth and breadth of talent and expertise to benefit NASA's future. With years of experience, ISSSPD employees know the criticality and life-cycle cost benefits of factoring operations issues and requirements into early design and development phases of ground and flight systems.

Lessons the ISSSPD applied to the ISS Program (ISSP) based on its heritage include:

- The discipline required for the formation and execution of test teams, and distributing lessons learned across geographically distributed test sites
- Methods for incorporating traceability into procedure development tasks
- Incorporating standard KSC Safety processes into ISS assembly facilities across the world
- Providing contractors with NASA technology transfer for hardware development, and with implementation techniques for integrated planning and scheduling of assembly and test operations
- Coordinating comprehensive ISS pressurized element leak testing, and developing a Pressure Vessel Integration Plan
- Developing and implementing Multi Element Integration Tests (MEIT) at the launch site.

The value of performing MEITs as part ground processing was clearly shown during testing of the ISS P6 Integrated Truss Structure for ISS Flight 4A aboard the Shuttle Endeavour on STS-97. The element was critical for the ISS' ability to convert solar power into electrical power. (8) During MEIT 1 Test Configuration 1, the ISSSPD test team discovered a P6 truss design flaw that prevented the element's activation. They were able to fix the problem on the ground, and perform a regression test to verify the solution prior to launch. If this problem would have remained unseen until orbit, it could have required a dangerous return (landing with a heavy payload), or a significant time critical redesign task for an orbit repair on the next mission. Both of those options would have posed significant cost and schedule impacts to the remaining sequence of ISS assembly and utilization flights.

Those same lessons that were applied to the ISSP from legacy programs represent some of the explicit and tacit knowledge that is being transferred to the CxP. Additional lessons the ISSSPD is applying to the CxP include those related to designing and operating a payload/spacecraft processing facility. KSC test teams prepared Spacelab payloads for Shuttle launches in KSC's Operations and Checkout (O&C) building in the '80's and '90's. ISS payloads and elements are processed in KSC's Space Station Processing Facility (SSPF). The CxP's Orion spacecraft will be processed in KSC's Multi Payload Processing Facility (MPPF).

Based on O&C lessons, the SSPF was designed with support areas (technician shops, kitting areas, fluids ground support equipment area, hardware inspection area) immediately off of the high bay. The same approach is being used for the MPPF to support Orion processing. Also, because extensive crane operations were required in the O&C to move payloads and experiments around and through the facility, the SSPF was designed with a very level floor to allow for the use of air bearing pallets to reduce crane operations. This approach is also being incorporated into the MPPF for Orion processing.

Today, ISSSPD engineers analyze the use of eight footprints in the SSPF. For CxP, engineers are analyzing three trenched areas to be used as footprints in the MPPF to determine Orion processing space requirements.

Goals

A primary ISSSPD goal for the transformation is to continue leveraging the meaningful experiences from its history into NASA's future. Its Knowledge Management goal is to provide an infrastructure (tools, culture and training) that will enable the CxP to fully leverage the ISSSPD's knowledge gained and lessons learned from its ISS and spacecraft processing activities. KM can enable a learning organization within a mature program to evolve to meet the challenges of a new program, while satisfying the technical, schedule, and cost requirements of both. In a fully functioning "knowledge market", experience gained while providing service to an existing customer can greatly benefit the service provided to a new customer.

Learning and knowledge acquisition differ from memorization, and are not accomplished by a mere transfer of stored documentation or information. Actual learning requires understanding the associated contexts and experiences of existing information well enough to successfully apply it to new domains. As the ISSSPD transforms, it seeks to ensure that CxP is fully leveraging what the ISSSPD has learned about Operations Engineering during ISS.

In order to create a successful market, the ISSSPD must ensure that the tacit knowledge of workers in the current ISS era (KW-I) becomes the tacit knowledge of workers in the Constellation era (KW-C). Effective transfers of KW-I to KW-C require the ISSSPD to manage the supply and demand for knowledge. Leveraging the experiences that form the knowledge of KW-I, and constructing relevance to knowledge required by KW-C are critical factors to the extraction, generation, and distribution steps required to accomplish the transformation goal.

The ISSSPD's KM practices must enable lessons the ISSSPD learned during ISS ground operations to be fully exploited to improve designs, reduce life cycle costs, and manage/mitigate risks for the Orion and Altair projects. The organization's KM infrastructure must create and feed the KW-C's demand for knowledge from the KW-I's supply. The KM goals will be achieved when the ISSSPD provides a knowledge market environment where an accurate, meaningful, usable supply exists to meet an intelligent demand, with consumers knowing how, when, and why to acquire the commodity.

CURRENT KM INFRASTRUCTURE

The KM market within the ISSSPD has an intermittent, incomplete supply, from only a subset of available suppliers, and almost non-existent demand. Its potential knowledge suppliers represent many domains, including technical, human capital, contract management, acquisition strategies, ISS/Shuttle retirement, teamwork, and customer service.

The supply side of the market for technical knowledge has been improving over time, evidenced by the publication of the official Lessons Learned SPP in 2006. (9) As the ISS/Shuttle retirement approaches, the directorate's knowledge supply for managing the transition related risks is also improving. Still, the most developed mechanism for knowledge demand and re-use is human-to-human communication.

The elements of the ISSSPD's KM infrastructure are tools, culture and training. Tools help manage the supply side of the market, while the culture and training elements influence the demand. The difference between information and knowledge is not distinguished in the KM infrastructure. That distinction exists in the contexts and experiences of knowledge workers, not the infrastructure's elements.

Tools

The ISSSPD's potential knowledge market is robust, yet only a subset is managed by its current toolset. Its knowledge supply resides in formal documentation, information technology (IT), and individuals. Representative samples of each type of tool include:

Table 1: Some of the ISSSPD's KM Tools

Documentation		
Misc. Standard Practices and Procedures (SPPs)	Lessons Learned SPP	Interim Problem Reports (IPRs)
Risk Management	Work Area Rules	Problem Reports (PRs)
Kennedy Documented Procedures (KDPs)	Integrated Master Schedule Development	Work Authorization Documents (WADs)
IT		
Integrated Risk Management Application(s)	System for Administration, Training and Educational Resources for NASA (SATERN)	Lessons Learned Information System (LLIS) (10)
Goal Performance Evaluation System (GPES)	Competency Management System (CMS)	Boeing Non-conformance System (BNS)
Tech Doc	Web sites & Bulletin Boards	Share drives
Individuals		
Log books	Meeting minutes	Emails
Decision Boards	Brains –each with unique memory	Test status notes

The three most developed knowledge supply sources are from the technical, transition related risks, and human capital management domains.

Technical

The ISSSPD accomplishes its technical work by forming mission processing teams to correspond to each Shuttle mission. These teams are multi-disciplinary teams whose purpose is to perform all of the ground testing and operational steps required to prepare the payloads and/or ISS elements that will be launched together on a single Shuttle mission. The teams use tools from all three categories to plan and perform their work.

The Lessons Learned SPP enables mission processing team members, or any employee, to record data and information about a lesson into a CAPPS-provided tool. Lessons can be captured and recorded as soon as they are recognized, whether before, during, or after a mission flow.. An internal process vets the lessons and elevates those with general NASA applicability to NASA's Lessons Learned Information System (LLIS).

That SPP is the ISSSPD's first published official document on the subject. Its primary effect on the ISSSPD's knowledge market has been to provide a consistent approach to knowledge supply. Prior to formally defining the process, lessons learned were captured in spreadsheets, presentations, and white papers.

The Lessons Learned SPP also attempts to formalize the demand for knowledge by suggesting times throughout ground processing activities when employees may benefit from reviewing captured lessons. Historically, informal processes such as ad hoc conversations between employees and mission teams were the primary knowledge transfer practices.

For ISS mission processing, ISSSPD and CAPPS personnel use Work Authorization Documents (WADs) to document knowledge regarding methodology, criteria, and standards used during payload processing.

Though all WADs are generated, revised, and stored electronically via Word templates in an electronic repository called Tech Doc, they are signed off and executed on paper. Although the ISSSPD is piloting a paperless WAD system in its depot repair and fabrication facility, the current method for all mission processing operations requires manual recording of data, handwriting, and stamping of the work steps. Once the WAD's steps are complete, all associated documents are scanned into .TIFF files and archived in Tech Doc.

The Tech Doc electronic repository is another concentrated area of knowledge capture. It is the repository for all process documents such as KDPs and SPPs, WADs, archived completed WADs, and other official publications, such as training manuals and customer agreements.

Knowledge is also captured in the IT tools used to implement and execute the SPPs. The IT tool the ISSSPD uses for non-conformance reporting is an electronic CAPPS-provided tool called the Boeing Non-conformance System (BNS). BNS captures the general knowledge and experience gained during the course of addressing Problem Reports (PRs) and Interim Problem Reports (IPRs). The tool contains several optional data fields for capturing judgment calls to categorize the nature and value of the problem solved or risk averted (e.g., injury or life, mission or science, ground or flight operational impact, or other).

In providing these judgment calls, the owner of the BNS report can include rationale that explains the categorization. Each of these items represents significant knowledge gained about successes and failures encountered during the resolution of non-conformances. The judgment calls provide context and experience to the data capture, enabling effective re-use of the organization's knowledge.

Even with formal procedures and the availability of electronic tools, individuals' informal methods and tools for technical knowledge capture are still among the primary methods used. Emails contain test status notes, and critical conversations with customers, payload developers, and program representatives. They may also include test configurations, requirements development, procedural content, documentation requirements and troubleshooting concepts. Other informal knowledge capture methods are log books and test notes generated by various team members. Informally captured knowledge also resides in meeting minutes and decision packages recorded by individuals for various decision boards. These minutes and packages are often posted on a combination of share drives or web sites.

Transition Related Risks

In order to address some of the programmatic issues that must be resolved for a successful transition, the ISSSPD employees document risks in the Integrated Risk Management Application (IRMA) systems of the ISS and Constellation programs. One of the important decision boards the ISSSPD uses to manage ISS transition-related risks is the Risk Advisory Board (RAB), which is managed by the ISSSPD. In that board, the ISSSPD captures knowledge to help ensure the continued post-Shuttle success of the ISS program. The ISS RAB assesses KSC's ISS processing risks in the ISS IRMA and elevates issues that require ISS Program attention to the ISS Program Risk Advisory Board (PRAB). A similar process occurs for the Constellation IRMA risks.

One example of a transition-related programmatic issue pertains to the risks on the requirements system used for ISS flight systems, Operations and Maintenance Requirement System (OMRS). The OMRS is maintained by the Space Shuttle Program and is scheduled to terminate with it in 2010. Yet, ISS operations will continue for a number of years past 2010, into the Constellation era.

Another example of a transition related risk is the funding for the SSPF. The current usage schedules for the facility result in several years of complete or partial funding gaps between ISS usage and potential Constellation usage.

The ISSSPD has begun to identify methods for integrating risks with Lessons Learned as a way to develop risk mitigation plans and resolve these and other transition related issues and risks. NASA's Exploration Systems Mission Directorate (ESMD) is successfully integrating risk management with KM. (11) Because approaches to resolving these issues can greatly increase the KW-I to KW-C knowledge transfers, the ISSSPD is seeking to learn from the ESMD's methods.

Human Capital Management

NASA plans maximize current human capital capabilities by expanding, rebalancing, and realigning existing skills where necessary. Although CxP plans are not yet adequate for detailed workforce planning, NASA is assessing the competencies of the current workforce, forecasting the future needs as CxP content matures, and addressing any actual or potential competency gaps. (1, p8 & p15) To perform its associated tasks, the ISSSPD uses human capital management tools to maintain knowledge of employee responsibilities, training, and competencies.

The Goal Performance Evaluation System (GPES) system stores NASA employee performance plans. In it, employees log their accomplishments towards meeting their plan elements. The ISSSPD also uses the Competency Management System (CMS) to identify the expertise levels its employees have in various disciplines required to perform the ISSSPD's functions.

The System for Administration, Training and Educational Resources for NASA (SATERN) contains electronic training materials for technical, safety, and agency topics. Employees complete training courses offered via SATERN. Administrators use it to coordinate requirements for, and track completion of, training for employees in every job classification.

While the ISSSPD has many tools for capturing knowledge, the supply side of the market is still inadequate. In order to create and sustain an adequate supply, the ISSSPD needs to more fully exploit its existing tools, more tools to capture its full range of explicit knowledge, tools to capture tacit knowledge, and tools to integrate the numerous supply chains. The tools also need to capture knowledge context and experience to enable effective transfer and re-use. The remaining elements of the KM infrastructure, Culture and Training, are critical for the market's demand side.

<u>Culture</u>

An organization's culture is arguably the single largest factor to influence the demand for goods from its knowledge market. While the ISSSPD's organizational culture contains a wealth of potential opportunities for knowledge transfer and re-use, its current KM culture is somewhat ambiguous.

At the mention of "KM" to many employees, their body language exclaims defensive messages, and their skepticism is palpable. These reactions indicate that KM evokes confusion and doubt throughout the culture. Some likely causes of the current cultural perception include:

- Lack of a clearly defined and communicated definition
- Lack of information on what is required to invest in KM, and its expected Return on Investment
- Mistaken belief that KM is yet-another-IT-tool that will end up cluttering desktops and minds
- Notion that we've "been there, done that", and had no measurable result.

Because of the confusion on what KM really encompasses, and what it enables, there is probably more of it occurring throughout the directorate than is currently accounted.

In the ISSSPD, KM seems to occur most at the grassroots level among and between mission processing teams sharing best practices and lessons learned through informal or formal processes and tools. The knowledge market functions well at this level because the demand is driven by a need to apply specific technical and procedural knowledge to a task, and the ease of identifying common, repeatable tasks.

The ISSSPD has a vast storage of latent knowledge supply, which needs to be cultivated. As the specificity of tasks expands or differs, the natural transfer of knowledge does not readily occur. For example, the transfer and re-use of knowledge between teams processing ISS Multi-Purpose Logistics Modules (MPLMs) for separate missions is more natural than the transfer of knowledge between a team that has processed an MLPM to a team that is processing another payload, such as a Truss segment. While there is much valuable knowledge to be shared between those teams (testing philosophies, engineering disciplines, launch vehicle integration tasks, customer service, requirements tracking and implementation, etc.), the level of demand and the success of the transfer often depends on the experiences and personalities of team members. The relevance and linkages of existing knowledge to new or different tasks must be intentionally constructed and communicated.

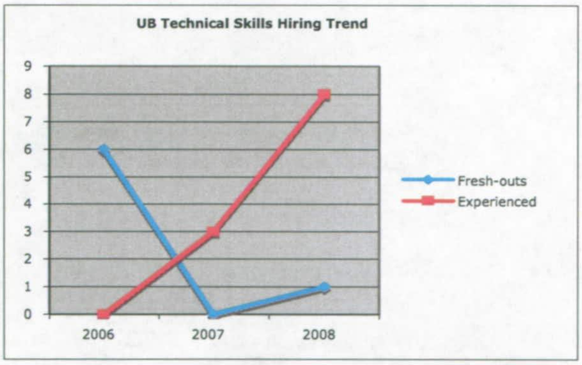
The remaining ISS/Shuttle flights provide an opportunity for the ISSSPD to strengthen the KM market throughout the culture. In an effort to maximize the benefit of the Lessons Learned SPP during the final flights, the ISSSPD is introducing motivational factors to encourage its use. The ISSSPD and CAPPS are incorporating required lessons learned reviews for specific processing milestones, a form of a "pause and learn" technique. Additionally, the ISSSPD Mission Managers are being held responsible for ensuring their team's lessons learned are captured. In order to increase awareness of the benefits of these practices throughout the culture, the ISSSPD will intentionally communicate the results through recognition meetings and widely distributed email messages.

The practice of defining relevant lessons learned and best practices between missions with dissimilar payloads and launch vehicles will assist the ISSSPD's ability to effectively transfer and re-use knowledge in the CxP era. A culture with a healthy demand for knowledge will also drive the market to fill any gaps in its supply chain.

<u>Training</u>

In order to attract and retain a highly skilled workforce, the ISSSPD relies on strategic hiring practices and a robust training program. In addition to embracing standard NASA practices such as formal courses, mentoring, and diverse work assignments, the ISSSPD's training approach includes hands-on work assignments, strategic organizational alignment, and a leadership development program emphasizing "gray-beard" sessions.

Prior to NASA's announcement of the Shuttle Program's retirement in 2010, the ISSSPD's hiring practices focused on hiring employees fresh out of college. As 2010 draws closer, the ISSSPD has shifted its hiring practices to gain more experienced employees, especially those who have worked as KSC contractors and have acquired expertise in various disciplines supporting KSC's missions.



Because the KSC workforce consists of only 14% NASA Civil Servants, Contractors perform the bulk of hands-on work. Hands-on work includes creating work documents, testing and assembling flight systems, operating ground support equipment, and troubleshooting. The ISSSPD recognizes that hands-on experience is one of the best methods for training engineers, increasing their ability to retain and re-use knowledge in new contexts. For this reason, one of the key elements in the ISSSPD's training approach includes reserving the hands-on processing of ISS experiment payloads as a Civil Servant activity. Through this training method, employees gain and maintain critical skills and competencies in the diverse disciplines associated with hands-on work, and gaining a systems engineering mindset. This area of the directorate is staffed primarily with early career civil servants, guided by a core of experienced leaders to provide continuity. Reserving this segment of work for Civil Servants also helps NASA build and maintain the intellectual stewardship required to be a smart buyer of contractor services.

KSC's management strategically placed its future responsibilities for the Constellation Program into organizations currently engaged in Shuttle and ISS operations. In order to facilitate training required to build competencies for CxP tasks, the assignment of responsibilities is aligned to leverage the current skills and experiences of existing organizations, thereby accelerating knowledge transfer and re-use.

Assigning the responsibilities of integrating and processing the CxP's launch vehicles, Ares I and Ares V, to the current Space Shuttle Launch Vehicle Processing Directorate eases the transfer of tacit knowledge in that domain. Likewise, assigning the responsibilities for processing the Ares vehicles' payloads, Orion and Altair, to the ISSSPD eases the transition of relevant knowledge in that domain.

Throughout each year, the ISSSPD invites former and current leaders from across the space industry to share leadership principles with its employees. "Graybeard sessions" are a key component of the ISSSPD's leadership development program. These forums enable employees to hear first-hand accounts of lessons learned and best practices from veterans of the Apollo program and the transition from Apollo to Shuttle. This practice also creates a thread uniting the generations of the space program, revealing the transcendent nature of the work.

The leadership development program also hosts current and emerging leaders. As a result, the ISSSPD is able to identify key training and leadership development principles that withstand the tests of time and complexity across the space industry. As an example, two of the ISSSPD's guest speakers in 2007 were T.J. O'Malley and Wayne Lee. Mr. O'Malley is a retired space program veteran from the earliest Apollo days, and Mr. Lee is a current NASA JPL employee and an expert and leader on Mars robotic landers. Even though they are 60 years apart in age, and have experience in different NASA programs and missions, both revealed lessons emphasizing the importance of engineers developing a systems engineering perspective, and methods for engineers to demonstrate and prove their competencies.

CURRENT KNOWLEDGE MARKET WEAKNESSES

Problems within each element of the KM infrastructure can cause weaknesses in both sides of the knowledge market, supply and demand. Taken separately, the impacts of problems in tools, culture, or training may not seem too significant. When examined as an integrated infrastructure supporting an organizational need, problems that threaten the knowledge market's foundation become more visible.

Supply Side

Current infrastructure problems weakening the market supply include:

- Tools do not enable integrated or comprehensive data capture processes
- Culture does not motivate employees to identify and capture all pertinent knowledge; even with tools in place, supply is incomplete
- Electronic systems for knowledge capture are disparate and segmented
- Informal and tacit knowledge are not captured in a way to ensure future re-usability for the general work force, i.e., ISSSPD lacks proper tools to construct relevance, contextually capture these types of knowledge.

Demand Side

Current infrastructure problems weakening the market demand include:

- Employees are not consistently trained on when, why, where, or how to retrieve all knowledge they need for a task
- Training and culture do not identify relevance across projects, missions, programs, organizations, etc.
- Culture's primary knowledge transfer methods are informal and ad hoc/accidental
- Graphical scans of WADs into Tech Doc limit the electronic search of data. Scanned, archived data reflects the actual work performed including buys, data, notes, and any changes required to the planned procedure. It captures knowledge gained during the work process after the document was originally issued. That valuable knowledge is difficult to obtain electronically.
- The synthesis of data and the ability to search, retrieve, and use the data are limited because there is no integrating element or architecture to enable that, and no cultural norms or processes to effectively create and sustain the demand for knowledge re-use
- Upon the conclusion of the CAPPS contract, Boeing will turnover the BNS data to NASA/the ISSSPD for future use. There is currently no tool to utilize that data outside of the contractor proprietary BNS tool. This problem is typical of ISS to Constellation transition-related challenges
- Because some data fields are optional in the BNS tool, opportunities to develop relevancy and re-use of risks averted and problems solved are lost
- KSC has no formal KM organization or consistent approach across its directorates, which impairs knowledge transfer (12)
- Some government processes can complicate the ability and benefits of knowledge transfer throughout the culture. For example, annual budgets make it difficult to justify life-cycle cost reductions afforded by incorporating operations considerations and requirements into designs.
- Tools and culture do not facilitate KM as an intrinsic part of ground processing activities. (12)
- The culture has a lack of responsible personnel for developing and maintaining an effective KM market; other priorities prevail. (12)

These lists reveal that the demand side's weaknesses, influenced by the infrastructure's culture and training elements, pose the largest problems to the market. In order to create an effective knowledge market for the ISSSPD, weaknesses in the current knowledge market must be considered along with factors influencing the future market conditions.

FACTORS INFLUENCING FUTURE MARKET CONDITIONS

The goal to successfully leverage the ISSSPD's experience from serving an existing customer (ISS) to a new customer (CxP) presents many challenges. One of the greatest challenges is determining methods for retaining useful knowledge in a significantly changing environment. The environment's significant changes appear in three realms: the ISSSPD's transition is evolutionary in nature; the CxP's missions occur in a progressive, evolutionary fashion; and the workforce is evolving. In order to adapt to and thrive during these simultaneous evolutions, the ISSSPD's KM infrastructure must yield a self-propagating market.

The ISSSPD's Evolutionary Transition

In its transition from ISS to CxP, the ISSSPD will traverse many interim steps. Today the ISSSPD prepares ISS elements and payloads to fly to the ISS in the payload bays of NASA's Space Shuttle orbiters. Upon retirement of the Shuttle Program, the ISSSPD will continue providing service for some ISS payloads or supplies launched on International Partner vehicles, commercial vehicles, and eventually the CxP's Orion. These incremental transition phases provide opportunities to strengthen the ISSSPD's knowledge market by learning to identify relevance between lessons and best practices across each interim step.

CxP's Evolutionary Design

CxP is designed to be an evolutionary program, spanning across decades. (2) (3) The CxP represents to the ISSSPD a new customer with new tools, new missions, new technology, new processes, new personnel, and new risks. Each progression of its evolution produces more dynamic conditions. Changes to resources and requirements occur often.

These conditions influence all three types of tools in the ISSSPD's KM infrastructure: documentation, IT, and individuals. The ISSSPD needs to identify leverage opportunities it its IT toolset, and requirements and priorities for integrating with CxP's IT tools.

An example of an IT area to examine for leverage is the CxP's Constellation Data Architecture. The CxP established it to facilitate data exchange between the electronic tools used throughout the Program. This design enables better utilization of data, which improves the knowledge market. To fully exploit this tool, the ISSSPD needs to identify relevance of historical knowledge and assist in populating the CxP knowledge repositories, and constructing proper semantic links.

Workforce Evolutions

The evolving workforce influences the ISSSPD'S knowledge market through all three elements of its KM infrastructure, tools, culture and training. There are many contributing factors to the dynamic workforce environment. New skills required by CxP technology and missions, contract changes and employee re-assignments, and the presence of "Gen-Y" workers are key factors in the workforce evolution.

Requirements for New Skills

In order to succeed in CxP, the ISSSPD's workforce must acquire some new technical skills. In addition to leveraging experience from the ISS era, a fully functioning knowledge worker in the CxP era must also obtain knowledge from sources and experts outside of ISSSPD, KSC, and NASA.

In addition to acquiring new technical knowledge, ISSSPD employees must develop skills required to build and sustain a self-propagating knowledge market. The resulting market must serve not only transitioning ISSSPD workers, but also those from other organizations who are transitioning to CxP.

The acquisition of new technical and knowledge management skills can be assisted by the KM infrastructure's culture and training elements.

Contracts and Re-assignments

Contract changes, workforce reductions and personnel reassignments impact the ability to retain market supply, and the demand for and ease of knowledge transfer and re-use.

In preparation for the end of the CAPPS contract, the ISSSPD is assessing the current KM infrastructure to identify and mitigate the risks to the government from this impending event.

As the ISSSPD assumes more of its CxP responsibilities, many of its employees are already assigned to CxP tasks. This practice requires careful management of resources to ensure the remaining ISS flights are not impacted by personnel re-assignments. Dual assignments also enable knowledge workers to begin to construct relevance between the two programs.

Gen Y Presence

As CxP evolves, so does the workforce required to execute its multi-generational missions. As NASA's workforce expands to include more workers from the Gen Y population, the ISSSPD is developing strategic methods for successfully attracting and retaining this valuable group, and integrating them into the existing workforce.

The ISSSPD will benefit from the integration of this group into the workforce because they will increasingly demand high-tech tools to accomplish their tasks, (13) which will enhance the overall function of the knowledge market.

The ISSSPD initiated an intentional Hands-on Work initiative in order to train and retain the younger workforce. This initiative is being implemented under the KSC Foundations of Leadership (FoL) project. In it, a team of promising early-career civil servants are evaluating historical contexts of hands-on civil servant work activities and associated technical, cost, program, and organizational benefits. They will make recommendations in Fall 2009 for potential work segments within CxP to reserve for civil servants.

ELEMENTS OF A SELF-PROPAGATING KNOWLEDGE MARKET

SPKM Description

An effective knowledge market provides its consumers with practical methods for acquiring and providing accurate, meaningful, usable, timely knowledge that is of value to an individual and/or organization. When consumers consistently receive significant benefits from it, a knowledge market will permeate and replicate itself naturally through an organization, becoming a Self-Propagating Knowledge Market (SPKM). This will occur as consumers demand that it be integrated it into all aspects of their work. Although an initial investment is required to provide a solid foundation for a SPKM, with repeated successful use, a SPKM will become a self-sustaining knowledge market. High-performing, complex organizations can be characterized by enabling such markets.

Organizations receive the highest return on initial investments when they direct them toward the infrastructure elements of culture and training. The payback on those investments will materialize in a strong demand throughout the market, a critical factor for SPKMs. "The problem to be solved is not IT, it is culture and re-use." (14) That statement is justified by a fundamental characteristic of human nature: beliefs shape behaviors, which also explains why "transformation" is key to a successful "transition". When workers believe there is knowledge that will benefit them, they will seek it and apply it.

The statement claiming that IT is not the problem is further supported by an important distinction between information management and knowledge management. "Mastery of information can be demonstrated by its reproduction; mastery of knowledge is demonstrated by its novel applications. To transform information to non-trivial knowledge you need co-presence, tutelage, and a community of learners. All impossible to do well via technology." (15)

In order to build and sustain a thriving SPKM, an organization must provide:

- A culture rich with intrinsically motivated employees at all levels, and within all subcultures
- Senior leaders who embrace, model and consistently communicate KM as a beneficial business strategy, with IT <u>an</u> enabler
- A market that clearly operates within and across organizational and functional lines
- Integrated solutions for strengthening all weaknesses in the elements of its KM infrastructure (tools, culture, training)
- Strategic use of highly trained missionaries, farmers and bridge builders.

Intrinsic Motivation

While intrinsic motivation is the desired state, most organizations must intentionally transform to that state by first constructing extrinsic motivation and rewards. Typical motivation factors for learning and changing include:

- Responsibility for knowing and using the information (i.e., empowerment with accountability)
- Requirement to explain or teach something (e.g., to a colleague)
- Recognition, meaningful and public
- Request for a promotion or new assignment.

Extrinsic motivators can be measured and tracked to assess progress toward the desired end state. For example, organizations can require employees to demonstrate their proficiency in pertinent lessons learned and best practices prior to granting re-assignments or promotions.

Additional motivation can be accomplished through training techniques that account for different learning types, pique interests, and make lessons easy to remember and recall. For example, a "Heritage Hall" containing succinct, meaningful quotes (e.g., "test like you fly") from leaders and technical experts can help transform parts of an organization's KM culture. Story telling is another effective technique that increases learning and motivation, while transforming a culture.

Another strategy for reaching a state of intrinsic motivation is to connect the market's product (e.g., lessons learned, best practices) to an organization's need to manage and mitigate real risks, as is currently being implemented NASA's ESMD Risk and Knowledge Management Officer. (11)

Solutions for Infrastructure Weaknesses

Shifting from a cultural norm of "need to know" to "need to share" will provide a foundation for integrated solutions to address market weaknesses. These types of messages need to be frequently and honestly communicated throughout the organization. Because culture is an output of behavior, it is critical for organizations to analyze and influence behavioral norms in order to achieve desired culture changes. When workers believe their jobs are secure and their tasks are significant, their behavior will naturally exhibit more open sharing of knowledge.

A cultural norm that encourages and requires workers to be in a continual state of learning will pave the way for improved organizational learning and leveraging experiences and resources. As organizations embark on the journeys of continuous intentional learning required for complex missions, it is important to adopt the philosophy stated in the famous quote, "The beginning of knowledge is the discovery of something we do not understand." (16) A simple way to begin this shift is to reward employees who willingly and consistently share information to help others learn.

Integrated solutions also arise from training methods and philosophies. A comprehensive approach to training will:
- Include employees at all levels of an organization
- Teach techniques required for building and sustaining a SPKM, such as pause-and-learn, knowledge harvesting, and identifying relevance across projects, missions, programs, and organizations.
- Instruct employees on discovering what, when, why, where and how to retrieve all information required for a task.

Solutions for strengthening the culture and training infrastructure elements will naturally drive out requirements for solving any weaknesses in the tools.

Missionaries, Farmers, and Bridge Builders

Because a successful SPKM depends on transformed belief systems to enable the desired changes in behaviors, an organization needs employees who can advocate the SPKM benefits with almost missionary zeal. These advocates need to be skilled communicators, able to address all levels of employees, within and across organizational and functional boundaries. Their messages need to clearly convey what KM is, and convincingly debunk any misconceptions about it. They need to be well prepared to answer the inevitable question, "What's In It For Me?", to any listener or audience. They also need to know how and when to incorporate "converts" into strategic positions throughout the organization.

Placing knowledge farmers throughout the organization to harvest lessons learned and best practices from organizational and processing team forums is critical for building a successful SPKM. Giving these workers the responsibility to find and incorporate additional knowledge sources will ensure a robust market is developed.

An organization's bridge builders are critical for teaching people to think about relevance and the potential transfer of information and knowledge. They perform a vital role by helping people determine similarities between past experiences and future tasks, thereby identifying transfer and re-use opportunities. They help construct categories for knowledge contexts and experiences.

In order for today's tacit knowledge to become tomorrow's tacit knowledge, all of these tasks are necessary for the proper knowledge cultivation, transfer, and incorporation into a transformed organization. Communication is a required critical skill for all knowledge workers.

APPLYING THE FUNDAMENTALS/ CONSTRUCTING THE ISSSPD's SPKM

The construction of a SPKM within the ISSSPD involves three primary steps, planning for an evolving KM infrastructure, strengthening activities with the new customer, and monitoring and communicating results. These steps occur in parallel, and each one influences the other.

Plan for an Evolving KM Infrastructure

The more we learn, the more we learn there is to learn. Benchmarking studies reveal that most organizations with good knowledge management are 8-9 years in the making. (17) The ISSSPD's KM Infrastructure will constantly evolve, and the directorate plans for its growth. The ISSSPD will direct the market's growth by incorporating solutions to infrastructure weaknesses while being mindful of its customer's requirements and resources. Initial investments will focus on culture and training to provide the highest returns and stimulate demand.

The ISSSPD is engaged in many NASA KM activities including LLIS, the NASA KM Team, and the NASA KM Team's Ontology Sessions and Architecture and Search sub-teams. (18) The ISSSPD also seeks to learn best practices and solicit advice from the experts portrayed in NASA's Academy Sharing Knowledge (ASK) publications. (19) The ISSSPD not only learns by participating in these activities, but also provides use case scenarios to help test the concepts and products these groups develop. The ISSSPD plans to leverage the extensive repository of KM resources available through these networks now, and as its market evolves.

For example, as initial steps to strengthen its KM infrastructure weaknesses, the directorate will:

- Train a strategically selected group of workers to become certified in KM, then task them with specific missionary, farmer, and bridge builder roles (Johnson Space Center used KM Pro to certify workers; Goddard Space Flight Center offers training by its Chief Knowledge Officer (20), SATERN offers 12 KM classes)
- Provide the "missionaries" with real data and clear missions (Marshall Space Flight Center has concrete ROI data on search studies, (20))
- Train employees to find and use stored knowledge that is relevant to their expanding or changing roles and responsibilities
- Obtain senior management endorsement of KM as a business philosophy (Glenn Research Center achieved this by developing requirements for a "knowledge worker infrastructure", (20))
- Increase demand by tying knowledge in the form of lessons learned and best practices to risk mitigation, cost/benefit analyses (life-cycle, systems engineering based), and skills development
- Incorporate ESMD's "knowledge-based risks" approach (11) into ongoing ISS activities, to devise a transferable process for future work
- Look for tools to cultivate tacit knowledge from individual workers' repositories such as emails (Ames Research Center's Science Organizer tool contains this feature, (21))
- Examine for ISSSPD adaptation and use the survey JSC's developed for its SSP Tacit Knowledge Capture pilot project (20)
- Focus on knowledge cultivation/harvesting to formally capture more tacit knowledge, investigate and implement methods described in NASA's ASK magazine (22)
- Use extrinsic motivators, such as formalized accountability, to capture more tacit knowledge throughout the mission processing teams and other team forums
- Fully exploit existing ISSSPD tools, and populate them with harvested knowledge
- Develop methods for helping workers identify the knowledge and expertise required for specific ISS and CxP tasks and milestone events, and find experts to help train them (Jet Propulsion Lab has an "Expertise and Experts" tool, KSC has some mentor-protege matching tools, NASA Engineering Network has POPS Expertise Locator, Langley Research Center has a web-based phone book that is evolving into an "Experts Directory")
- Map some ISSSPD processes to NASA's recently documented taxonomy and metadata (23)
- Continue identifying and incorporating best practices from a broader KM community (e.g.,24,25)
- As much as possible, use the remaining ISS work to improve tools that will enhance CxP work processes (e.g., expand the Electronic WAD pilot project used at the depot to mission processing operations in the SSPF to identify improvements unique flight hardware processing requirements)
- Incorporate pause-and-learn sessions after the story-telling events of the ISSSPD's leadership development program; link the stories to competencies and expected behaviors of leaders.

The ISSSPD's tools, culture and training will each evolve as the directorate makes initial investments. Each evolution will infuse more self-propagating and self-sustaining characteristics into the ISSSPD Knowledge Market.

Strengthen Activities with New Customer

NASA is managing the CxP with the benefits of forethought and hindsight, aided by many lessons learned from legacy programs such as Apollo, Space Shuttle and ISS. Whereas initial Shuttle processing flows were based primarily on ideas and concepts, the CxP has been able to develop preliminary detailed flows, often down to hour increments, based on decades of experience with operations such as hazardous fueling, resource management, testing, and spacecraft and vehicle integration.

The ISSSPD's involvement in the early phases of CxP while executing its ongoing ISS responsibilities, is enabling many lessons from Shuttle Payload and ISS ground operations to be incorporated into CxP ground support and flight systems' designs as early as possible. Current practices ISSSPD uses to infuse its ISS operational knowledge into CxP designs include:

- Selecting ISSSPD individuals with specific experience and placing them in key CxP positions
- Influencing discussions with design engineers and project managers to force risk/cost analyses of ISSSPD requirements
- Participating in as many tests (e.g., launch and pad abort) as possible as early as possible to build systems engineering capabilities
- Integrating ISSSPD employees into CxP manufacturing sites at KSC and Michoud Assembly Facility (i.e., building on SSHIO's success in infusing operational considerations into assembly plans at the factory)
- Performing simulations as a way to build and maintain skills, e.g., in spacecraft fueling operations
- Identify areas of specialized work from other programs that ISSSPD and CAPPS personnel can perform now to build skills required for future work (e.g., took over fueling operations for the Expendable Launch Vehicles)
- Examining official documentation and standard practices to determine which ones will benefit the CxP, and how to best incorporate them into its framework.

The CxP is also benefiting from lessons learned in NASA's legacy programs regarding approaches to contract selection and management. For example, NASA is at risk of losing critical knowledge when contractors are allowed to declare certain information to be proprietary, and when contractors are allowed to use data management tools that do not integrate with tools used throughout entire functional processes by multiple implementing organizations.

Some of the lessons CxP learned from the Apollo Program were more challenging to obtain than those from more recent programs. Because NASA and the National Archives have such limited Apollo/Saturn documentation, and so few of the original designers are available, in April 2007 the CxP commissioned a team of current engineers to perform forensic examinations on museum hardware in order to tap the experience of past engineers as it develops Orion. ISSSPD personnel assisted in the disassembly and reassembly of the Command Module to Service Module umbilical of Apollo Command/Service Module #119 (CSM-119), which is on display at the KSC Apollo/Saturn V Visitor Center. (26)

Pic 3: Engineers analyze umbilical wiring between Apollo Command Module's service and crew modules.

While this task provided an exciting opportunity for the team of engineers who performed it, it demonstrates the criticality of capturing available information and personnel resources from shuttle operations to benefit future designs of re-usable vehicles, and from ISS operations for future designs of long term manned space habitats such as those for the moon and Mars.

As CxP matures, it is important for ISSSPD employees to intentionally seek knowledge leveraging opportunities in all of the domains where it has expertise. Strengthening its CxP involvement will also help the ISSSPD to prioritize its KM activities according to the most pressing needs of its customer.

Increased awareness and use of the CxP's tools (e.g., decision boards, processes, IT), culture and training enables ISSSPD employees to determine effective methods and priorities for incorporating "knowledge based changes" into CxP throughout its evolutions. Increased CxP involvement, in concert with a focus on strengthening the ISSSPD's SPKM, will enable the ISSSPD to leverage more resources for NASA. Intentionally identifying ways to carry relevant knowledge forward will improve a broad range of activities from contract acquisition activities to the preservation of assets (e.g., some may be valuable in technical and KM-related skills development).

Monitor and Communicate Results Regularly

Continuous monitoring and communication of the ISSSPD's value to its customers is an essential step in establishing a SPKM with a high return on investment for its consumers. The realization of benefits further increases the market's demand.

The benefits of the ISSSPD's SPKM, and of the directorate's value to CxP need to be intentionally captured and strategically communicated. Effective communication will enable the ISSSPD to adjust its priorities and align its resources according to market assessments and customer requirements.

The ISSSPD will be proactive in helping the CxP implement its transition strategies for NASA. A critical strategy the ISSSPD's SPKM can execute is "The Constellation Systems Program shall actively seek lessons learned from the Space Shuttle and ISS Programs and is required to implement those appropriate to leverage existing and future resources." (1, p9)

CONCLUSION

NASA has embarked on an exciting journey to enable humans to return to exploring the solar system beyond low earth orbit. The complex missions required to actually take that journey rely heavily on NASA's ability to successfully execute its internal "transition mission". Effective knowledge management practices in each involved organization can provide critical change elements required for NASA's transition. As shown by the ISSSPD's analysis of its current KM infrastructure, a key to successful transitions is found in an organization's ability to use KM to transform its culture and train its workforce for the future. A key purpose of KM for an organization in a transition is to help leverage the organization's valuable experience.

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