SANDIA REPORT
SAND2013-3671
Unlimited Release
Printed May 2013

Considerations for Implementing an Organizational Lessons Learned Process

Erik Fosshage

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Considerations for Implementing an Organizational Lessons Learned Process

Erik Fosshage
System Quality Engineering
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-MS0638

Abstract

This report examines the lessons learned process by a review of the literature in a variety of disciplines, and is intended as a guidepost for organizations that are considering the implementation of their own closed-loop learning process. Lessons learned definitions are provided within the broader context of knowledge management and the framework of a learning organization. Shortcomings of existing practices are summarized in an attempt to identify common pitfalls that can be avoided by organizations with fledgling experiences of their own. Lessons learned are then examined through a dual construct of both process and mechanism, with emphasis on integrating into organizational processes and promoting lesson reuse through data attributes that contribute toward changed behaviors. The report concludes with recommended steps for follow-on efforts.

ACKNOWLEDGMENTS

This report is a collaboration between the Surety Engineering Group (0420) at Sandia National Laboratories (SNL) and the School of Industrial Engineering at Purdue University. Funding was provided by the University Part Time program at SNL as part of a Master of Science in Industrial Engineering (MSIE) program, and this report serves as the author's independent study project (IE 590) for the Spring 2013 semester in pursuit of that degree.

The author wishes to thank Professor Barrett S. Caldwell at Purdue University for technical guidance and direction during the preparation of this report. This document, as well as subsequent project initiatives regarding lessons learned, is championed by Marcey Hoover, Senior Manager of the Surety Engineering Group. Technical advice at SNL was provided by Brent Blankenship, Ted Kreifels, Dave Peercy, Cary Pratt, Glen Smith, Caren Wenner, and Paul Werner. Additional thanks for technical guidance are offered to David Oberhettinger and Rick Paynter at NASA/Caltech Jet Propulsion Laboratory and Gabriela Galavíz at MIT Lincoln Laboratory.

CONTENTS

FIGURES

NOMENCLATURE

AFKN	Air Force Knowledge Now (web portal)
DOE	Department of Energy
DS&A	Defense Systems and Assessments
FFRDC	Federally Funded Research and Development Center
INCOSE	International Council on Systems Engineering
LL	Lessons Learned
LLS	Lessons Learning System
SAE	Society of Automotive Engineers
SELLS	Society for Effective Lessons Learned Sharing
SNL	Sandia National Laboratories
XML	Extensible Markup Language

1. INTRODUCTION

Knowledge-based organizations must continuously deliver value to their customers in the products and services they deliver, while simultaneously learning in order to improve their knowledge faster than the competition (Argyris and Schon, 1978; Daft and Huber, 1987; Stata, 1989; Huber, 1991). The challenge of project-oriented organizations is the collection and dissemination of knowledge to benefit those across the organization—both inside and outside of the project—who require relevant information to perform their work. Most organizations that attempt to tackle this challenge establish a lessons learned (LL) process that focuses on "causes" and other linear factors with little thought given towards either the needs of the end-user of this information or the relevance of this knowledge to a wider learning process across the entire organization.

Sandia National Laboratories (SNL) is a knowledge-based organization that is project-oriented to deliver value to a variety of national security stakeholders. SNL is chartered as a federally funded research and development center (FFRDC) and is legally obligated to only deliver solutions that cannot be provided by the commercial marketplace. An environment that addresses continuous learning is essential to a competitive environment where it is our nation's adversaries that are constantly attempting to infiltrate or degrade our systems. Owing to the high-consequence nature of our products and services, it is the natural responsibility of the surety organization to foster these learning activities in both the implementation and assurance roles.

The purpose of this pilot study is to research how the Surety Engineering Group (0420) at SNL, as well as other organizations within and outside of the laboratories, can implement a lessons learned process. While the primary purpose of this system is to serve an organization's goals, it will be shown that this activity can be used as both a vehicle for disseminating knowledge and a framework for establishing a Learning Organization culture. Emphasis should be placed on both integrating lessons into existing organizational processes and promoting lesson reuse by establishing a data structure that targets changed behaviors. As with any initiative that attempts to improve or change an organization's processes, to say nothing of its cultural framework, success can only be accomplished by an iterative process and this paper is intended to only be the first step in a long-term chain of events.

The various definitions of lessons learned and similar records of knowledge are described in Section 2, and Section 3 details why this undertaking is so difficult to accomplish. The concept of the learning organization is introduced in Section 4 as both an organizational framework and an end goal of this system. Section 5 examines lessons learned from the process standpoint, while Section 6 studies the structural framework that is also necessary for successful use. Section 7 concludes the paper by considering the next steps in the implementation process.

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2. LESSONS LEARNED DEFINITIONS

2.1. Definitions

The definition of a lesson learned has undergone an evolutionary process since Juran (1986) generally described it as "a catchall phrase describing what has been learned from experience" and Stewart (1998) conceived them collectively as guidelines, tips, or checklists of what went wrong in a particular event. These early definitions were narrowly focused on an experience being captured as only a record of what happened, and it soon became apparent that a "lesson identified" was not a "lesson learned" until it was shared and applied by others. When agencies such as the United States Navy, Lawrence Livermore National Laboratory, and Lockheed Martin began to integrate LL processes into their operations, they soon realized that the ultimate goal was to both preserve and expand knowledge in the organization. The Department of Energy's (DOE) Society for Effective Lessons Learned Sharing (SELLS) organization, also an early adopter of the LL process, in 2000 presented the following standard definition: *A lesson learned is the knowledge acquired from an innovation or an adverse experience that causes a worker or an organization to improve a process or activity to work safer, more efficiently, or with higher quality.* When the United States Air Force began implementing its Knowledge Management Center (now the Air Force Knowledge Now, or AFKN, web portal) it expanded to a more systematic and overlapping definition (Weber et al., 2001):

> A lesson learned is a recorded experience of value; a conclusion drawn from analysis of feedback information on past and/or current programs, policies, systems and processes. Lessons may show successes or innovative techniques, or they may show deficiencies or problems to be avoided. A lesson may be:
> 1. An informal policy or procedure;
> 2. Something you want to repeat;
> 3. A solution to a problem, or a corrective action;
> 4. How to avoid repeating an error; or
> 5. Something you never want to do (again).

The most complete LL definition was jointly crafted and adopted by the American, European, and Japanese space agencies:

> A lesson learned is a knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. Successes are also considered sources of lessons learned. A lesson must be *significant* in that it has a real or assumed impact on operations; *valid* in that is factually and technically correct; and *applicable* in that it identifies a specific design, process, or decision that reduces or eliminates the potential for failures and mishaps, or reinforces a positive result (Secchi et al., 1999).

This definition (1) accepts the legitimacy of learning from successes as well as failures; (2) reframes the LL as an artifact of knowledge; (3) re-orients towards an emphasis on reuse; (4) clarifies the guiding criteria for reuse (i.e., significant, valid, and applicable); and (5) focuses on the processes that a lesson can impact (Weber et al., 2001).

These comprehensive definitions serve a purpose in establishing the wide-ranging criteria that must be considered when implementing a lessons learned process. Ultimately, the lesson learned object cannot stand on its own; it must be defined in terms of how it fits into a larger system.

2.2. Lessons Learning Systems

Kotnour and Kurstedt (2000) defined a lesson learned as a knowledge-sharing mechanism that incorporates a plan, recommendations, and results; more importantly, they recognized that lessons learned are part of a larger system that serves Huber's (1991) organizational learning framework with three primary functions:

(a) acquire and store information in organizational memory;
(b) refine organizational memory; and
(c) retrieve and distribute information to support a current decision-making or problem-solving task.

This framework, which has been described in terms of knowledge management (KM) by Davenport and Prusak (2000), includes multiple knowledge artifacts besides lessons learned that have their own distinct features and intended uses. These artifacts, or records, are briefly described below (Weber et al, 2001).

Incident reports. These explain the factors and context surrounding unsuccessful experiences, without offering recommended solutions. The most common uses are for systems that track and monitor safety/accident or security investigations.

Alerts. Reports of problems experienced with a particular item or technology that are shared with other organizations, typically in the same industry, who may benefit from this knowledge. Note that alerts may act as source material for a lesson learned.

Corporate memories. This is more of an abstract term to reflect both a process and repository of knowledge artifacts, which may include alerts, incident reports, data warehouses, corporate stories (both in print publications and video clips), best practices, and lessons learned.[1]

Best practices. These describe previously successful ideas that are intended to address wider strategies within the organization, though they may also target individual processes. They differ from lessons learned in that they do not capture specific experiences and they only capture successful stories.

Additionally, many organizations make use of case-based or rule-based systems to maintain and disseminate knowledge. Each are defined with a different perspective on how knowledge is represented (Weber et al., 2001):

Cases. These share the same assumptions as lessons, namely that problems are expected to recur and similar problems can be solved using similar solutions (Leake, 1996). But

[1] This subject matter is examined extensively by Stein (1995), though the term "corporate memory" is not specifically identified. Sidell (1993) mentions it as a catch-all phrase without further definition.

whereas cases are organized to accomplish a specific task, LL processes are tailored to reuse data for a variety of tasks. Also, cases and lessons may not share the same grain size because there may be multiple lessons (or other records) per case.

Rules. As with lessons, these associate a set of conditions with a response. But rules require a perfect match of conditions, as well as consideration of any interrelations, before performing the response. In contrast, lessons require the user to possess domain-specific knowledge in order to apply the lesson's response given the *context* of the set of conditions. This complicates the lesson's effective use by requiring additional data (or experience) before proceeding, though it does allow for wider applicability because only a partial matching of conditions may be necessary.

These knowledge artifacts are often defined as a *Lessons Learning System* (LLS) that is typically used to improve an organization's processes. Collectively, they represent attempts by the organization to transform individual *tacit* knowledge into organizationally available *explicit* knowledge products (Caldwell, 2013b; Guinery, 2011). The challenge in mixing lessons learned with other artifacts, though, is that it becomes a complicated process to both find and apply lessons from multiple artifact sources if they are not oriented towards reuse. Many LL systems therefore focus only on lessons learned artifacts as a matter of technical necessity in order to address the needs of the future "seeker" of knowledge, rather than the current "reporter." An additional complication is that systems with intermixed artifacts are not technically structured in the same manner at the data attribute level; this decreases their searchability by causing problems with lesson verification, collection of reuse statistics (and other automated metrics), duplicate entries, confusion about results being applied to one or multiple conditions, and the ability to apply artificial intelligence (AI) heuristics to the data (Weber et al., 2001).

2.3. Impact

Kotnour (1999) pinpointed how the lesson learned artifact serves two equally important roles; it acts as a *process* for identifying actions to avoid (or replicate) and solutions to implement, and a *mechanism* to share this knowledge with others. This approach directly addressed the barriers to organizational learning and knowledge sharing that were identified by Purser et al. (1992)[2], which are beyond the scope of this paper; however, the concept of the *learning organization* will be covered in Section 4. Nonetheless, the process and mechanism viewpoints are necessarily coupled because this dual framework is essential to the ultimate success criteria of impacting both organizational processes and individual behaviors. Before these parallel considerations of process (Section 5) and mechanism (Section 6) are addressed, it is important to examine why many lessons learning systems are so difficult to implement.

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[2] 1) knowledge sharing and planning barriers, 2) knowledge frame of reference barriers, 3) knowledge retention and procedural barriers, and 4) knowledge acquisition barriers

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3. WHY CURRENT PRACTICES FAIL

Shortcomings of existing LL practices have been well-documented across multiple industries (Fisher et al., 1998; Weber et al., 2000; Bickford, 2000; United States General Accounting Office, 2002; NASA, 2012). Hendrick and Benner (1986) reported deficiencies in the investigation process that make it difficult to develop and disseminate lessons learned:

- Data gaps in incomplete descriptions or explanations of what happened, leading to unlearned lessons;
- Logic errors in sequencing or coupling elements of descriptions and explanations, or in the conclusions drawn from the data, leading to misleading or inconsistent lessons;
- Misinterpretation or misrepresentation of observations due to unsuspected biases, unwarranted assumptions, ambiguities, ambivalence, or unknowns, leading to unjustified or misdirected lessons;
- Biased data selection to fit predetermined hypotheses, prior experiences, anticipated litigation posture, or obstinate mind sets, obstructing potential new lessons;
- Generalizations or abstractions masking actionable details about LL, leading to users' misinterpretation or disregard of lessons;
- Premature conclusions leading to inadequately investigated or misdirected findings and incompletely defined lessons; and
- Deliberate falsehoods or omissions, leading to false outcomes.

Werner and Perry (2004) summarized a common set of barriers to the capture and use of lessons learned in the commercial aviation accident investigation process that is an effective representation of challenges in other high-consequence industries:

- Lessons are not routinely identified, collected, and shared across organizations and industries;
- Unorganized lessons are too difficult to use because there is too much material to search, there may be no standard format across different reports, work pressures do not allow time or resources to find and learn these lessons, and thus they are not quickly available;
- Reuse is ad hoc and unplanned;
- It is often hard to know what to search for or how to find useful documents;
- Taking time to search for, identify, access and then learn from lessons within an organization is a problem; and
- Organizational barriers such as the lack of communication across companies or divisions.

Caldwell (2013) points out that these communication barriers inhibit the engineering design framework, and offers that the lessons learned process should increase the "coupling" of knowledge across organizational entities. Bickford (2000) reminds us that this organizational "stovepiping" can be a legacy effect at many companies in the national security enterprise that still inhibits the sharing of knowledge to this day. Unfortunately, either formal (security, or "need-to-know" information) or informal (within- or across-group competition) structures within an organization limit the effectiveness of sharing LL knowledge elements. In a national security setting, it may be strictly prohibited to provide detailed information that will allow users to directly determine the situational elements that explicitly indicate why a particular LL is related to the user's current situation. Here, the creation of an appropriate level of data and context aggregation is essential in supporting a usable LL database while maintaining appropriate confidentiality, security, or sensitivity of information. A more dangerous problem is that of an organizational culture of information withholding as a form of individual and group competition. Although this type of culture is prevalent, its actual value may be debated as a mechanism for ensuring organizational success (Kidder, 1981; Isaacson, 2011).

Additional negative perceptions identified by users and managers of existing lessons learning systems include the difficulty of wading through the "noise" of irrelevant lessons to find the few relevant "signals," repetitive lessons that simply recycle existing practices or instructions, suspect tools, the difficulty of overcoming the intransigence of existing cultural mindsets, an unedited way for employees to complain about their co-workers' mistakes, and lack of evidence that lessons are being applied toward future success (Cowles, 2005; Caldwell, 2013).

Carnes and Breslau (2002) collected these observations while implementing a lessons learned process for the Department of Energy:

- The concept of lessons learned was viewed negatively since it tended to be based on errors in performance or undesired outcomes;
- Management wanted greater emphasis placed on sharing of good practices;
- Ownership of lessons learned systems was at the staff level with little direct management ownership; and
- Refinements in search taxonomy were needed to improve usability of the LL database.

Methodologies from the author's background (Borror, 2008; Project Management Institute, 2013) and personal observations in the workforce over a 25-year span yield convincing evidence that the lack of timely and effective communications is a major impediment to team efficiency. There is wide consensus amongst the organizational learning and project management literature (Pinto and Slevin, 1988; Walsh and Kanter, 1988; Huber, 1991; Demery, 1995; Gioia, 1996; Hartman and Ashrafi, 2002) that effective communication is a critical success factor to any project or new process initiative. Empirical studies in the management of resources in both aviation and medicine, which share many commonalities of the high-consequence environments of SNL programs, cite poor communication as both impediments to team performance and precursors to accidents (Helmreich and Schaefer, 1994; Sexton et al, 1998; Helmreich and Merritt, 2001). Thus for many organizations that attempt to implement LL practices, they set themselves up for failure by having poor communications and team leadership (addressed in Section 4) that are the required vehicles for success.

In addition to these examples of process deficiencies, equal attention must be placed on the *mechanism* of the lessons learning system because the framework and format are the most important factors in the ability to retrieve LL data for future use. Benner (2012) categorized these technical challenges to disseminating information in the following manner:

- Existing LL formats incorrectly focus on root causes rather than producing changed behaviors;

- Natural language barriers and balkanized systems (and data formats) impede computational and statistical analyses and search capabilities;
- Software obsolescence;
- Liability or security concerns that inhibit the sharing of knowledge; and
- The impossibility of deriving findings by applying statistical analysis methods to a single episodic occurrence, and the inherent risks in waiting for sufficient occurrences to do so.

The underlying motivation for implementing a lessons learned practice is to help an organization attain its goals. Many LL systems, however, poorly serve this function because they are not integrated into decision-making processes and are not structurally formatted to support knowledge collection, storage, dissemination, and reuse (Fisher et al., 1998; Weber et al., 2000; Weber et al., 2001). An additional complication is that many organizations' processes are geared toward delivering a product to a customer without any consideration of how project information can benefit the organization itself. Without this culture of learning, it is difficult to integrate project knowledge across an organization and the opportunity to increase capabilities for the future is lost (Kotnour, 1999; Kotnour and Vergopia, 2007; Oberhettinger, 2012). Before considering how an LLS is integrated into organizational processes, it is important to define the culture of a learning organization that those processes should be serving.

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4. THE LEARNING ORGANIZATION

The terms and constructs of *knowledge* and *learning* have been closely linked for many years. Peter Drucker first coined the term "knowledge worker" in his 1959 book *Landmarks of Tomorrow*, and was an early identifier of knowledge as the key resource in the modern post-Capitalist society (Drucker, 1994). Argyris and Schon (1978) noted that an organization learned by creating, sharing, and applying knowledge, and later research in both organizational knowledge (Bohn, 1994) and organizational learning (Fiol and Lyles, 1985) generally agreed upon a common definition of learning as a process by which knowledge is created from experience and the path by which improvement takes place. Huber (1991) extensively defined learning into four separate constructs (knowledge acquisition, information distribution, information interpretation, and organizational memory) and identified how knowledge and learning models should ultimately benefit the organization.

But Huber (1991) also reminds us of the challenge that much of what an organization learns is stored in the minds of its members. He continues:

> Science-making is a competitive industry, as well as a cooperative one. Scientists tend not to follow in the trails of others if blazing their own trail leads to ownership of part of the landscape. Further, this tendency not to follow the trail of others is exacerbated when lack of agreement on definitions and measures makes the identity of the right trail problematic. Finally, initial success tends to lead to specialization and, while specialization leads to competence and therefore more success, specialization also leads to niches and regions uninhabited by competitors, and so ignorance of the work of others persists.

Organizations like SNL - both project-oriented and knowledge-based – survive in part on their technical capabilities. Given that the development of knowledge from successes and failures is a central tenet of the technical profession, these organizations must continuously build knowledge from experience by learning processes that solicit feedback (Lindblom, 1959; Quinn, 1980; Petroski, 1992; Kharbanda and Pinto, 1996; Kotnour, 1999). Senge (1990) was an early adopter of the term *learning organization* that "continually expands its capacity to create its future," while Garvin (1993) asserted that it must be "skilled at creating, acquiring, and transferring knowledge and modifying its behavior to reflect new knowledge and insights."

Benner (2012) quotes the Wildland Fire Lessons Learned Center (2013) as the ultimate goal of a lessons learning system: "A lesson is learned when we change our behavior." He asserts that these behaviors and their relationships during incidents that produce the unintended outcomes are what end users specifically need, and this has indeed been a dominant research focus for more than a decade in a variety of disciplines in addition to lessons learning systems (Weber et al., 2001; Benner and Carey, 2009) such as error management (Helmreich and Merritt, 2001; Helmreich, 2000) and organizational change (Saka, 2003; Burnes, 2004). The roots of this behavior modeling stem from the early origins of organizational change research (Lewin, 1947), but it was specifically identified in the risk management models of Rasmussen (1997) as the essential factor in shaping human performance. He further asserted that modeling human behavior in the modern dynamic organizational environment is context-dependent such that it cannot focus only on decisions or "action sequences" of traditional task analysis, and that this led to his development of the skill-, rule-, and knowledge-based behavior models of cognitive control (Rasmussen, 1983). This suggests that "lessons identified" address only the actions or causes of what happened previously, while "lessons learned" should capture the performance-shaping factors of *changed behavior* that is necessary for future users to internalize such information.

Huber (1991) disagrees only slightly that observable changed behavior is necessary in order to learn. He quotes Friedlander (1983):

> Change resulting from learning need not be visibly behavioral. Learning may result in new and significant insights and awareness that dictate no behavioral change. In this sense the crucial element in learning is that the organism be consciously aware of differences and alternatives and have consciously chosen one of these alternatives. The choice may be not to reconstruct behavior but, rather, to change one's cognitive maps or understandings.

Huber thus offers that we may learn if our *range of potential behaviors* is changed, while not necessarily performing any new behavior ourselves. Perhaps this distinction is unimportant, however, because both viewpoints nonetheless understand the necessity to at least capture behavioral attributes and interactions in order to internalize any lesson (or other knowledge artifact).

Drucker (1994) offered that it was an important responsibility of both management and employees to effectively contribute towards the knowledge-base of an organization. Yet as Santos and Garcia (2006) and Saka (2003) point out, it is the managers perspectives on change that are the most powerful indicators of whether or not the change will be successful. Additionally, the learning organization cannot be as effective without the ability to provide closed-loop feedback that is focused on behaviors, and there is wide consensus within the literature on change management, risk management, and socio-technical engineering that only the leadership of an organization can reinforce both behavioral and cultural change from a top-down approach. Therefore, management is at the nexus of organizational learning, behavioral change, and cultural change… all of which are factors that must be aligned for the successful implementation of a lessons learned process (Rasmussen, 1997; Rasmussen, 2000; Burnes, 2004; Caldwell, 2013).

Carnes and Breslau (2002) identified a twelve-point strategy for optimizing organizational learning as the driving strategy for implementing a lessons learned process:

1. Establish a Leader that promotes cohesion and shared values;
2. Encourage individual learning;
3. Target learning;
4. Maximize team learning;
5. Challenge existing models;
6. Learn from others;
7. Learn from mistakes;
8. Integrate functional disciplines;
9. Develop a structure that promotes learning;
10. Develop a communication strategy that optimizes learning;
11. Measure performance - at project levels and for individuals; and

12. Manage information to promote learning.

These principles of a learning culture are an essential framework that should be at least addressed, if not in place, before an organization commits to employing a lessons learning system. These recommendations identify management, communication, structure, and organizational processes as lessons learned considerations, the latter of which is the topic of the next section.

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5. INTEGRATING LESSONS LEARNED INTO ORGANIZATIONAL PROCESSES

The first step in implementing processes to support and embed a lessons learned system is simply an awareness that the best way to learn and improve is to draw conclusions from past experiences. Management must enable the transition to a different way of making decisions, but ultimately any LLS must support existing organizational processes (Davenport and Prusak, 2000; Aha et al., 1999; Leake et al., 2000; Reimer, 1998).

Werner and Perry (2004) suggest an integrated, common infrastructure with the following characteristics:

- A structured process for incorporating lessons learned into existing organizational processes;
- An easily accessible system where project-specific decisions are available to other projects, including timely feedback to those already in service;
- A closed-loop process that ensures corrective actions are implemented, so that underlying sources of problems are corrected system-wide;
- A process that includes periodic reviews and feedback;
- A disciplined, data driven approach to identify root causes and determine the best actions to break the chain of events that lead to errors or incidents.

5.1 Root Causes, Context, and Precursor Events

The majority of lessons learned practices focus on negative events that undergo subsequent in-depth investigations and causal analyses. These investigations invariably search for the underlying "root causes" of the incident, and care must be taken not to look at isolated events but rather a complex system of conditions where only *together* are they sufficient to have caused the incident. The linear chain-of-events thinking in which incidents are discrete and instantaneous, called the "pinball" model, is often modeled by standard flow charts that fail to take in an overall system viewpoint. Werner and Perry (2004) preferred that root causes be considered "the first factor in a chain of events that can be controlled through a regulation, policy or standard; it is the point in the chain of events at which internal control can be exercised."

Caldwell (2008) offers that root-cause analyses should benefit from the understanding that is gained by identifying as many causal contributors as possible and then looking at patterns of causation across events. This clustering of events, called the "Pachinko" model", can happen in both spatial and temporal means and help identify additional *concurrent* contributing actions by various actors that produce an unintended outcome. While outside the scope of this paper, causal analysis models are an important partner activity to the lessons learned process in identifying all contributing factors. Sklet (2004) performed a thorough comparison of these methods and recommended that several be used during any particular investigation in order to achieve comprehensive lessons learned results. These methods that model parallel activities across time and space are often the only means of identifying how organizational structures and policies *themselves* can be significant and shared contributors to adverse events. This is essential when considering that the primary purpose of a lessons learned system is to integrate into organizational processes; in some cases, the LLS identifies how those processes must be changed in order to avoid unintended outcomes.

While the model of multiple causal contributors is preferred, there are nonetheless gaps in understanding that can only be addressed by capturing the full *context* of events. Ghaffarian (2011) notes that early efforts paid little attention to contextual elements but later, with the development of socio-technical systems, it was argued that events are both situated within *and shaped by* their contextual settings. As mentioned previously, Rasmussen (1983 and 1997) synthesized this impact of context on behavior into both human performance (cognitive control) and risk management models that are closely linked to the lessons learned process. Said another way, context is an important element for capture in lessons learned because of its ability to both fill in the gaps in knowledge and act as an identifier for use in other settings.

Whether an LLS is integrated into an organization's policy for risk management, safety, learning, design and production, or decision support, the implicit goal of the system is defect prevention. Events are not simply discrete and instantaneous activities but processes that may be partially identified and predicted in advance. Investigators and subject matter experts are attuned to identifying signals or triggers that anticipate the risk of future incidents, and causal analyses identify these event states as targets for corrective actions. Precursors are not necessarily technical in nature but can involve human factors such as inadequate procedures or poor decisions. They can be any experience or piece of data that could be interpreted as a predictor that an event consequence could occur if event conditions were present; as such, they are often unique opportunities to share knowledge with other stakeholders. Therefore, precursor data should be an integral part of any lessons learned process – and data structure - as a focal point for avoidance of repeat incidents and an opportunity for learning (Werner and Perry, 2004; Caldwell, 2008; ; Kletz, 2010; Sklet, 2004; Kotnour and Vergopia, 2007).

5.2 Lessons Learned Processes

It bears repeating that the underlying motivation for implementing lessons learned processes is to help an organization attain its own goals. These must be uniquely defined by the organization itself, and any existing templates from other entities cannot completely match all priorities for a particular organization. Nevertheless, many successful lessons learned practices share common traits that can serve as guideposts for consideration.

Weber et al. (2001) developed a generic lessons learned process after a survey of commercial, government and military organizations that had successfully implemented lessons learned programs; Cowles (2005) made additional modifications to fit the specific needs of his organization. The methods that are used within these processes are briefly described below.

- *Collect.* May be passive (organizational members submit their own lessons), reactive (members are interviewed for collection), after action (typically by interview at the end of a project), proactive (lessons are captured while problems are being solved), active (problems requiring solutions are identified first and then solutions collected in a group setting; another method is to scan existing document databases for lessons that require further sharing amongst group members), or interactive (proposed for systems using artificial intelligence).

Note that focusing only on negative experiences reduces the potential effectiveness of an LLS and misses opportunities to improve processes.

- *Verify.* Typically performed by a team of experts that validate lessons for correctness, redundancy, consistency and relevance. Many sources recommend the Gatekeeper role to validate criteria or enforce rules, but Caldwell (2013) discourages this function out of concern about information biases and the potential for censorship or prejudgment.
- *Store.* Addresses issues related to the framework and structure (refer to Section 6 of this paper) such as formatting, representation of data attributes, and indexing.
- *Disseminate.* Potentially the most important technique for promoting lesson reuse, consisting of the following options:
  - *Passive dissemination:* the most traditional (and ineffective) format in practice, users must search ("pull") a repository for lessons based on their own search criteria, often by keyword search using a substandard tool.
  - *Active casting:* lessons are broadcast to potential users based on their self-defined profiles that attempt to match the lesson's content (targeted "push").
  - *Broadcasting:* bulletins are sent to everyone in the organization, regardless of their interest (indiscriminate "push").
  - *Active dissemination:* users are notified of relevant lessons based on the context of decisions that they are making elsewhere in the system (targeted "push").
  - *Proactive dissemination:* the system predicts when to prompt the user with a relevant lesson based on how the user interface is modeled.
  - *Reactive dissemination:* initiated by the user when they realize that they need additional knowledge; popularly manifested by the "Help" option in most software systems.
- *Reuse.* The ultimate purpose of the system; focuses on encouraging/promoting lessons to be used by someone other than the submitter.
- *Organizational Innovation and Deployment (OID)*[3]. A process area within the Capability Maturity Model Integration (CMMI) methodology, this identifies incremental and innovative improvements that will measurably improve an organization's processes and technologies. This could be characterized as both the process and mechanism for the learning organization.

Kotnour (1999) offered that the plan-do-study-act (PDSA) cycle, which originates from quality management and is used extensively by the project management community, offers an excellent mechanism to support the learning organization by providing the opportunity to share (and therefore create new) knowledge both within and between projects. The lessons learned artifact provides a routine, ongoing store of information that is integrated within the project for the next cycle, or it can be shared with other projects as an entrance criterion for the "plan" step. This highlights one of the drivers for an organization to implement a lessons learned process: to improve the efficiency and effectiveness of its processes, communications, and future projects. Additional implications for a learning organization in using lessons learned within the PDSA cycle are:

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[3] Renamed to Organizational Performance Management (OPM) upon the release of CMMI version 1.3 in November 2010. Refer to Software Engineering Institute (2010).

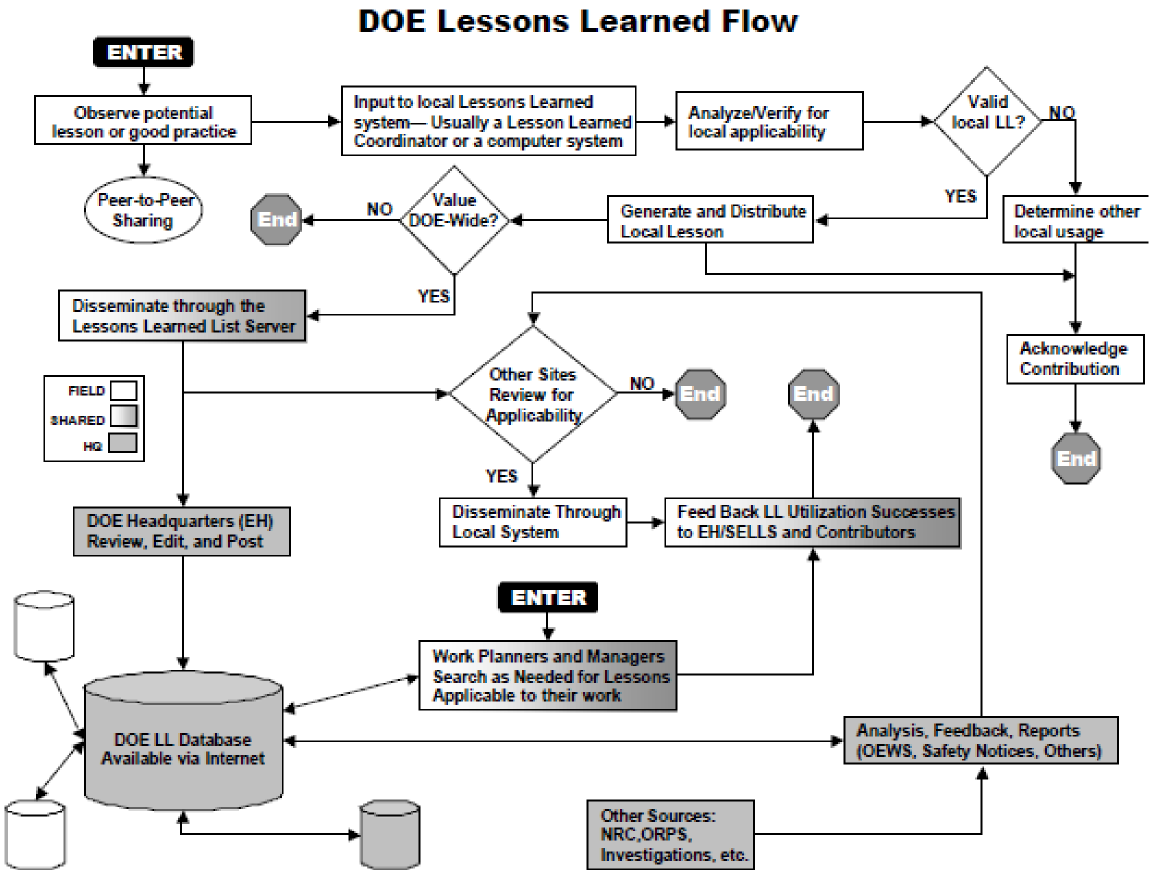
- *The opportunity for learning is an inherent part of the project management process.* The lessons learned artifact is therefore uniquely suited to benefitting the organization in this manner.
- *The project management planning and control tools provide the foundation for learning.* These already fulfill the process role, and the lessons learned artifact can serve as the mechanism to document and share this learning.
- *The use of lessons learned can be conducted throughout the project life cycle, not just at the end.* In practice, our biases at the end of the project influence what we choose (or have time) to document; thus, we miss the opportunity to capture earlier (or positive) events that may benefit either the current or future projects.
- *The learning process can break down at any stage of the PDSA cycle.* Not using the lessons learned process (and mechanisms) in a systemic way can lead to a breakdown of learning at each step of the cycle. For example, in the "do" step learning can break down by not collecting data on performance; in the "act" step the process may fail when lessons learned are not shared with the next project.

When attempting to tailor a lessons learned process for specific goals, an organization need not limit itself to only business processes for guidance. Caldwell (2013) points out that there are three stages of a lessons learned process that can map to FDIR (fault detection, isolation, and recovery) techniques:

- *Signal detection and interpretation:* recognize that a failure (or suboptimal) event occurred;
- *Problem understanding and recognition of critical precursor events:* determine what the correct (or optimal) approach should have been;
- *Documentation and dissemination:* capture and disseminate both the corrective action and the method for determining when a precursor event has occurred.

Sandia National Laboratories is managed by the Department of Energy, which has its own success story in the establishment of the DOE Lessons Learned Program. A number of DOE rules and policy orders require that lessons learned be identified, evaluated, shared, and incorporated into projects and operations, but by the mid-1990s it was determined that there was no comprehensive standard or guidance on setting up lessons learned programs at individual DOE locations. In1995 DOE established the Society for Effective Lessons Learned Sharing (SELLS), a formal community of lessons learned practitioners, and recommended the establishment of both a technical standard and electronic system that would develop, maintain, and share lessons learned across the DOE complex. Today, the DOE Corporate Lessons Learned Program technical standard [4] is focused on corrective actions for Environment, Safety, and Health issues only; thus, it may provide limited usefulness for R&D engineering or production environments. Nevertheless, the DOE Lessons Learned process flow, depicted in Figure 1, is an illustrative example of how lessons learned processes should be effectively aligned with – and tailored specifically for - organizational objectives (DOE, 1999; Carnes and Breslau, 2002).

[4] Part of the Corporate Operating Experience Program, and administered by the DOE Office of Health, Safety, and Security. Refer to http://www.hss.doe.gov/sesa/Analysis/ll/ (retrieved April 2013).



From DOE,1999

Figure 1. The DOE Lessons Learned Process Flow

Carnes and Breslau (2002) catalogued the early iterative efforts of DOE in setting up the Lessons Learned Program, and provided a set of eight "lessons learned about lessons learned" that can serve as guidelines for any fledgling efforts:

1. *Senior management ownership and accountability is essential.* Management focus may be the only method of finding solutions to "stovepipe" barriers and overcoming resistance to change (Rasmussen, 2000; Helmreich, 2000; Helmreich and Merritt, 2001; Saka, 2003; Santos and Garcia, 2006; Galavíz, 2013)

2. *Incentives must be developed to effect a culture change so that the organization actively seeks to identify lessons, learn from them, and share with others.*(Burnes, 2004; Cowles, 2005; Helmreich, 2000; Helmreich and Merritt, 2001; Saka, 2003; Santos and Garcia, 2006; Galavíz, 2013)

3. *Metrics are difficult but essential.* Early attempts to develop metrics only addressed usage of the system, but those focused on reuse of lessons provide more tangible benefits. (Cowles, 2005; Benner and Carey, 2009)

4. *Organizational processes must be re-engineered to make identification and use of lessons part of the normal business practice.* NASA refers to this process as infusion, whereby the

organization is not dependent on any particular person to apply a lesson at the proper decision point in a product lifecycle (Oberhettinger, 2012)

5. *Care must be taken to provide the context in which the lessons are learned.* Context is essential for identifying behaviors and interactions as well as communicating the applicability and potential value of the lesson beyond the initial circumstance in which the lesson was identified. It may also be the only way to effectively share sensitive information between organizations without compromising confidentiality or security rules (Rasmussen, 1997; Bickford, 2000; Ghaffarian, 2011; Caldwell, 2013)
6. *The value of a lesson is a function of the quality of analysis.* A causal analysis is often needed to understand why an identified lesson has been learned and contributed towards improvement.
7. *Multimedia should be used to communicate lessons.* Communicating the full context and implications of lessons may require multiple levels of detail. However, care must also be taken to identify sufficient attribute data (ie: metadata) such that metrics and usability statistics of lessons are not hindered.
8. *Early prototypes must iterate and mature.* Effective knowledge management systems may begin as grassroots emergent systems, but in order to effectively integrate into organizational processes they will eventually require formal systems analyses that identify roles and responsibilities, information sources, lessons generators, lessons users, validators, communications networks, and media types.

These eight findings were later used by DOE and the IEEE Human Factors Committee to create the recommended practice of IEEE Working Group 5.5[5], which communicates key attributes of effective lessons learned programs for nuclear facilities. This industry acceptance suggests that best practices from any previous lessons learned initiatives can, despite any differences in competitive industry or business culture, nonetheless be useful to emerging processes given sufficient tailoring to specific organizational goals.

Effective lessons learned processes must be actively championed and maintained, periodically reviewed for effectiveness, and integrated to improve organizational processes. They must also focus on the reusability of the lessons, and in order to do so searchability is an essential function of the *mechanism* of the lessons learned artifacts. Attention now turns to considering the data attributes of the system that that are necessary to make lessons useable.

[5] Refer to http://standards.ieee.org/develop/wg/WG_5.5.html (retrieved April 2013).

6. PROPOSED LESSONS LEARNING SYSTEM ATTRIBUTES

It was mentioned previously that many lessons learned systems are not structurally formatted to support knowledge collection, storage, dissemination, and reuse (Hendrick and Benner, 1986; Fisher et al., 1998, Weber et al., 2000, Weber et al., 2001, Werner and Perry, 2004; Benner and Carey, 2009; Benner, 2012). Before addressing the system attributes of the lessons learned *mechanism*, however, it is important to distinguish between the *structure* and the *format* of that mechanism. A lesson is a record that is presented to the reader in a particular format, with distinct components or subsections on the form that is used for user input and retrieval. Alternatively, the lesson can be built on a structural foundation of data comprised of different attributes that in some cases are not captured on the form; in other words, metadata. This is another matter of grain size, where the structural *lesson data* are used to create a lesson record that is presented in a particular presentation format.

Benner and Carey (2009) offer more specifics on the shortcomings of many LL system attributes that result from poor planning of the data structures:

- Lesson formats are confusing and unstructured;
- Lessons and recommendations are reported in undisciplined natural language format;
- Because of the undisciplined format, there is confusion and divergent views of whether or not a lesson is being reported as a root cause, contributing factor, conclusion, finding, issue, statement, recommendation, or scenario;
- Lesson relevancy or usefulness cannot be immediately determined but instead requires perusal of extensive verbiage in the natural language reports;
- Assimilation of lessons by anyone other than an intended recipient is haphazard and not measurable; and
- Lesson reporting suffers from proposing a response to causes and factors instead of specifying behavioral changes that need to be made.

Simon (1991) recognized that knowledge is only useful if it exists at the decision points where it is relevant, so Kotnour and Kurstedt (2000) followed this idea in examining the *quality* of a lesson learned by how well it contributes to knowledge sharing and decision-making performance. Their findings support having a formal data structure from which the lessons are drawn:

- Having a lesson learned (either partial- or full-format) leads to higher decision quality than having no lesson learned;
- Having a formal LL format resulted in higher decision quality; and
- A formal LL format results in higher decision quality than an informal LL format.

It is primarily the natural language format that makes the searchability and reuse of lessons so problematic for the future users of this knowledge. Unlike a “professional language” like those that exist in medicine or music, the undisciplined language format tolerates wide variations in vocabulary, morphology, syntax, meaning, and context. One mitigation is to provide a data definition dictionary to improve consistency, but this does not address the lack of a fundamental lesson data structure that is the more essential element. Without the ability to ascribe metadata-like attributes to a lesson, it then becomes difficult to perform numerical and statistical analyses or other data manipulations that are necessary for categorization, reporting, and search algorithms. For these reasons, the majority of lessons learned systems that allow the use of natural language suffer from low information density and therefore impede both the understanding of a lesson as well as its relevancy to other issues (European Community, 2006; Benner, 2012).

Benner and Carey extensively studied how these data attributes could be defined in order to enable more successful use of lessons learning systems. Benner (2012, which was originally authored as draft proceedings in 2007) first offered the Extensible Markup Language (XML) as a solution because it was a common protocol created by the World Wide Web Consortium and could therefore be read by software agents. Benner and Carey (2009) then proposed a list of the desired lesson data attributes that would provide the underlying (and missing) *data structure* for lessons learned systems:

- *Behavioral Interactions*. Because potential LL users work with dynamic processes having many interactions, and the success criterion of any LL is a changed behavior, an attribute should describe the behavioral interactions among the people involved… rather than linear "causes" or abstract "factors."
- *Multiple change options.* This system feature would allow users to choose from a list of options in how to change their activities to avoid a negative outcome, since any "recommended" change may not be the best option due to different context factors from the original incident. This also allows a wider reuse of lessons to those potential users whose activities or circumstances do not directly match the original context. This would likely require the uncoupling of lessons and recommendations (which may be separate components in the lesson format) and the recasting of recommendations as remedial examples (Burnes, 2004).
- *Context identification.* This is potentially the most important (and usually missing) attribute that both identifies and maximizes the opportunity for sharing and reuse. Context should be described in terms of both behavioral interactions and predecessor activity, and independent of the specific causes and responses of the incident.
- *Accessibility*. This is proposed as a data field that would indicate how the lessons data is structured, such as the XML protocol or any other format that is available. Backward compatibility with other systems may also be identified as a Boolean data field.
- *Latency.* The system would report the length of time between the incident and when its documented lesson becomes available to other users. Note that "gatekeepers" or intermediaries would increase LL latency, while interim recommendations would decrease them. Accelerated timeframes that bypass analysis elements such as findings, conclusions, and causes may maximize latency.
- *Signal to Noise Ratio.* This metric would allow the reader to determine the difficulty in extracting useful information, acting as a measure of the most information in the fewest words and therefore the quality of the information presented.

- *Relevance.* While this would be a subjective determination by users, this metric is now used online at many retailers who allow customer recommendations to be posted. The mere existence of this attribute may improve lesson inputs by encouraging authors to avoid generic recommendations, ambiguous statements or vocabulary, judgmental accusations, or extreme verbosity (Galavíz, 2013; Caldwell, 2013).
- *Assimilability.* This would measure both the internalization of an LL as well as its integration into the users' environment. Both repetitive and longer term uses of an LL would increase this metric.
- *System Scalability.* This would speak to the ability of the data repository to increase the quantity of lessons without sacrificing the quality of searchability and reuse.
- *System Price Sensitivity.* The goal here is to provide a metric that shows the value of the LL system in terms of results it has produced, and therefore a "tipping point" where its usefulness is questioned. The management goals, intended scope of the system, size and "learning culture" of the organization, and system simplicity would all affect this attribute.
- *Socialization.* This would quantify the social recognition of the LL system and its integration into future activities. Positive drivers for this metric would be the ability to change behaviors, countering resistance to change, or promoting collective learning.

These recommended data fields represent the most fundamental attributes from which the data structure is comprised. The literature also suggests that the following *system* attributes be considered (Weber et al., 2001; Benner and Carey, 2009; Benner, 2012):

- System performance metrics are necessary to measure how much the system is being used, either for successful implementations of lessons or how they were acted on differently (or not at all);
- LL repositories must facilitate timely updating (to include both data and hardware);
- To promote consistency and efficiency, specifications must be defined for input data to include grammar, syntax, and vocabulary;
- An objective process must exist for quality assurance and validation of lesson data;
- An automated process must be established for repository uploading (to include legacy data), statistical processing and reporting, and notification and dissemination activities;
- A lessons learned system is most efficient under a single, structured, and homogeneous format [though Weber et al. (2001) advocates different formats for planning LL and technical LL roles]; and
- A rapid search and filter capability is essential to minimize user time and workload.

This last identified system attribute, keyword search capability, is probably the most essential function of any knowledge-based system and likely the determining factor of its usefulness. Scientific studies (Gordon and Pathak, 1999; Hawking et al., 2001; Carnes and Breslau, 2002) and the success of Google (Levy, 2011) support the idea that search algorithms will either make or break a system's ability to acquire, extract, and disseminate knowledge. It will therefore be one of the most important features necessary for a lessons learning system to impact the goals of users and the organizations they serve.

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7. NEXT STEPS

This paper has addressed the many aspects that need to be considered before utilizing a lessons learning system. With the stated goal of this review to be the first step in a long chain of events, it is now necessary to address the scope of continuing efforts. Section 7.1 is intended to be useful to all organizations with both fledgling and mature experiences in closed-loop learning by identifying common considerations for employing lessons learned. Section 7.2 concludes this paper by focusing those considerations on the subsequent implementation of a lessons learned process within the SNL Surety Engineering Group (0420).

7.1 Common Considerations

This paper has reviewed the existing literature on lessons learned in a twofold attempt: to gather and interpret contemporary best practices, and to synthesize a common approach for the difficult task of "getting started" with the methodical and time-consuming effort of implementing a lessons learned process. Organizations should consider this section as generic guidance that must be specifically tailored for their own goals and processes. As such, the most useful approach is to offer some discussion points and raise questions that need to be asked and answered locally.

What is the scope of the initial effort? No lessons learned process can satisfy every need of both the organization and the individuals within, so it is important to identify the most useful impact areas in a collaborative and concentrated effort. Objectives for the LL system need to be derived from organizational goals that ideally already exist, but in their absence the first consideration must be an honest critique of whether the success criteria of company culture, processes, and management commitment are in place before proceeding any further. Use cases may be helpful in identifying goals, defining objectives, locating impact areas, and gathering team momentum. The appropriate inclusion of KM artifacts (i.e., cases, rules, best practices, etc.) should be determined, as well as the sources of legacy data that can be fed into the system once it is in place.

Special attention must be paid to the expected timeframe for having a functional and useful lessons learned prototype. This is often defined by the constraints of both funding calendars and triage efforts for problems in the present; these pressures must also be balanced with creating an enduring framework that builds long-term resiliency. For these and other reasons, it is important to have early victories; therefore, starting small and expanding the scope later is a recommended approach.

While the lessons learned approach requires equal attention to both process and mechanism, as a matter of priority the process considerations need to be addressed first.

Who are the critical stakeholders? Management support is an essential ingredient for any organizational process - especially those that often face corporate cultural barriers - otherwise there will be no traction or momentum. Embedded in the term "management" are the trinity of champion, sponsor, and funding source with the distinction that they are often not the same person. Other decision makers may reside in a different part of the organization, within either the line- or project-management disciplines. Equally as important is to identify the end-users of the system that will make it work, including system administrators. Identifying end users should begin with the questions “Who is your customer? And who is their customer?” A primary goal of identifying these critical stakeholders is to include them in the early development of the LL process, in order to build support for - and ownership of - the initiative.

What are the existing processes that lessons learned will support? Since the LL system supports organizational goals, examining existing processes is an essential first activity to identify the following (Oberhettinger, 2012; Caldwell, 2013):

- All of the stakeholders, as well as their needs;
- Decision points (in both time and space) where lessons learned can be the most useful if applied at that location; and
- Process artifacts (such as design guides, technical procedures, or design reviews with entrance and exit criteria) that exist at those locations as both the vehicle for infusing lessons learned and the criteria to which the system will be assessed.

Lessons learning systems need not be stand-alone but could also be incorporated into existing tools or mechanisms such as decision support systems, risk management products, or resource planning tools.

How will the system gain visibility? Carnes and Breslau (2002) offered solutions that are detailed in Section 5 of this document. Beyond the management commitment, the LL process should act as a bridge between the people and the data; therefore, it must be well publicized and tied to both organizational and individual performance objectives. Building a trusted and collaborative environment, as well as a user-friendly system interface, can lead to the change in corporate culture that is necessary to alter the ways people approach their daily activities. Both “pull” and “push” options for communicating lessons to the user community should be employed, though only as a calculated and measured approach such that users can locate relevant lessons at their decision points and avoid being overloaded with the “noise” (Cowles, 2005, Benner, 2012; Galavíz, 2013).

What are the perceived barriers to implementation? This question will be answered differently by each organization, but a few examples are offered here to germinate further considerations:

- With the rapid pace of activities in most organizations (Rasmussen, 1997; Rasmussen, 2000), it is difficult to deploy a new organizational process while simultaneously working to deliver a customer product. There may also be a time decay of the validity of a lesson if the collection process is delayed until the end of the project. What is the best way for critical stakeholders to assign priority to the use of a lessons learned process?
- Some potential users will see any new initiative as “more work” that they are being asked to accomplish. Users always have a perception of being “too busy”, and Rasmussen’s (1997) concept of the “gradient towards least effort” is a natural phenomenon of human activity. How does the organization overcome these mental blocks and reframe the LL process as being an activity that is value added?

- Without a dynamic and predictive system that is - at best - available in only the most mature and robust lessons learning systems, it is difficult to place useful lessons *and their associated impact* at the time and place where they are necessary to influence decisions. In other words, it is not only an issue of phasing but also that many users will not internalize a lesson unless they are directly involved in a "teachable moment[6]." How can the organization truly *infuse* the lessons learned process into decision points and knowledge artifacts in order to maximize their value?

7.2 Tailored Approach for the Surety Engineering Group

The SNL technical advisors for this research project (refer to the Acknowledgements section of this paper) have identified a recommended approach that is specific to the unique environment of Sandia National Laboratories. Future initiatives will likely refine and expand these propositions, but it is hoped that they are nonetheless beneficial to near-term activities.

Scope of initial effort and identification of existing processes. The immediate focus needs to be on existing Group 0420 customers and their projects, including those in both the Nuclear Weapons and Defense Systems and Assessments (DS&A) strategic management units. A pilot project is recommended for a medium-sized program that is sufficiently early in the design lifecycle to benefit from infusing lessons learned into existing processes. Nuclear weapons programs enjoy a more mature process methodology and legacy experience base at the laboratories; the combined product lifecycle activities map (containing the Weapon System Development Process, the Product Realization Process, Concurrent Qualification activities, and the Requirements Modernization and Integration milestones) already has natural decision points built in. Some DS&A programs in Centers of Excellence with recent successes also have robust architectures (such as those drawn from the INCOSE Systems Engineering Handbook and the SAE AS9100 Aerospace Standard) and key staff still in place for the possibility of an accelerated timeframe. Programs currently performing triage efforts are good candidates for small and early victories. The question of an appropriate timeframe may drive the selection of a particular pilot implementation candidate.

The author does not recommend studying or implementing any new tools or software architectures at this time, until the applicable organizational processes are selected and a detailed assessment of existing systems is conducted.

Critical Stakeholders. Besides the Group 0420 Senior Manager as the current champion and sponsor of this project, the Group 0420 Managers represent the important decision makers for a lessons learned development effort. Equally important decision makers reside in the project- and line management of the selected pilot implementation. Depending on the project location within the SNL organization, the funding source is likely to involve either the Chief Engineer for Nuclear Weapons and the associated Directors or their counterparts in the Defense Systems and Assessments strategic management unit. The primary users of the LL system should be the Group 0420 quality engineers, technologists, and matrixed staff who are embedded onto project

[6] This concept is best captured by Vilfredo Pareto, in *Comment on Kepler* (1876): "Give me a fruitful error any time, bursting with its own correction"; as quoted by Helmreich and Merritt (2001).

teams for their independent engineering assessments and advocacy for best practices in product realization.

Management Commitment. The critical stakeholders must commit to a lessons learned effort through their actions; at SNL, this translates into funding and management attention. This latter activity can be emphasized and prioritized to the staff by the adoption of learning organization principles and processes, incorporation into structured training, inclusion in training registers and annual performance management objectives, and communications that are "timely and often." The perception of an LL process being value-added may gain traction if the argument is re-framed towards incremental change and defect prevention, the latter being the simplified mission statement of the Surety Engineering Group.

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