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Modeling Operational Reliability: The Discovery of the Organizational Learning Loop

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Abstract: There has been considerable debate over organizational learning strategies as a worthwhile endeavor. This paper examines the issue within the context of High Reliability Organizations (HROs) through a recent ethnographic study that focused on organizational learning and its role in understanding of the dynamics of operational reliability. A review of the literature examines factors that influence organizational learning effectiveness within the context of the Sullivan-Beach model (Sullivan & Beach, 2009), which provides a conceptual framework from within which the dynamics of High Reliability Organizations (HROs) can be explained. Empirical data was gathered over a six month period in a high reliability environment supporting US Navy operations. An operational failure and the organization's response are analyzed using the Sullivan-Beach model. The analysis assisted in identifying factors that led to the operational failure and the remedial action that ultimately resulted in a dramatic improvement in operational reliability. The findings of the study support the notion that effective organizational learning strategies are critical to operational reliability, particularly in recovering from operational failures or preventing them altogether (Sullivan, 2007). In addition, the discovery of the Organizational Learning Loop within the Sullivan-Beach model suggests that success and failure with organizational learning depends on the same set of interrelated factors. Critically the paper provides insights into how organizations can learn from failure.

Key words: organizational learning; organizational learning loop; operational reliability; high reliability organizations; Sullivan-Beach model

JEL codes: L21, L23

1. Introduction

This research contributes to an on-going study that builds on the seminal contributions of the Berkeley Group from the 1990s to early 2000s to develop the most complete understanding possible of operational reliability. The organizational characteristics that contribute to and detract from operational reliability, the dynamic relationships that exist between them and their influence over time reveal how reliable an organization is. Unfortunately, even those organizations that are under the most pressure to achieve the highest levels of operational reliability occasionally fail, often resulting in publicly visible, highly consequential outcomes. What separates these organizations from those traditionally considered to be less capable is the way these organizations respond to

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failure and even the potential for failure (Roberts, 1990; Sullivan, 2007; Sullivan & Beach, 2009; Vaughn, 2005; Weick & Sutcliffe, 2007). It has been said that HROs have a persistent desire to know what they do not know (Roberts & Bea, 2001), that learning, either from failure, or to prevent failure, is important to them, even critical for their survival. Collective learning and communication are integral components to the reliability culture found in some of the most hazardous work environments imaginable (Roberts & Bea, 2001; Weick, 1987).

There has been considerable debate over the effectiveness of organizational learning strategies. The purpose of this research is not to propose that organizational learning is effective in all cases all the time. Rather, the purpose is to develop an understanding of the dynamics of organizational learning, to identify conditions, factors, and influences that contribute to effective organizational learning outcomes, and similarly, what, if any, indicators are the early warning signs of the process breaking down. It is proposed that in some environments it must be effective, and for those cases, it follows a predictable pattern of interdependent processes. When those processes are operating effectively, the organization evolves operationally from learning from failure to learning without failure, and ultimately leading to long periods of operating without significant failure at all. Conversely, when those processes begin to break down the organization will begin to experience a downward spiral of operational unreliability, which will lead to more frequent failures and repeating failures with the same root causes.

It is believed that if the dynamics of organizational learning can be more fully understood that it might enable the development of predictive assessment models that could be used to identify early signs of process breakdowns and provide an opportunity to implement corrective action before more significant problems materialize. The context of HROs is used to provide insight into how organizational learning works in an environment where it absolutely must work. To that end, the Sullivan-Beach model (Sullivan & Beach, 2009) provides a framework from which to study the dynamics of HROs, and specifically, the organizational learning component within the model.

2. Methodology

This research incorporates a single case study approach. Case studies are particularly compatible with “contemporary phenomenon within some real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin, 1994, p. 13). In this study observing the dynamics of organizational learning in the HRO setting is enhanced by the emersion of the observer in the environment. Examining phenomena in its natural setting as a means of generating meaningful, relevant theory from observing actual events is an accepted research technique that enables questions of why and how to be answered within the context of the nature and complexity of the phenomena (Benbasat et al., 1987; Meredith, 1998). The case study allows small samples to be used for theory verification (Flynn et al., 1990) providing the research design is informed by existing theory (Voss et al., 2002). This research involves uncommon access to participants in their operating environment and draws on existing theory in organizational learning with application to HRO research. The unique nature of the research subject was also an important factor in determining the approach adopted.

As a data collection technique, ethnography can provide an opportunity to obtain a much deeper understanding of a specific environment and social phenomenon than other approaches; the researcher becomes immersed into the community in which the observations are made (Morvaridi, 1998) and is thus able to make contextual observations as the phenomena occurs. The presence of researchers in the subject environment can, however, influence the behavior of the observed and may even be construed as an unnecessary interference. In this case, the extended presence of an outsider could also increase the risk of a compromise (although unintended) of

classified/confidential material. Even so, this situation is not without precedence. The seminal research project by Dr. Karlene Roberts of the University of California, Berkley and several of her colleagues, referred to as the Berkeley Group, used ethnography in their research of operations on flight decks aboard U.S. Navy aircraft carriers. The research team members spent between four days and three weeks aboard aircraft carriers over a five year period (Roberts, 1990). This uncommon level of access provided invaluable data that enabled the development of much of the foundational theory relating to HROs.

The similarities between the Berkeley Group's research environment and this one make this opportunity to conduct an ethnographic study in a military setting of particular interest. Post-September 11, 2001 access to military facilities has become difficult to obtain, so when the opportunity to study this organization became available, it was eagerly embraced. Obtaining the rich qualitative data necessary to understand the phenomenon under study would have been impossible by any other practical means.

3. Literature Review

The topic of organizational learning has been studied for decades. Early studies refer to "learning by doing" (Arrow, 1962) or an accumulation of knowledge over time (Adler, 1990). Corsini (1987) refers to this as declarative knowledge, an organized body of knowledge that allows learning to occur in a collective environment. Argyris and Schön (1996) use the term deuteron-learning to describe organizational learning through external sources, such as observations of other organizations, the experience of consultants who are familiar with other environments, and customers who interact with multiple types of organizations. Guha et al. (1997) summarize the goal of organizational learning as providing positive outcomes by effectively adapting to environmental changes resulting in operational improvement. Freeman and Perez (1988) suggest that in areas of technology, for example, effective adaptation includes not only making appropriate responses to technological advancements, but learning from other organizations that have been successful in doing so in accordance with industry best practices.

Jennex and Olfman (2002) suggest that to make a positive impact in organizational effectiveness, organizational learning has to be considered in relation to knowledge management and organizational memory. For the organization to be effective, it uses organizational learning to improve critical activities to remain competitive. Knowledge workers use knowledge management systems to identify meaningful information to be retained and implement mechanisms for capturing it. Organizational memory is the physical IT infrastructure that facilitates the storing, searching, and retrieving factual information (Jennex, 2008). Thus, improvements to organizational effectiveness are the result when management monitors organizational performance and establishes knowledge requirements. Knowledge engineers identify and capture knowledge for future use. Finally, IT personnel maintain the physical infrastructure that that makes knowledge available to knowledge users and managers where it is used to affect organizational effectiveness (Jennex & Olfman, 2002; Jennex, 2005).

Clearly, any organization that embraces this approach would have to make a significant commitment to implementing such a program and be persistent in monitoring its execution to realize the benefits it promises. Thus, it would appear that learning must at some level be important to the individuals, particularly the leadership, of the organization. Presumably, there has to be a motivation to learn that is shared by all (or nearly all) members of the organization. There is evidence of this in the literature. For example, some have suggested that learning occurs more readily in smaller more nimble organizations that are less formal, less political environments. These organizations provide the opportunity to assess success and failure more objectively (Baumard & Starbuck, 2005;

Starbuck, 1993; Sullivan, 2007) because individuals in these organizations can more readily link success to their own individual gain.

Others (Roberts & Bea, 2001; Saleh et al., 2010; Weick & Sutcliffe, 2007) have suggested that the organization must develop a culture of learning and continuous improvement in order to sustain organizational learning. Cultural learning, and the processes of organizational change that accompany it, presume the ability for collective *unlearning* (Fiol & Lyles, 1985). As such, an organization must be able to overcome resistance to change as part of the learning process. Citing organizational culture research, such as external or national culture, informal culture within the organization, and formal embedded organizational culture (Schwartzman, 1992), organizational culture is a "body of shared knowledge built up through learning" (Bierly & Spender, 1995, p. 643).

Still other research has suggested that organizational learning can be enhanced by incorporating "no-blame" practices (Provera et al., 2010; Zhao & Olivera, 2006). Under this principle, analysis of operational failures and near misses is done with a more constructive mindset without assigning blame to individuals. Ramanujam and Goodman (2003) refer to failures as deviations from planned courses of action and near misses involve cases where previously implemented remedial actions have prevented deviations from materializing into full blown disasters (Ramanujam & Goodman, 2003; Zhao & Olivera, 2006). It is believed that it is more important to objectively review the activities surrounding a deviation event so that corrective action can be implemented, or what Sullivan (2007) referred to as, "observe what is true, choose what works". The main underlying principle of the "no-blame" paradigm is to encourage individuals to report errors and near misses, the information from which can help improve operational processes and potentially prevent future mishaps. This approach is a shift in the thinking about operational failures from the assignment of blame for mismanaged duties performed by individuals or groups, to the view that failure is an operational lesson that promotes organizational learning and improvement (Provera et al., 2010). The atmosphere of trust that develops is considered to be essential especially in high hazard environments where safety concerns are a top priority.

3.1 Critics of Organizational Learning

The above withstanding, organizational learning effectiveness has its critics. It has been suggested that opportunities to learn are plentiful and even planned for, yet organizations squander learning chances (Baumard & Starbuck, 2005; Busby, 1999; Husted & Michailova, 2002; Mellahi, 2005; Milliken et al., 1992; Starbuck, 1993; Sullivan et al., 2008). For example, many organizations managing Enterprise Resource Planning (ERP) system implementations schedule postmortem project reviews to assess the performance of the project once the project is complete. Busby (1999) asserts that while these obvious learning opportunities have the potential to provide value to an organization, the results are often poorly disseminated or they fall into disuse. Reasons for this include the time it takes to conduct them, a desire by project participants to look ahead to new projects rather than relive old ones, anxiety that findings of project activities to be perceived as criticizing colleagues, and the perception that the experience of the project was a sufficient learning experience on its own. Regardless, one glaring weakness with postmortem project reviews is that the review occurs *after* the project is complete, when it is impossible to implement any kind of corrective action from what is learned in the hindsight-oriented review. Although not specifically mentioned by Busby, project team members intuitively know this. So why do it?

In another example, the Federal Emergency Management Agency (FEMA) response to Hurricane Katrina was widely criticized as an operational failure. The Select Bipartisan Committee established to investigate FEMA's preparation and response to Hurricane Katrina cited numerous operational break-downs that made conditions in the New Orleans area worse and endangered the people they were supposed to help (Congressional

Report, 2006). Among the many causes was a failure to capitalize on organizational learning opportunities.

Most experts agreed that the city of New Orleans was at risk of catastrophic damage if it were to suffer a direct hit from a category three or higher hurricane. In 2004 Innovative Emergency Management, Inc. (IEM) of Baton Rouge, Louisiana conducted the "Hurricane Pam" exercise, a five day simulation with emergency officials from fifty local, state, and federal agencies (FEMA, 2004). The purpose of the exercise was to develop operational plans to enable joint agencies to respond to a strong category three storm in the New Orleans area (Congressional Report, 2006). Some agencies found that they were better able to respond to Katrina as a result of the exercise, however, many of the lessons learned were not implemented in time. Also, the opportunity to develop a full complement of response plans was squandered when funding for the exercise was cancelled before it was complete. In addition, Katrina revealed many weaknesses in the few response plans that did exist (ibid). In the aftermath of Hurricane Katrina, the Congressional Committee concluded that there was "a perplexing inability to learn from Hurricane Pam and other exercises" (Congressional Report, 2006, p. 359). It is impossible to determine how FEMA's response to the storm would have improved had the Hurricane Pam exercise continued to completion, however, it is clear in the wake of the disaster that preparedness was inadequate to handle the event and an organizational learning opportunity was lost.

To propose that organizational learning can be effective in all types of organizations all the time would be more than a bit optimistic. It would be equally short-sighted to declare that it does not work ever, anywhere. Clearly, the body of research suggests that organizational learning can be effective under certain conditions. It also shows that a lack of motivation to learn or poor prioritization of efforts result in missed opportunities to learn that might have prevented failure. Perhaps the most appropriate way to begin a discussion of the effectiveness of organizational learning might begin with a question, "How does organizational learning actually work?" The following sections examine organizations that are considered to be effective learners—HROs.

3.2 High Reliability Organizations

One of the defining characteristics of HROs, such as NASA, nuclear power plants, and the military, is a persistent drive toward improvement through a culture of organizational learning (Hopkins, 2006; Leveson et al., 2009; Vaughn, 2005; Weick & Sutcliffe, 2007; Young, 2011). These organizations require nearly error-free operations at all times (Weick & Roberts, 1993). Any significant deviation from planned courses of action is likely to evolve into a publicly visible man-made disaster that "could lead to destruction of the organization and/or a larger public" (Roberts, 1990). In addition, they treat near misses with the same sense of urgency as a failure, being ever mindful that the circumstances that led to a near miss could reemerge as a disaster (Denyer et al., 2011). HROs seek "continually to search for improvement via systematic gleaning of feedback and the conduct of program and operational review" (LaPorte, 1996). This principal forms a basis for a continuous drive to improve that governs the way these organizations operate, and in particular, how they view failure. By constantly monitoring performance, HROs promote an environment among their personnel of never being satisfied with the *status quo*. They "exhibit a quite unusual willingness to *reward the discovery and reporting of error*, without at the same time pre-emptor ally assigning blame" (LaPorte, 1993). HROs monitor performance to compile a thorough record of performance and experience data (Provera et al., 2010; Zhao & Olivera, 2006; Weick & Sutcliffe, 2007).

Further, HROs are particularly effective at preventing other organizational goals from taking higher priority than reliability (Leveson et al., 2009). Weick (1987) reported that HROs are different from other types of organizations in that they place reliability as a higher priority than any other objective, including profit. The

culture of a US Navy nuclear submarine provides an extreme example of this principle. Obviously, a non-profit organization, reliable performance of each member of the vessel, and the performance of the vessel as a whole can be a matter of life and death (Dworetzky, 1987). It is best for all concerned to keep the reliable operation of the vessel as top priority. Cost has no influence over decision-making, …ever.

Not surprisingly, military culture has always involved a predictable process of reward and punishment that reinforce the importance of a continuous drive toward improvement through collective learning. Aboard ship, the Commanding Officer (CO) is the absolute authority of the vessel, and is responsible for everything that occurs, or fails to occur, as expected (Bierly & Spender, 1995). Further, consequences for noncompliance with ship's policies involve a high degree of visibility, and notices of disciplinary actions are displayed publicly. This high degree of accountability is thought to be a major contributor to reliability in the military environment. Researchers have suggested that visibility and accountability for inadequate performance are methods used to effectively communicate that one crew member's poor performance is a reflection that the entire crew is not performing up to standard. As such, each member of the organization understands the importance of his or her contribution to the greater organizational objective (Weick, 1987; Roberts & Bea, 2001).

There is considerable evidence that organizations can learn from past experience and that those with highly evolved cultures of reliability can even mitigate imagined failures by developing strategies in advance, essentially learning without failure (Jennex, 2008; Sullivan, 2007). For example, the operating characteristics of the airline industry, energy generation industry, and the military provide evidence that cultures of reliability exist, are effective, and should not be dismissed. These organizations have a similar organizational makeup and mindset that sets them apart from organizations in less critical operating environments. They exhibit what is commonly referred to as a "culture of reliability" (Roberts, 1990; LaPorte, 1996; Grabowski & Roberts, 1997; Sullivan, 2007; Sullivan & Beach, 2009).

A big part of the reliability culture is the focus on a prime directive, which is clearly communicated and reinforced to each member of the organization. Each member aboard a U.S. Navy aircraft carrier, from the captain to the cook, understands the prime directive of the ship; "to launch and recover aircraft safely". The culture of the vessel does not allow for competing directives because nothing is as important (Roberts & Bea, 2001). Failure at any level is considered to be a comprehensive failure to which everyone on board is viewed as a contributor; remedial action is swift, significant, comprehensive, and visible. Operating under such conditions drives the persistence of HROs to learn from failure, improve, and become more competent (Roberts, 1990; Sullivan, 2007).

The literature suggests that organizational learning has the potential to provide value as well as to fail miserably. It appears that to make it work there must be a supporting cultural element, a motivation to learn, accountability for meeting performance standards even if it is a no-blame policy, and a clearly communicated (and accepted) prime directive for the organization. In the following sections, a review of the Sullivan-Beach model and a failure analysis conducted within the context of the model are presented.

3.3 Sullivan-Beach Model

The Sullivan-Beach model (Sullivan & Beach, 2009) is a conceptual representation of the dynamics of the operating characteristics of HROs (Figure 1). It has been shown to be a useful context from which to explain operational phenomena that are indicative of operational reliability and unreliability (Sullivan & Beach, 2012). When the balance between capability and risk is maintained, or when capability outweighs risk, the scale remains balanced and the organization is considered to be operating reliably. When risk, comprised of expectations and risk factors, outweighs capability, comprised of resources and competence factors, failure occurs and consequences follow.

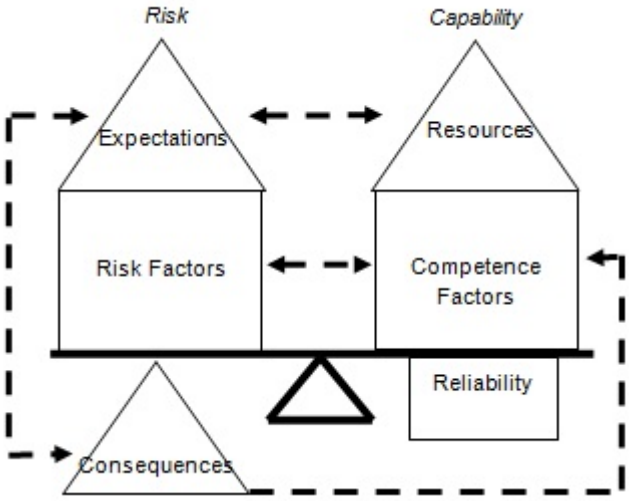

Figure 1 Sullivan-Beach Model for High Reliability Organizations

Two-way relationships exist between expectations and consequences, risk factors and competence factors, as well as expectations and resources. The relationship between consequences and competence factors is one-way as competence factors have no perceptible impact on consequences. Expectations and consequences are related in that the consequences for failure are experienced according to the level of missed expectations, with significant failures normally causing an increase in future expectations, e.g., the reorganization of NASA after the Challenger disaster. Resources and expectations are related because as stakeholders provide resources they attach expectations to the allocation, e.g., return on investment. The reverse is also true. Reductions in resource allocations are not surprisingly accompanied by demands on stakeholders to lower expectations, e.g., commercial and/or operational performance. Risk factors and competence factors are related in that risk factors left unchecked, e.g., office politics, groupthink, complacency, etc. will degrade organizational competence. However, a healthy HRO environment will demonstrate the opposite affect; a propensity to proactively identify potential risks and mitigate them before they manifest as operational failures, e.g., mitigating risk by learning without failure. When failure does occur, however, the one-way relationship between consequences and competence factors captures the experiential learning: failure invokes consequences, which provide opportunities to learn and become more competent (ibid).

4. Case Study: The Cable Manufacturer

The subject organization for this study manufactures outboard cables for U.S. Navy submarines. Outboard cables carry signals between electronic devices and must remain reliable under the intense pressures of the harsh underwater environment. Even though a failure of one of these cables cannot result a single point of failure for a submarine the way a hull breech would, cable failures can limit a submarine's ability to operate normally and carry out its mission. The requirement to perform to specification the first time, every time, requires a manufacturing process that consistently exercises tight process controls, e.g., a highly reliable operational environment.

The construction of each cable involves several processes, review and approval through at least three manager level checkpoints and a government inspection/acceptance procedure. All processes and checkpoints are

documented and signed by the operative responsible for each task. After assembly, cables are pressure tested well beyond the operating specifications for their service life cycle. After a final examination by Government representatives, accepted cables are entered into the inventory system for the U.S. Navy Submarine Fleet. During their service life, every activity related to the cable's installation and maintenance is documented, and the Navy maintains complete traceability back to its assembly and the suppliers of the component parts for each cable. If at any time a cable fails, it is replaced, and either repaired or destroyed. Cables that reach the end of their design life are replaced and destroyed.

The prime directive of the case organization is to build, test, and document reliable outboard cables for the U.S. Navy Submarine Fleet. The Navy ensures that contracting organizations maintain a reliability focus and do not waiver from the prime directive. To support that mission, manufacturers must maintain and report accurate and timely production metrics. Statistical process control data for each manufacturing process, checkpoint, pressure test, and government acceptance is reported to the Navy each month. All rework is documented and statistical trends are identified and analyzed. Typically, the manufacturing facility experiences less than one failure in more than one thousand cables built. Excessive failure rates negatively affect a manufacturer's compensation from the Navy which, in extreme cases, can result in the termination of contracts. Thus, the Navy has structured a reward system where consistently meeting the prime directive also satisfies another critical organizational requirement—to remain financially viable. Consequently, it was cause for concern when fifteen out of sixteen cables failed pressure testing in one month.

4.1 Failure Analysis

The cables in question were manufactured in batches of four. In the first batch, three of the four cables failed pressure testing. The remaining three batches of cables failed as well. Post-test analysis revealed that the polyurethane was de-laminating from the cable jacket (Figure 2). A search through manufacturing records found no previous incidents of de-lamination involving this type of cable, connector body, or brand of polyurethane. Engineers examined and tested the raw materials for defects and "out-of-specification" design modifications. The connector body was exactly the same as those previously used that tested successfully. The polyurethane, comprised of a resin and a hardening agent, was found to have no variation in composition from previous batches. The machine used to mix and dispense the polyurethane had been properly maintained and was operating within specification. The only variation discovered was in the jacket for the raw cable, which had significantly more paraffin wax in its chemical composition than previous lots, which inhibited the bonding of the polyurethane to the cable. Though still within specification, it did provide a plausible explanation for the failures.

To test whether wax in the cable jacket was the problem, a test cable was assembled, and before the polyurethane was applied, the raw cable was treated with a chemical to remove excess wax from the jacket. The cable was otherwise manufactured in accordance with normal procedures so that this variation could be isolated. The cable passed the pressure testing and showed no signs of de-lamination. The technical cause of the failure had been determined and effective remedial action implemented. The problem and solution was documented and disseminated to all members of the manufacturing facility. Normally, it would be time to move on. However, for HROs simply solving the technical problem is not enough. A bigger question was why further batches of cables had been manufactured when the first batch had revealed a 75% failure rate. This question speaks to the essence of what it means to be a HRO.

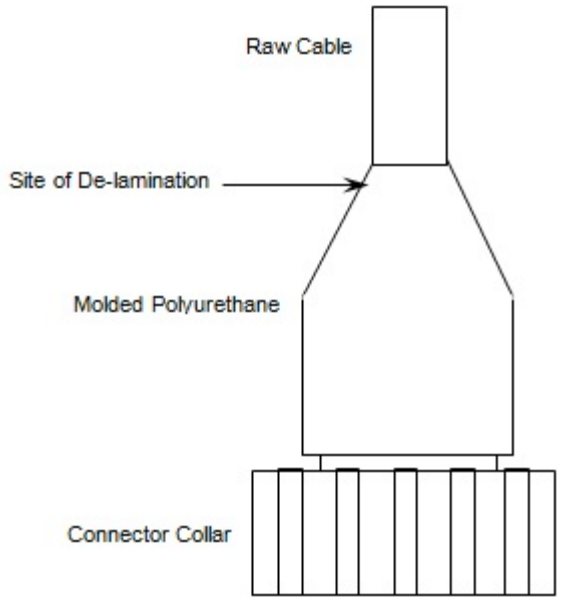

Figure 2 Cable Connector Assembly

4.2 Operational Unreliability in the Cable Manufacturing Facility

Further investigation into the details of the case reveals a deviation from the normal HRO mindset. Absent was the "culture of reliability" to strive to know what they do not know. Further, there was an inability to communicate to each member of the organization how what they do fits in the big picture and an absence of reliability-centric reward systems that are called for by Roberts and Bea (2001). Individuals in the cable manufacturing facility demonstrated weakness in all three of these areas resulting in operational failures.

- First, the drive to know what they do not know had eroded into an atmosphere of complacency. Rather than learning and becoming increasingly competent, they had devolved into stagnant complacent behavior. One contributing factor was that a recent period of employee turnover left five of the eleven operatives with less than one year experience on the job. Also, the new workers were not accustomed to the demands of a high reliability environment, and were having difficulty adjusting to its culture.
- Second, many workers had grown increasingly skeptical as to the importance of their role and how they contributed to the larger organizational picture. Divisions between senior members and new members became established and intensified, and the sense of cooperation and heedful interaction normally associated with the HRO environment was gone. When mistakes were identified workers were more concerned with assigning blame than using the experience to prevent further errors.
- Third, the reliability-centric reward system and the closely associated system of accountability had completely broken down. Deficiencies normally considered minor and administrative had been frequently overlooked with larger mistakes now going uncorrected. Documented procedures were not followed resulting in a growing number of careless human errors (i.e., forgetting signatures at checkpoints). While these might appear to be minor issues, these are symptomatic of a failing HRO environment.

Thus, the de-lamination problem was a technical problem requiring a technical solution, but the incident was an indicator of growing underlying organizational issues. The effect of the three organizational factors noted above on the reliability of the cable manufacturing operations is represented by the model as follows (Figure 3). The first area of weakness, complacency, can be explained by the risk-competence factors relationship.

Complacency is a risk factor for HROs as it undermines the drive to know what they do not know. As complacency becomes more established, individuals become less attentive making careless mistakes until a significant failure occurs. The second area of weakness, described here as a toxic organizational culture, can also be shown by the risk-competence factors relationship. Since the work environment is affected by its organizational culture (the norms, unwritten rules, customs, and rituals among workers), an adversarial culture is a risk factor that further diminishes competence. That is, the group as a whole is less able to operate reliably when contentious relationships allow competing objectives and personal agendas to supersede the organization's prime directive. Regrettably, this condition is often only discovered in the aftermath of an operational failure.

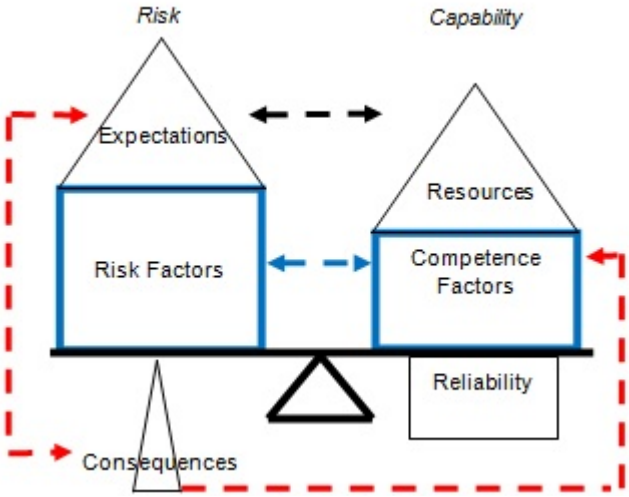

Figure 3 Sullivan-Beach Model Depiction of Cable Manufacturer's State of Unreliability

The third area of weakness is the lack of accountability for not meeting performance expectations. Expectations were not unreasonable in that the organization had sufficient resources, personnel, tools and raw materials for them to be met; the relationship between expectations and resources was thus in alignment. However, when expectations were not met, there was no accountability at the operative level. No matter how often failures occurred, consequences were minimal at best, and provided no motivation by individuals or the group to improve. Accountability, as mentioned above, is often thought of as severe punishment for undesirable behavior, particularly in military environments. When there is no accountability, high expectations can become misaligned with minimal or non-meaningful consequences with the result that opportunities to capture experiential learning are lost and failures are repeated. Worse, repeated instances of failure with no accountability contributes to the mindset of complacency mentioned above, and over time the severity of the failures can intensify.

4.3 The Discovery of the Organizational Learning Loop

During the above failure analysis, the model began to reveal a pattern of relationships affecting each other rather than operating in isolation. Until then, the relationships had not been viewed as interconnected and part of a process. The failure analysis demonstrated not only the interaction of relationships, but sequences of activities that have positive and negative impacts on the overall reliability of the organization.

Accountability and consequences have a profound influence on organizational learning. A prominent characteristic in HROs, accountability for not meeting expectations and the consequences it invites, motivate individuals and organizations to learn and become more competent so that future failures are avoided. The reverse is also true. If the individual or organization is not held accountable, it removes the all-important motivation to

learn and become increasingly competent, and more significant failures are likely to ensue.

Within the operational reliability context, an organizational environment with a strong drive toward improvement will exhibit what is referred to here as the *organizational learning loop* (Figure 4 in red). A prerequisite condition is the relationship between resources and expectations must be in alignment, as the learning processes will be thwarted if stakeholders have unrealistic expectations, e.g., insufficient resources to meet expectations. Once that has been established, an appropriate culture of reliability must exist for the process to be effective, e.g., the organization will have a prime directive to which all participants understand and buy in.

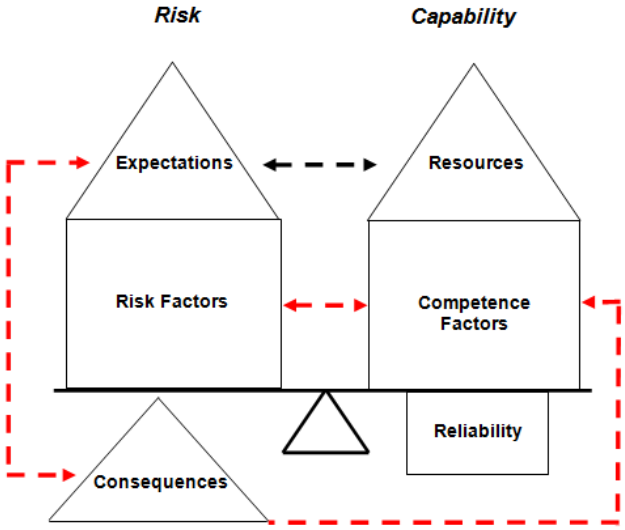

Figure 4 Sullivan-Beach Model: The Organizational Learning Loop

Typically, the organizational learning loop is initiated as a result of an operational failure. Stakeholder expectations are not met and consequences commensurate with the degree of missed expectations are imposed. These consequences facilitate organizational learning in a manner that will prevent repeat failures. The learning process focuses on two main issues. First, consequences lead to an increase in competence factors, and thus, the organization learns from its failure. Second, risk factors that influenced the failure are mitigated, or at least marginalized. Thus, the combination of increased competence and reduced risk contribute to making the organization as a whole more reliable. From this point the organizational learning loop can be maintained by the HRO culture which perpetually seeks to achieve a state of balance between competence factors and known risk factors. Thus, the organization becomes more competent as it explores potential risks and seeks to mitigate them before they have an adverse impact on the operation.

4.4 The Learning Phase in Cable Manufacturing

An analysis of the conditions the manufacturing facility makes it clear that it was not actively involved in the organizational learning loop. First, the risk factor-adversarial culture, had caused the group as a whole to become less competent. Second, a lack of accountability had led to an absence of meaningful consequences, which had undermined any previously established organizational learning mechanisms. Consequently, there were only limited means of increasing organizational competence and no indication that looming risk factors could be mitigated. With a source of competence atrophy on one side and an absence of learning mechanisms on the other, the organization was in a state of steady competence decline in a high risk scenario. Failure was inevitable. Something had to change.

The facility managers implemented changes that addressed each of the three areas of weakness mentioned above:

- Diminished competence: Senior members of the facility were tasked with conducting formalized training sessions for all staff covering topics from the most basic to more advanced. Senior members were thrust into leadership roles to engender a sense of ownership and responsibility for the competence of the group. It was also their responsibility to effectively communicate to the more junior workers through words and action the importance of buying in to the high reliability culture.
- Fitting into the bigger picture: The shop foreman delegated administrative tasks (i.e., monitoring training and safety inspection schedules) to junior members of the group. Thus, junior members were given responsibility for part of the operation further facilitating the all-important buy in of the culture. It also freed up the foreman's time to take a more proactive role in managing the facility. He was able to mentor junior staff and inculcate the importance of performing each task in the process precisely so improved process reliability would provide the required product reliability.
- Accountability, consequence and learning: Since this is a military style environment, intense forms of accountability could be expected. However, with half the operatives unaccustomed to such strict forms of accountability, and considering they all had the option to leave their positions (that military personnel do not have), a different approach more closely aligned with the no-blame philosophy was chosen. Two messages were emphasized to everyone in the facility—"if one of us fails, we all fail" and "observe what is true and choose what works". Workers were empowered to bring any concerns they had to managers and were guaranteed immunity from retaliation regardless of who was involved. Members of the facility were constantly reminded to view their mistakes as opportunities to improve rather than as personal attacks. This not only promoted an atmosphere of accountability between managers and workers, but also between workers themselves. Workers who were reminded of forgotten signatures began to respond with gratitude rather than scorn. It became viewed as "covering my back" rather than "stabbing me in the back". Ultimately, reminders became far less frequent as time went on.

Shortly after this episode in the cable manufacturing facility, a batch of four different types of cables was returned from pressure testing. Two failed. The Engineering Manager was called to the facility only to find several of the operatives actively involved in the initial stages of failure analysis. Each contributed to the building of the cables. This time, instead of finger-pointing, they were working together trying to find the cause of the failure.

5. Contributions and Limitations of this Research

The above remedial actions resulted in a dramatic improvement in the operational reliability of the facility. This scenario is also consistent with the three-pronged approach proposed by Jennex and Olfman; learning how to improve critical activities, identifying meaningful information and developing techniques for capturing it, and implementing useful storage and retrieval infrastructure. As junior operatives enhanced their technical skills and contributed to administrative tasks within the facility, they bought in to the culture of reliability that is essential for HROs. Senior members became more engaged as they saw how passing on their knowledge and experience to junior members increased the value of their respective contributions and the operational reliability of the group as a whole. Managers documented lessons learned, incorporated them into future training exercises and made them accessible to other managers through technical bulletins and written procedures.

Although far from conclusive, it appears the main contribution of this research is that it looks at the defining

characteristics, accountability, organizational learning, and risk management, as a series of interrelated processes, not just attributes in isolation. It proposes that if one breaks down, then it can lead to a breakdown of others. In fact, the case presented here seems to suggest that if accountability is not present, the rest of the process withers. It would be unrealistic to expect that organizational learning could take place if the organization did not at least recognize its failures. So, accountability, even "no-blame" accountability, appears to be an essential process to effective learning. Further, an organization that is not becoming increasingly competent would not normally be expected to seek out unknown risks and mitigate them. Essentially, if an organization cannot learn from failure, it is unrealistic to believe it will learn without failure. While the literature provides a multitude of authors who have identified and described these attributes as characteristic of HROs, an example of a description of the interrelatedness of them had not been found at the time of this research.

As for limitations, in the short term, it appeared that the organizational learning loop was operational. The Sullivan-Beach model appeared to accurately reflect the conditions of the case organization, both in a state of operational unreliability and as the situation improved and the facility returned to a more reliable condition. The case of the cable manufacturing facility demonstrated how a malfunctioning organizational learning loop can lead to a disturbing trend in operational maladies that will almost certainly lead to operational failures. The contributions of the Sullivan-Beach model in the context of this study are encouraging, however, it is only one case, and further exploration involving other case organizations would provide a higher degree of confidence for any conclusions drawn.

6. Conclusion

As illustrated by this study, organizations can learn from mistakes if it is important for them to do so. More highly evolved organizations in the operational reliability context learn without failure by developing techniques to seek out unknown risks and implement mitigation strategies in advance. This attribute is more prominent in organizations like the US Navy where a catastrophic failure (i.e., the loss of a submarine and its crew) invites consequences of such severity that it becomes cost effective to invest plentiful resources and effort into elaborate risk mitigation strategies. Those strategies require a robust culture involving a persistent desire to learn what they do not know. While the notion that organizational learning contributes to operational reliability remains controversial, this study has provided promising evidence that organizations can learn from failure to the benefit of their operations. Further, there is evidence that effective organizational learning activities might follow a predictable pattern of behavior, both when persistent learning is occurring and when it is not.

A scenario for how organizational learning can succeed and fail was presented through the discovery of the organizational learning loop within the Sullivan-Beach model. It should be noted that there are two prerequisite conditions that must exist for the organizational learning loop to operate effectively. First, there must be a clear prime directive to which all within the organization espouse, and second, expectations cannot be unrealistic, e.g., sufficient resources must exist to meet expectations. (Perhaps future research will reveal that this relationship is a functional part of the organizational learning loop.) As organizations fail, consequences are applied in accordance with the degree of missed expectations. The organization learns from the failure and becomes more competent whilst mitigating sources of risk so that repeated failures are avoided. Further, as competence increases, the organization develops techniques for identifying risk factors and mitigating them before failure occurs, essentially, learning without failure.

There are some environments that require organizations to learn from their mistakes and to develop mitigating strategies to avoid repeat failures. These are the characteristics of the HRO. However, these principles might be adaptable to other environments traditionally considered to be less capable. With an increasing necessity for higher levels of operational reliability from organizations not normally considered to be highly reliable, future research might adapt what has been shown here to other environments. Changes in operational expectations of many organizations have increased the importance of understanding operational reliability and its component parts, which include the conditions under which organizational learning works and does not work. For example, internet access to formerly "brick and mortar" institutions has drastically increased the importance of safeguarding personal information to prevent and identity theft, a concept that would have been completely foreign forty years ago. Just as in the case presented here, the financial welfare of some organizations may be placed in jeopardy by periods of unreliability. Further, their attitudes toward failure and how they respond to it may affect their survivability. In the not too distant future, failure may simply not be an option.

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