AN AIRCRAFT MAINTENANCE TECHNICIAN'S APPROACH ON AIRLINE SAFETY

A Project Presented to the Faculty
of
California State University, Stanislaus

In Partial Fulfillment
of the Requirements for the Degree
of Master of Business Administration

By
Marben Bermudez
October 2017

CERTIFICATION OF APPROVAL

AN AIRCRAFT MAINTENANCE TECHNICIAN'S

APPROACH ON AIRLINE SAFETY

By
Marben Bermudez

Signed Certification of Approval page
is on file with the University Library

Dr. Andrew Hinrichs Faculty Advisor, Professor of Management	Date
Dr. Sijing Zong Project Coordinator, Professor of Finance	Date
Ms. Katrina Kidd Director of MBA Programs	Date
Dr. Tomas Gomez - Arias Dean of College of Business Administration	Date

DEDICATION

To my sons, Maleck Brae Lee Bermudez and Matthaeus Brasen Lee Bermudez. Thank you for the inspiration and the motivation of your smiles.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

ABSTRACT

The purpose of this paper is to understand the discipline of safety and uncover the attendant literature as it pertains to the field of airline maintenance. My goal as the author, as an Aircraft Maintenance Technician (AMT) situated in the technical operations department of an airline organization, is to relate the body of current literature to the AMT role. The analysis focuses on the various factors that surround an AMT in his work environment that may help further their impact on safety and risk management. With the lack of published information on the scope of control of an AMT, the paper highlights certain events that characterize a human operator's behavior and responsibilities. As an AMT, I hope to give an overview of pertinent norms that affect an AMT in promoting safety.

CHAPTER I

INTRODUCTION

In an effort to better understand aircraft maintenance errors, countless initiatives have been published for a better understanding of its causality. Aircraft maintenance is necessary and crucial for the safety of the aircraft and those that utilize the airplane for transportation (McDonald, Corrigan, Daly & Cromie, 2000). In 2003, the International Air Transport Association (IATA) safety report found that 24 out of 93 accidents (26%), were caused by maintenance-related errors. Maintenance issues are also the leading cause of flight delays, and in turn create costs for airlines (Marx and Graeber, 1994). Accordingly, the cost associated with such maintenance errors was estimated to be 20% to 30% of engine in-flight shutdowns at $500,000 per shutdown. Fifty percent of delays are due to engine problems, costing $9,000 per hour; and 50% of flight cancellations are due to engine problems at $66,000 per cancellation.

The complexity of the process behind maintaining an aircraft in the airline industry compels different prospects of uncertainty or safety risks. Reducing such uncertainty can be derived from many variables such as organizational culture, human factors, safety systems, situational awareness, and authority in decision making. In which this paper covers these important variables and relays their significance as they interact to the role of an Aircraft Maintenance Technician (AMT).

Figure 1 provides an overview of the development of error caused by human and machine. As the machines have become more efficient the main research focus of accidents has turned toward human error, which constitutes 70% of aircraft accidents (Hawkins & Orlady, 1993). It then becomes a necessity to further understand aircraft maintenance error in relation to the operator – the AMT – so practicing managers can better identify the causes and reduce unsafe outcomes.

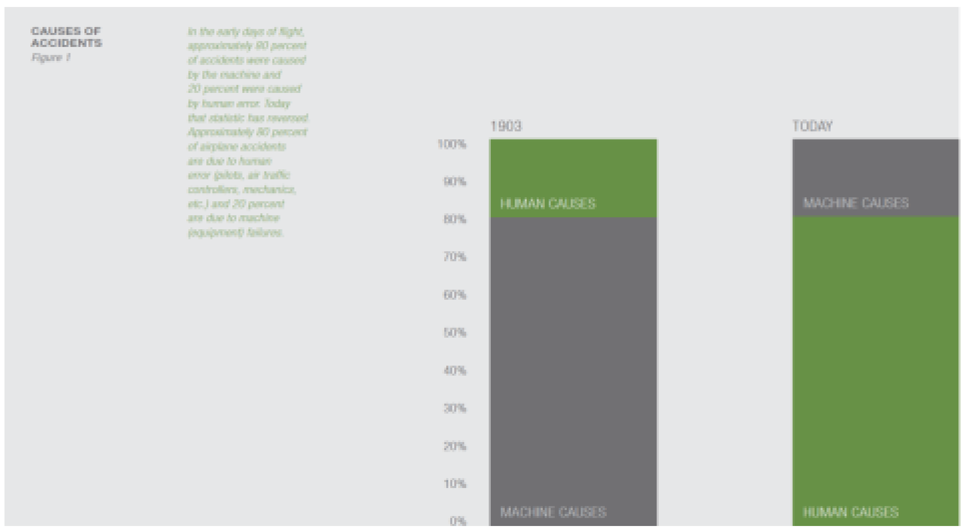

Figure 1. Causes of Accidents. Source: International Air Transport Association, 2003.

In this paper, I will also review the various literature that encompasses human error in the airline industry, focusing on aircraft maintenance. This literature is focused on realizing the factors that impact AMTs in their safety work processes and acknowledging the causal chain of events that may trigger an unsafe act in relation to an AMT's everyday work processes. An AMT is immersed in the everyday activities of this environment and can relate to the norms and technical practices comprising the technical operations department of an airline organization. It is hoped that, through this review, a greater understanding will be gained of the cultural and social world of an AMT in a maintenance organization. I will also describe an AMT's scope of control and its importance. As a participant in the everyday life of an airline organization, I have gained experience and insights that would have remained hidden, since information about safety issues is extremely difficult to obtain through other research methods (Atak & Kingma, 2011).

The U.S. Airline Industry

The airline industry in the United States of America pioneered aviation maintenance. With the deep history of invention and design, the U.S. has advanced innovations and standardized practices that are accepted throughout the industry world-wide. The U.S. fleets consist of both narrow body and wide body aircraft, from the Boeing airplanes from Seattle, to the Airbus fleet from Europe. U.S. airline maintenance bases can service the majority of maintenance work, and can provide heavy maintenance visits. Maintenance programs such as maintenance checks, composite repair, component overhaul, and engine overhaul to tooling and machining, are all being in-sourced at these facilities, thereby making the maintenance operation self-sufficient.

With thousands of AMTs across the system to verify the airworthiness of the aircrafts, the technical operations play a major role in the performance and safety of the airline fleet. Because of the need for high levels of risk awareness and preventive measures that organizations in the field of aviation possess, the U.S. airline industry can be considered a high-reliability organization (HRO) (Weick & Sutcliffe, 2001).

HROs are identified as a subset of hazardous organizations that enjoy a record of high safety over long periods of time (Roberts, 1990). For this review, the airline industry will be considered an HRO and used to understand the uncertainty that exists in the interactive complexity of the systems that aircraft maintenance organizations possess that affects the AMT. This is important since aircraft maintenance covers a wide scope in the daily operations of the U.S. airline business, and has a direct effect on the efficiency and reliability of its operations.

CHAPTER II

HUMAN APPROACH

Reason (1990) stated that the term error applies to situations where there was an intention to perform some type of action, and if the action did not proceed as planned, the outcome would be attributed to an error from the original intended action. If the action did proceed as planned, an unwanted outcome would be associated with an error from an intended but mistaken action. In both occasions, an action resulted in an unwanted or adverse outcome.

The concept that errors are not random events, but rather manifest in response to causal factors has been evident in countless research studies that relate human performance in technological systems to error factors (Heinrich, 1941; Reason, 1990). One contributing factor in terms of human performance or human fallibility is in the association of cognitive origin (Hobbs & Williamson, 2003). The fundamental limitations that exist in the human sensory, cognitive, and motor processes give basis for this human error. Various models of human information processing have been developed. Wickens and colleagues (1998) explain that sensory information is received by the body's receptor cells and is stored in a system of sensory registers which is then processed only briefly. With selective attention, subsets of this vast collection of information become designated for further processing known as perception. Perception then becomes the organization, identification, and interpretation of sensory information (Schacter, 2011).

Contributing Factors

As the human component in Aircraft Maintenance, Aircraft Maintenance Technicians (AMTs) are succeptible to perception, and incriminately to fallibility. Perceptual error can be considered as an important error factor in the aviation environment (Wiegmann & Shappell, 2001). A summary of Hobbs's (2003) error taxonomy is presented in Table 1 to further define the various errors caused by human factors.

Table 1

Hobb's Error Taxonomy

Error	Definition
Perceptual Error	A failure to detect and be aware of the environment
Memory Lapse	Forgetting an action that the person intended to perform
Slip	The failure to carry out such an action correctly; this category includes fumbles and trips
Rule-based Error	A failure to follow policies like written manuals
Violation	An intentional deviation from procedures or good practice
Knowledge-based Error	An error in a situation that was unfamiliar or for which neither automatic mapping nor rules exist
Mischance	The person adhered to correct procedures, but his or her behavior was nevertheless instrumental in leading to the occurrence

Although certain contributing factors are generally associated with all forms of error, it can also be said that particular contributing factors can have a stronger association with the prevalence of specific errors (Hobbs & Williamson, 2003). One specific contributing factor will be more apparent in certain errors, and is therefore specific to an AMT's work processes and work environment. That factor is maintenance error.

The Dirty Dozen

Dupont (1997) created the widely accepted list of concepts of contributing factors to human error in aircraft maintenance that can act as a precursor to accidents and incidents. Best known as the "Dirty Dozen," the list became a useful tool for training and discussion of human error in not just the aviation field but in other industries as well. The United Kingdom's Civil Aviation Authority (CAA) and its U.S. counterpart, the Federal Aviation Agency (FAA), have pioneered the promotion of the Dirty Dozen as a way to address human factors in aviation. Table 2 lists these contributing factors.

Table 2

The Dirty Dozen

Lack of communication	Failure to transmit, receive or provide enough information to complete a task
Lack of knowledge	Shortage of the training, information, and/or ability to successfully perform
Complacency	Overconfidence from repeated experience performing a task
Distractions	Anything that draws your attention away from the task at hand
Lack of teamwork	Failure to work together to achieve a shared goal
Fatigue	Physical or mental exhaustion threatening work performance
Lack of resources	Not having enough people, equipment, documentation, time, parts, etc. to complete a task
Pressure	Real or perceived forces demanding high-level job performance

Lack of assertiveness	Failure to speak up or document concerns about instructions, orders or the actions of others
Stress	A physical or emotional factor that causes physical or emotional tension
Lack of awareness	Failure to recognize a situation or what it is, and predict possible results
Norms	Expected, yet unwritten, rules of behavior

Source: faasafety.gov

Since human fallibility can be the precursor to a specific or general form of error, the outcome can also be generally considered as having a correlation to the specific or general form of errors. For example, fatigue is more likely to interfere with automatic processing wherein work is consistent and predictable; a sample of an outcome are trips and falls, a *slip* error. Pressure on the other hand, can be more of an interference that involves variability in tasks; outcome can be a wrong part installed on aircraft, a *violation* error (Fisk, Ackerman, & Schneider, 1987). Although minimal research is available regarding a more statistical analysis of the ‘dirty dozen’ and the forms of error, it is a widely accepted concept in the aviation industry. Thus, a real world situation will provide a better illustration of its validity and causality to an AMT’s daily work procedures. To lessen the ambiguity of this point of view, Table 3 lists some possible events that may have become precursors to human factors or human fallibility, with its form of error and outcome.

Table 3

Dirty Dozen Sampling

Prior Event	Dirty Dozen (Contributing Factor)	Error	Form of Error (Taxonomy)	Outcome
Previous shift left early	Lack of Communication	Bolts in fuel tube installed but not torqued	Perceptual Error	Leak in the Fuel tube when fuel pump was operated
No prior training	Lack of Knowledge	Slat Circuit Breaker not pulled	Rule-based Error	Slat moved without intent when flap handle was moved
Not referencing the AMM (Manual)	Complacency	Over servicing the Nose Strut	Memory Lapse	Nose strut oil leak
Social conversation	Distractions	Missed to install a bolt	Slip	Component was found loose by inspector
Team not collaborating with sequence of steps	Lack of Teamwork	Engine hinges not flushed in pylon	Perceptual Error	Engine needed to be re-installed
Graveyard Shift, Lack of sleep	Fatigue	Not verifying tensions of thrust reverser latches	Rule-based Error	Latches popping out
Tool not in station	Lack of Resources	Used an improvised pin	Violation	Flight control rigging failed
End of maintenance visit	Pressure	Fan cowls closed without clearance or inspection	Rule-based Error	Found rags inside fan cowl on the next station

Multiple operational check	Lack of Assertiveness	Wrong switch activated	Perceptual Error	Unintended pressurization of Aircraft
Personal issues	Stress	Forgetting to apply sealant on bolts	Memory Lapse	Corrosion on bolts
Not paying attention	Lack of Awareness	Walked over a puddle of hydraulic fluid	Slip	Slip Accident
Majority sampling	Norms	Not using safety goggles	Mischance	Hydraulic fluid caught in the eyes

Outcome from Processes

As the prevalence of a specific contributing factor (one of the dirty dozen) could have a higher degree of correlation with a specific form of error, the unwanted outcome will be based on the certain processes that supports the task. For example, as noted in Table 3, the contributing factor *distraction*, the outcome is described as "a component found loose by inspector," only applies because the task at hand was a component installation worked by the AMT. If a different task was being performed, for instance, the servicing of tires, then the outcome of the *distraction* might be "tires are under serviced or lacks pressure." Regardless, the form of error is still a ***slip***.

Although the unwanted outcome is based on the processes of the current task, the form of error may be a reflection of multiple contributing factors. With the tires being under serviced example, both *distraction* and *lack of awareness* could be contributing factors. As such, both can be a precursor to the form of error that is termed *slip*. Although unwanted outcomes may be based on processes of certain tasks, the contributing factors may have a higher focus of relation to certain processes of an AMT at work. In Table 3, *lack of knowledge* was listed as the contributing factor for the outcome "slat moved without intent," because the AMT was not knowledgeable of the systems. Thus, in this scenario, *lack of knowledge* was the main contributor for the error. With this example, the importance of identifying which of the dirty dozen affects certain work processes will obviously be beneficial for any safety or error management program in aviation.

Figure 2 is a simple illustration of a model that can provide data sets for a further statistical research on such correlations. In addition, possible questions to represent the equation are added to illustrate its use.

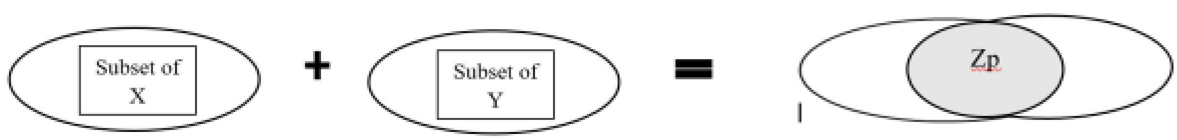

Figure 2. Effects of the Dirty Dozen on AMT Work Processes (Bermudez,2017)

Wherein subset of X equals *which of the "Dirty Dozen"* and subset of Y equals *which "Form of Error,"* Z equals subset of X + subset of Y, indicating what subsets are specific to p, wherein p equals to an AMT work process:

1. What forms of error (Y) have a higher degree of correlation with each of the dirty dozen (X)?

2. What subsets of question (1) will have a higher effect to promote unwanted outcomes on certain or specific AMT work processes? This is (Z_p).

CHAPTER III

SYSTEM APPROACH

According to Reason (1990), humans are fallible and errors are to be expected. The assumption is that even though the condition of human fallibility is constant, the conditions under which humans work can be changed. Reason also states that errors are consequences rather than causes, and that systematic factors like organizational processes and error traps gives rise to them. Therefore, a systematic approach will be used in this chapter using Reason's Swiss cheese model of system accidents to broaden the causation of error in terms of organizational factors.

Reason proposed that in an ideal world, defensive layers like barriers and safeguards are intact. In reality, however, they are more like slices of Swiss cheese with many holes, although unlike in the cheese, these holes are continually opening, shutting, and shifting their location. When the holes in many layers momentarily line up, this permits a trajectory of accidents. Figure 3 illustrates this concept.

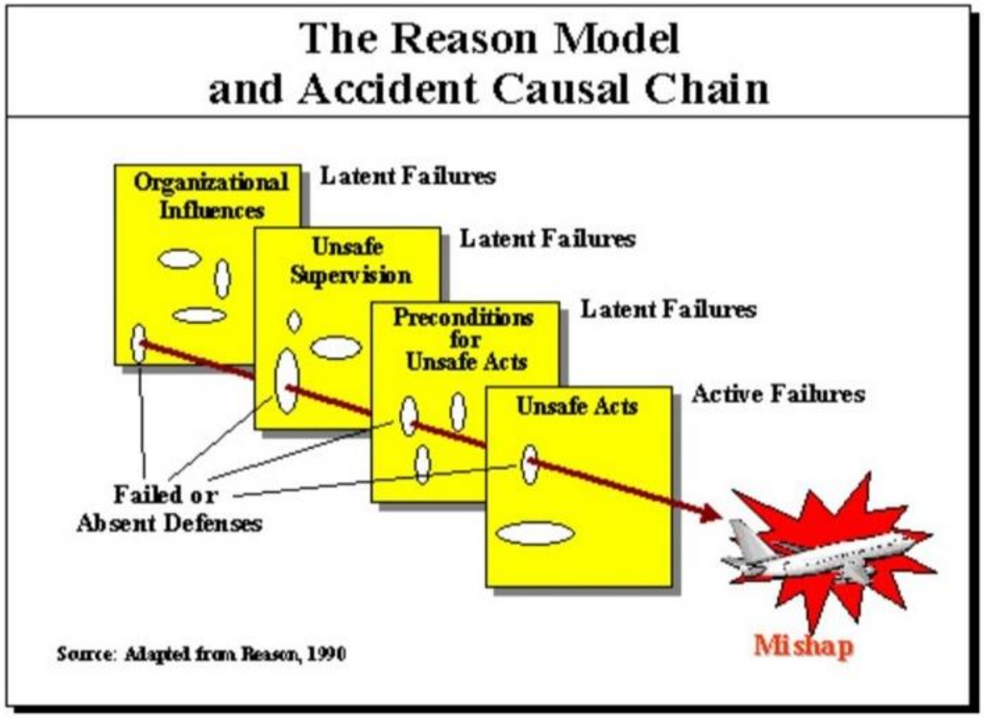

Figure 3. Reason's Swiss Cheese Model of System Accidents

In addition, holes in the defenses arise for two reasons: active failures and latent conditions. In Reason's description, active failures are unsafe acts committed by people, and latent conditions are the inevitable system factors that arise from the decisions made by designers, builders, procedure writers, and top-level management. Latent conditions can promote error-provoking circumstances and create long term holes or weaknesses in the defenses. In this context, latent conditions can be further described as the contents and processes behind a systematic approach when exemplified through an HRO (High Reliability Organization). Constructs and processes such as administrative policies, regulatory factors, economic factors, political environment, human resource management (HRM), procedural manuals, and organizational culture are all latent conditions.

High Reliability Organizations (HRO)

As the context of systems approach focuses more on the organizational aspect of safety, HROs tend to occupy a key position in the barrier of these systems. This is attained via the placement of safeguards and defensive layers, and its primary function is to protect potential victims and assets from hazards (Reason, 1990). Barriers can be physical objects like warnings and alarms, technological safeguards (hardware and software), sensors, and machines. They can also consist of procedures and administrative controls like protocols, manuals, standard practices, and training. Human barriers such as operators, inspectors, and AMTs can also occupy this context. A noticeable redundancy in the barriers is a distinguishing characteristic of an HRO.

The definition of an HRO as stated in Chapter I, is the subset of hazardous organizations that enjoy a record of high safety over long periods of time (Roberts, 1990). To substantiate the airline industry as an HRO, four implementing characteristics of an HRO are claimed: 1) Prioritization of both safety and performance as organizational goals across the organization (La Porte et al., 1991); 2) promotion of a "culture of reliability" in simultaneously decentralized and centralized organization (Weick, 1987); 3) use of organizational learning that maximizes learning from accidents, incidents, and near misses (La Porte, Roberts, & Rochlin, 1991); and 4) extensive use of redundancy (Rochlin et al., 1987).

In reference to these claims, the airline industry has made it pertinent that safety goals are met through daily briefings and statistical data to monitor consensus of its safety objectives. The use of organizational learning is standardly promoted in the airline industry and the use of incident reports as a way to learn from errors is presented on a computer based program. Constant, recurrent training on processes and safety is also distributed and applied to all AMTs. The mode of redundancy can be noticed in the system through human, machine, and policy barriers (e.g. inspectors, AMTs, alarms, back-up system, hardware, training, lock-out and tag-out policy, evacuation procedures). Such safety actions exemplifies the consistency of the airline industry as an HRO.

However, more often than not, safety goals may be in conflict with performance goals unless the sole objective of the organization is to maintain safety (Marais, Dulac, & Leveson, 2004). In the airline industry, technical operations' general prioritization on safety obviously has a clear tie with its performance objective since the safe transport of people is the nature of the business. In a large organization, certain divisions not directly affecting this objective may have lesser coupling with such safety motives. But as this research focuses more on technical operations, it is assumed that all centralized and decentralized divisions under technical operations have an interactive coupling as regards to safety.

Normal Accidents Theory

Charles Perrow's theory of Normal Accidents states the idea that, in some technological systems, accidents are unavoidable or "normal" (Perrow, 1999). In his theory, he defined two related dimensions—interactive complexity and loose/tight coupling—as determinants of a system's susceptibility to accidents.

According to Perrow (1999), Interactive Complexity refers to the interaction of discrete variables present in the systems, making them vulnerable to normal accidents, while a tightly coupled system is one that is highly interdependent. In other words, parts of the system are linked tightly together, and one part's state can affect the status of other parts.

Because of the interactive complexity and the tightly coupling of systems, a "spark" can cause a cascading effect in the systems that makes it hard to mitigate and predict accidents. A spark is a triggering event that sets off a chain of events that can ultimately lead to an accident (Sharit, 2006). Sparks may include disruption in work process, absence of right tooling, a random failure of machinery, and human errors.

Systems

Since systems such as the airline industry consist of networks of human and technical resources, they contain interdependencies between divisions to perform and achieve its goals. As with technical operations, such interactive complexity is robust and the coupling of divisions and technical processes under this umbrella is quite visible. For example, the use of redundancy as barriers in the maintenance base. When an airplane comes in for a heavy maintenance, certain processes takes place: 1) AMTs from different skills areas perform their operational tests; 2) Quality Control coordinates with production control and AMTs on their own tasks; 3) checks and balances are performed depending on the maintenance program and the findings of the inspectors; 4) depending on the repair, engineering orders are attained; and 5) final work may again be inspected and an operational test performed. This is but a very brief generalization of what takes place in the maintenance base.

As for safety barriers and redundancy, work platforms are set up, lock-out/tag-outs are performed in the various aircraft systems, pins and locks are installed, strap barriers are placed, personal protective equipment is used, warning lights are visible, announcements are done, and other safety barriers that promote awareness and control are implemented. To add to the complexity, it is paramount to understand that the safety structure and environment may change depending on the technical process required to do a maintenance task. For example: 1) The airplane can be on jacks, which puts the airplane in a state of elevation;) Engine could be off or removed, which affects the balance; 3) Operational tests are performed wherein airplane surfaces and landing gear will move; 4) APU (Auxiliary Power Unit) is on wherein ignition can cause fire hazard; 5) Pneumatic pressure is introduced to the airplane and hydraulic pressure at 3000psi is utilized; 5) Electrical power may be powered that it introduces voltage throughout the aircraft, and all other intricacies that change the state of the airplane and the environment necessary to perform a task. This may be considered as a normal dynamic for aircraft maintenance. With the changes in the airplane's status and the safety structure, it is imperative that personnel, tasks, barriers, and production flow are coordinated to attain and maintain a safe environment.

Since processes and division are coupled by design to maximize efficiency, it also promotes risks and uncertainty because of this interconnection. In large-scale systems, subsystems are often characterized paradoxically by both autonomy and interdependence (Grabowski & Roberts, 1997). This means that on certain levels, divisions and subsystems operate independently from other systems and are autonomous entities, while other subsystems are interdependent, and rely on coordination to fulfill their role and maintain growth. Because of this autonomy and interdependence, risk mitigation can be difficult; for instance, in the required coordination between different AMT skills during operational checks. Sheet metal repair tasks can initially be independent, but when flight controls are required to be operated either to verify work or to gain added access, all AMT must be notified to clear the airplane and assure safety clearances on the surface's movement and that all work related to the system being operated is a "go” or is safe to operate. This could mean coordination between AMT skills, verification with production control, and clearance from a supervisor.

On a broader scale, interdependencies can be simply a need for engineering support such as a tool or part that is located at a different airport and would require coordination with the supply chain; a grounded plane that would require communications with network operations; or an innovation that needs sponsorship from inter-divisions. In the safety aspect of the coupling of these subsystems, it is clear that complications or intricacies exist in the design of either a spectrum of procedural processes or structural coordination within the organization. Thus, in risk and error mitigation, measures of interdependent systems must consider the effect on both the subsystems and the overall systems, or between autonomous and non-autonomous systems.

Communication

In large scale systems, communication can help make autonomy and interdependence among system members explicit and more understandable, providing opportunities for sense making in a geographically distributed system (Grabowski & Roberts, 1997). This is even more apparent in an airline where the system structure is based on a network model of spokes and hubs, thus making certain systems independent and others interdependent. With a concise communications structure in a large system, roles are more clarified, responsibilities are structured, and relationships of couplings are understood. Even though the description of organizational structure and roles are indicated formally in policies and procedures, through communication can it only be exampled and provide social proofing of these roles. With the right communications, the development of culture and shared values are readily promoted, thus presenting a more profound mental model among its members.

CHAPTER IV

CULTURAL APPROACH

In a large organization, communication can be further developed through culture. Strong culture can help reinforce the focus of safety and reliability. Attention to policies and procedures becomes standard to the organization that promotes mitigation of risks as part of its mission and goals. Culture becomes part of the barrier in the protection of systems and a controlling factor in the coupling of subsystems. To be effective, risk mitigation measures in large-scale systems need to address the cultural needs of systems (Grabowski & Roberts, 1997).

Due to the technical environment in which they are situated, AMTs are expected to have discretion in decision making and only through cultural norms that the organization's goal of safety, can a comprehensible message be sent to its work force. Through the empowerment of choices and discretion given to an AMT, norms will act as a catalyst for safety awareness and promote reliability on the task being accomplished.

Richter and Koch (2004) define safety culture as "the shared and learned meanings, experiences, and interpretations of work and safety, expressed partially symbolically, which guide people's actions toward risks, accidents, and prevention (p.705)." Some scholars pointed out that culture can be integrated into an organization, meaning that culture can be injected to shape the way of thinking and behavior of the organization. Indeed, this perspective can be utilized in the earlier stages of an organization, during which values and norms are still being formed and explicitly formulated. However, in a more mature organization, safety culture is often more or less differentiated (Gherardi, Nicolini, & Odella, 1998). In *differentiation*, this perspective focuses on the lack of consensus and the formation of subcultures. It may result from a wide range of influences, both external and internal, such as differences in power, leadership, gender, groups, tasks, experience, spatial layout, and knowledge (Atak & Kingma, 2010). Another perspective presented in application to safety culture is *fragmentation* (Martin, 2002). Fragmentation presents ambiguity and lack of concise settings or changing meanings in an organization.

The three perspectives of safety culture—integration, differentiation, and fragmentation—each present a unique point of view to help reveal an objective effort on safety culture. It was also identified that the three perspectives can coexist, but the balance is often unequal (Richter & Koch, 2004). In a later analysis by Richter and Koch, they found that integration in the safety culture was rather weak, whereas differentiation and ambiguity were much stronger. By this argument, I will use the differentiation perspective to explicitly relate this point of view to an AMT.

AMT Subculture

As previously indicated, the differentiation perspective focuses on the lack of consensus and the existence of subculture. In the U.S. airline industry, certain workgroups and frontline personnel are represented by labor unions; this is the case as well with aircraft maintenance technicians. Labor unions in the AMT work group may present the opportunity for the creation of an independent viewpoint that, when accepted by consensus, becomes norms and values leading to the formation of a subculture. Through the differentiation perspective, the characteristics of the subculture can be relative to the group's reaction from influences, power distance, leadership, experience, and knowledge. These cultural antecedents are not covered in this review, but is a good topic for additional research to learn its effect in the organizational culture as regards to safety.

AMTs are unionized in the major U.S. airlines and in effect can form their own shared understanding of norms and values. AMTs can form a strong professional subculture, which can be relatively be independent of the organization. According to McDonald and colleagues (2000), this professional subculture mediates the effect of the organizational safety system on normal operational practice. The subculture can influence the acceptability of risk, the attitude toward accidents, and preventive measures taken into consideration by the work group (Atak & Kingma, 2003).

The Federal Aviation Administration (FAA) has endorsed the use of ASAP (Aviation Safety Action Program) that encourages AMTs to voluntarily report safety information that may be critical to identifying potential precursors to accidents. Under ASAP, safety issues are resolved through corrective action rather than through punishment or discipline and provides a degree of protection to the reporting party. Currently, all of the major U.S. airlines are participating in this program.

Although the program promotes error reporting and proactive intervention, the willingness to report errors can vary depending on the perception of workers toward the openness of leaders and the characteristics of the organization (Edmondson, 1996). For instance, hierarchical characteristics of an organization may impede the capacity of employees to engage in desirable and compliant behaviors (Hinrichs & Hinrichs, 2014). In addition, detection of error may vary in such a way that teams that need the most improvement in production are also less likely to report errors, a dilemma for the safety management goal of safety reporting and detection. Another hurdle can be the level of trust that AMTs perceive in the organization. The ASAP program can only be effective with the support of the sub-culture and consensus of its population. Thus, finding the organizational characteristics that would deprive or promote ASAP in prevalence to the sub-culture is necessary. For example, embedding a "no fault" mentality when it comes to error reporting can further diminish doubt in the consensus. Even as far as placing rewards system for reporting errors may be a good practice to embed ASAP in the sub-culture.

Humans can act as barriers in the system. Since humans themselves can act as detectors and can self-correct certain errors, the subculture can be an imperative goal for management to assess and inject a form of social control into the subculture. However, since such groups are highly independent from the organization, social control can manifest unwanted reactions from the AMT. Therefore, it would be good to further practice a collaborative effort instead; by exercising safety engagement, communication, and informational tools to demonstrate the importance of safety to the workgroup. As mentioned, differentiation is a needed factor in safety culture. Social proofing from leaders in terms of a pro-active decision making in reaction to employee error, may initiate such differentiation.

CHAPTER V

AUTHORITY OF AN AIRCRAFT MAINTENANCE TECHNICIAN

The "Irony of Maintenance," is that an increased frequency in schedule of maintenance may actually increase system risk by providing more opportunities for human interaction with the system (Reason, 1997). This statement infers that human interaction is unpreventable in aircraft maintenance and that periodic maintenance is necessary to maintain a safe and reliable aircraft. But, as discussed in Chapter II, since human fallibility will never disappear and will always be part of organizational life, an emphasis on an AMT's scope of control and awareness can lead to understanding of the value of its authority. An AMT's authority not only affects the core safety of the business, but also the reliability and efficiency of the operations.

The processes and design of procedures behind an AMT's task is an integral part in complex high-risk systems to ensure effectiveness and the mitigation of risk. Procedures also represent a guide to policies and regulations to attain standard compliance in accordance with different government regulatory policies. The design of these procedures, like those written in the AMM (Aircraft Maintenance Manual) are congruent to the characteristics of an HRO, of instilling redundancy in the system (Rochlin et al., 1987). In contrast, as the "Irony of Maintenance" suggests, many of these procedures require human interaction, which creates susceptibility to errors. These could include identifying the wrong component, application of wrong force, and omitting steps. These errors leads us back to “The Dirty Dozen,” the human factors related to such interactions in maintenance.

The necessity of maintenance in an aircraft can also be pervasive and incline their users to errors (Drury, 1998). Certain procedures may not take into account the dynamic changes that can occur in the maintenance environment, such as the changing state of aircraft in contrast to production scheduling. For example, aircraft power is turned on, but production control issued a task that cannot be safely performed with power turned on. In this situation, it is the AMT’s prerogative to analyze the situation and decide how to proceed.

AMT License

The FAA recognizes two ratings for an aircraft mechanic, an airframe and a power plant rating. A mechanic who holds an airframe and powerplant rating may approve and return to service an aircraft or any related part after he or she has performed, supervised, or inspected minor repairs or alterations. He or she may also perform the maintenance actions required for a major repair or alteration. He or she may perform and return to service minor repairs or alterations which is part of the Code of Federal Regulations.

An airline mechanic holds both an airframe and a power plant license and is the sole authority and signatory for any repair and alteration performed on an airplane. An AMT’s scope of control is broad when it comes to aircraft maintenance. Therefore, it is crucial for management to realize how an AMT’s role can promote efficiency and productivity without compromising safety. Hobbs (2003) emphasized the importance of mental readiness so that maintenance workers can defend themselves against errors such as interruptions, time pressures, miscommunication, and unfamiliar situations. Therefore, problems that may have been created by procedural design or management policies can be mitigated by a proactive approach by minimizing, detecting, and recovering errors. This can be emphasized via an AMT's management of task activities under uncertainty and time constraints.

Authority in Situational Awareness

Assessing the current state of the aircraft requires a level of situational awareness to better process and coordinate information and variables to properly interpret the task at hand. Formally defined, "situational awareness is the detection of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988, p. 97). For an AMT, this means being aware of the state of the aircraft and its systems and understanding the relativity of the system being repaired to the other systems, since the status of the other systems can affect the state of the system being worked on or dictate the requirements necessary to perform the task. For example, a task to perform work on a flight surface such an elevator can require the activation or deactivation of the hydraulic system and the tagging or untagging of circuit breakers for power. In this example, the identification of the current state of the other systems could either be a task requirement or a safety requirement. Since a task can be relative to other systems, it has implications on both performance and safety for the airplane and the AMT.

An AMT's situational awareness can present an internalized mental model of the current maintenance environment of the aircraft. The levels of situational awareness indicated by Endsley (1999) propose different safety barriers in accordance to the changing dynamics of the aircraft in maintenance, thereby making an AMT's perception of the environment crucial in decision making and mitigation of risks. In this statement, the assumption is that the AMT can make better decisions by demonstrating situational awareness in the assessment of the current and future status of the aircraft.

Endsley (1999) indicated three levels of situational awareness. Level 1 is *perception of the elements in the environment;* Level 2 is c*omprehension of the current situation;* and Level 3 is *projection of future status.* In Level 1, an AMT needs to perceive the current status of the aircraft and its relevant systems or components in the environment. For instance, the aircraft may be on jacks, or having power in the airplane. In Level 2, an AMT needs to know the relevance of these elements in to his tasks or goals. This can be an indication of what tools to use, what safety barriers are required, and what technical information is necessary. From the earlier situation of the airplane being on jacks, we can further relay an example of the importance of knowing the elements. Concluding questions could be, would the repair of the elevator be possible if the aircraft is on jacks? Do I need electrical power to perform the job? Is it safe to use a mechanical lift to reach the elevator? From the perspective of the AMT, assessment is crucial to understand the current situation in order to make the right decision and reaction to a potential safety hazard. Level 2 also requires comprehension of events. For example, if hydraulic pressure is introduced in the aircraft, the AMT must determine whether the elevator is still compliant to its task or did that situation change the parameters required to perform the task or repair? Another question the AMT needs to ask is, is it still safe to perform the task? In Level 3, an AMT must maintain the ability to project future actions, at least in the near term. This constitutes an analysis of cause and effect applied to different scenarios. Then by comprehending such scenarios, the AMT can better plan a form of action and gain a mental conditioning toward a possible event.

Accordingly, situational awareness largely drives people's decision making and performance (Endsley, 1995). This can be more apparent in a dynamic system wherein the environment and elements of the aircraft are constantly changing. An AMT's situational awareness can impact not only the efficiency in the performance of the task but also as a safety barrier in the system. By this application, the AMT's decision making is based on an analytical assessment that incorporates real-time information (of aircraft), adequate understanding of possible events, and differentiating alternatives of future action, an argument that proposes the mitigation of risks and coping with uncertainties (Lipshitz & Strauss, 1997)

Authority in Information and Communication

An effective level of communication is crucial for safety in maintenance operations. In the maintenance base, where maintenance programs can last more than a month, continuity of tasks and goals can occur between multiple shifts. Therefore, the transfer of information such as safety, parts and tooling, technical procedures, and any pertinent information to be able to continue the task is important. This interaction or turn over reporting however, can be a cause of obtaining incomplete information. A breakdown in communication can occur that results in the lack of information or the gathering of wrong information. The significance of such information may mean the difference required to ensure the safety and reliability of the task and repair, and as such can reduce uncertainty and mitigate risks, since most accidents are related to breakdowns in coordination, communication, and decision making (Sexton, Thomas & Helmreich, 2000).

Smithson (1989) suggests that one prescription in reducing uncertainty is to reduce ignorance as much as possible by gaining full information and understanding. A noteworthy point of this statement is that it satisfies the conditional levels of situational awareness in which information is a discerning factor to promote a complete comprehension of elements in the environment and as a variable for mental preparedness. It also relates back to one of dirty dozen mentioned in Chapter II - lack of communication.

Authority in Autonomy

As a decision maker in the scope of aircraft maintenance, and responsible for both safety of himself and the aircraft, an AMT is subject to its own autonomy. Although organizational and federal policies demand a certain compliance of the AMT, the process by which the AMT performs his tasks is created by his own framework. Meaning, as an AMT performs a task by following procedural manuals (such as the Aircraft Maintenance Manual), the structure in which an AMT performs the tasks is self-managed. Examples include the obtaining or fabrication of tools, verification of parts, the setting of safety barriers, and the gathering and communication of information. In a dynamic setting such as the maintenance of aircraft, the structure could require changing and further assessment as needed. As such, the framework also sets the boundaries in the AMT’s management of time, information assessment, and safety decisions.

This self-governing nature of an AMT’s job is consistent with the commitment approach characterized by Bamber et al (2009), which involves more teamwork and cross-functional coordination, higher level of employee discretion, and more flexible job boundaries. It also promotes self-determination which describes how people prefer to feel they have control over their actions, so anything that makes a previously enjoyed task feel more like an obligation than a freely chosen activity will undermine motivation (Robbins & Judge, 2014). In a unionized work group such as that of the AMT, where autonomy is a requirement not just for the promotion of morale but also as a variable for efficiency, this perspective further explains that motivation can have an effect on an AMT’s framework. That is, the management of time, information assessment, and safety decisions.

An AMT’s autonomy may be necessary not only in the causality of its authority in the aircraft but also in the context of promoting an efficient framework of an AMT’s safety and work objective. Management should understand the benefits of an AMT’s decentralized decision-making environment and promote a commitment approach that allows an AMT’s discretion to execute his job as necessary. Airline safety managers should accept and implement empowerment strategies and explore ways to support an AMT’s self-efficacy. Chapter VI discusses and summarizes the literature on airline maintenance safety and what practicing safety managers can take away from this review.

CHAPTER VI

DISCUSSION

Safety risks and uncertainties play a major role in the airline industry. It is a variable that is unpreventable due to the nature of aircraft maintenance to assure air worthiness. Although certain compliance is regulated by the FAA (Federal Aviation Administration) and corporate policies, the AMT is an authority in the mitigation of risks and a major actor in the aircraft maintenance safety barrier. The variables of safety indicated from different approaches described in previous chapters has provided a small peek to an AMT's world of aircraft maintenance. The human approach, which discusses the human fallibility and susceptibility of an AMT to error, gave the perspective of its causes and outcomes via the "Dirty Dozen." The system approach explained how the interactive complexities in an organization can promote error and confusion for an AMT. The cultural approach described how a unionized work force like the AMTs of the U.S. airline industry can create subcultures and become independent from organizational objectives. The AMT's authority in decision making promoted situational awareness as a means of coping with uncertainties.

However, the different approaches solicit an ambiguous view in terms of understanding what kind of safety governance is the most applicable in aircraft maintenance, since the perspective of each approach warrants a beneficial form of information toward progression. Independently, each approach can be utilized as a tool for safety governance in aircraft maintenance. Coincidentally though, it can propose a conflicting perspective, especially for management. For example, if human fallibility is unpreventable, then an AMT's authority in autonomy sets a contradictory statement. It would make more sense to prevent human fallibility by relinquishing employee autonomy. The formation of subcultures in the AMT work group can also form difficulties in regards to re-organization of large scale systems, since subcultures can form a very independent objective that may not be aligned with the new organizational goals.

The airline industry exists in a dynamic environment that is occupied by human, social, and systematic variables. Thus, all aspects of these variables or approaches must be taken into consideration as both independent and co-existential in the airline maintenance environment. Therefore, a more interdisciplinary sharing between different literary studies on safety and aviation maintenance is needed. The cross-utilization of all safety approaches and applicable salient literature can set a standard guide toward a more focused and productive safety governance. The lack thereof can have adverse safety consequences.

Although this paper argues the importance of these approaches as a summation of a better safety governance in aircraft maintenance, the focus of this paper is more in the identification or understanding of causal factors that motivate and influence an AMT's safety objective. Realizing the importance of this work group in the context of safety and reliability can better enable managers to conceptualize strategies driven by a commitment or partnership approach toward safety goals.

Analogy of an Electrical Circuit

An electrical circuit requires three simple components. The first component, is the battery or “Source Side” of power. This component can vary in voltage and frequency. It is important to keep in mind that power from this component can have different degrees of influence toward the other components. The second component is the switch or the “Control Side,” which regulates power. In this component, power or influence from the “Source Side” is either permitted or not permitted to pass through, or is regulated in terms of varying demand. The third component is the resistor or the “Load Side,” which draws power. The output is the control and the regulated power that was decided by the “Control Side.” This very simple analogy or narrative can represent the stressors and values that surround an AMT and lead to further understanding of how its authority can mitigate risks and promote safety in a maintenance environment.

Figure 3 presents a modeling framework demonstrating this analogy. The first component, the “Source Side, represents our different safety approaches toward *systems, culture, and human fallibility.* In turn, these approaches are influenced by organizational values and organizational culture. Values and culture influence how *systems* are structured. The formation of the *subculture* is also adherent to its reaction toward the organization’s values. And while *human fallibility* is part of organizational life, its degree of attribution to an AMT is in reference to the values of the organization. Meaning, the contributing factors (the “Dirty Dozen”) are only injected into the organization in levels that are accepted by its values. The safety approaches are constant conditions that an AMT experiences in his work environment. They may or may not influence its perception on safety, mitigation of risks, and tasks compliance.

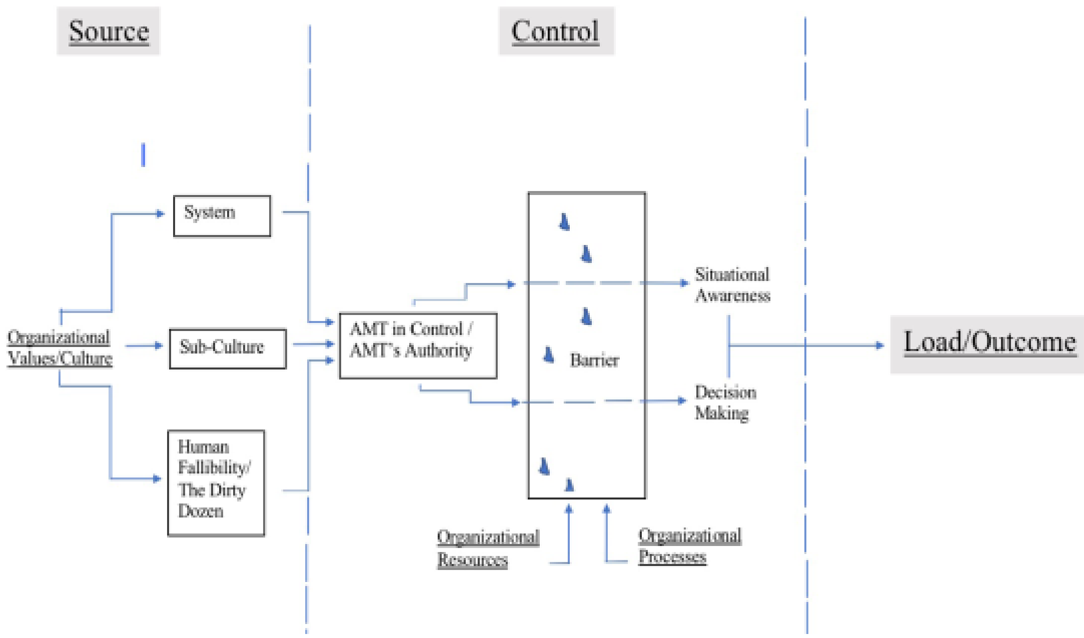

Figure 4. Analogy of an Electrical Circuit-AMT Error Framework.
Source: Bermudez (2017)

The second component, "Control Side," represents an important aspect of the safety barrier, the AMT. Simply put, the AMT is at work and making decisions regarding the task at hand. By exercising the authorities stated in Chapter V, the AMT is forming his framework on the management of time, information assessment, and safety decisions. This acts like a switch in the electrical circuit, wherein the AMT decides what factors from the source side will influence his framework. This is the scope of control for an AMT, and the authority of its governance. The task at hand as set forth in a procedural manual (the Aircraft Maintenance Manual), is understood and analyzed by the AMT in pursuit of completing the tasks. Whereby the mitigation of risks is exercised and decided by the AMT.

Barriers also occupy this component. This is attained via the placement of safeguards and defensive layers, and its primary function is to protect potential victims and assets from hazards (Reason, 1990). Barriers can be physical objects like warnings and alarms, technological safeguards (hardware and software), sensors, and machines. They can also consist of procedures and administrative controls like protocols, manuals, standard practices, and training. Barriers can be influenced by both organizational resources and organizational processes since barriers can be assets in terms of equipment and training. In Reason's (1990) Swiss cheese model of system accidents, safeguards and barriers are intact in an ideal world. But when the holes in the many layers momentarily line up, it permits a trajectory toward accidents. In relation to an AMT, as he proceeds in his tasks, these organizational barriers exist with the assumption that the "layered Swiss cheese" is closing and opening. Because of the closing and opening of the holes, an AMT's situational awareness is essential in the understanding and assessment of the current elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future (Endsley, 1988). Situational awareness must be present at all times on the "Control Side," before, during, and after the safety barrier; although again, the "Source Side" can alter and influence the AMT's perception. The third and final component, the "Load Side," is the product of the source and the control side. It is the result of the decision making of the AMT. He or she can either decide to not start the task, proceed with the task, or pause while in the task. In the context of our analogy, the AMT can either switch off the electrical circuit, regulate the electrical circuit, or continue introducing the power to the "load," with the primary objective of being safety and risk mitigation.

A general view of this error framework brings forward the responsibility and importance of the AMT in both safety and reliability of the airline fleets. The direct correlation of safety to operational efficiency and performance goals cannot be emphasized enough. With the airlines' objective of profits via the safe transport of people comes the necessity of fleet reliability. Safety and reliability needed for efficiency will drive the competitiveness of any airline. On-time departure and arrival is, after all, driven to a large degree by aircraft maintenance.

The AMT's scope of control and authority in the maintenance processes of an airline technical operations department are crucial in this fleet reliability and safety. AMTs serves as champions of safety and maintains responsibility and accountability of its own person and the aircraft. Although considered as a human barrier, the AMT is susceptible to fallibility, organizational culture, and organizational systems. Hence, understanding the factors that contribute to the safety role of an AMT is essential, and providing support or development of the AMT toward the mitigation of risk must be practiced. The different safety approach described in this paper, gives a point of view on how such factors can affect the environment and the framework that the AMT is residing on. It then pursues how such factors may influence the decision making of an

AMT. Thus by further utilizing such approaches, we can better understand its causality and help form a sound management decision in supporting, motivating, and advancing the Aircraft Maintenance Technician's work objective towards the organization's maintenance and safety goals.

REFERENCES

REFERENCES

Atak, A., & Kingma, S. (2011). Safety culture in an aircraft maintenance organisation: A view from the inside. *Safety science*, 49(2), 268-278.

Bamber, G., Gittell, J., Kochan, T., and Nordenflycht, A. (2009a), *Up in the Air: How Airlines Can Improve Performance by Engaging Their Employees,* Ithaca, NY: Cornell University ILR Press.

Drury, C. G. (1998). Case study: Error rates and paperwork design. *Applied Ergonomics*, *29*(3), 213-216.

Dupont, G. (1997, March). The dirty dozen errors in maintenance. In The 11th symposium on human factors in maintenance and inspection: *Human error in aviation maintenance.*

Edmondson, A. C. (1996). Learning from mistakes is easier said than done: Group and organizational influences on the detection and correction of human error. *The Journal of Applied Behavioral Science, 32*(1), 5-28.

Endsley, M. R. (1988). Design and evaluation for situation awareness enhancement. In Proceedings of the Human Factors Society annual meeting (Vol. 32, No. 2, pp. 97-101). Sage CA: Los Angeles, CA: SAGE Publications.

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. Human factors, 37(1), 32-64.

Endsley, M. R. (1999). Situation awareness and human error: Designing to support human performance. In Proceedings of the high consequence systems surety conference (pp. 2-9).

Fisk, A. D., Ackerman, P. L., & Schneider, W. (1987). Automatic and controlled processing theory and its applications to human factors problems. *Advances in Psychology*, *47*, 159-197.

Grabowski, M., & Roberts, K. (1997). Risk mitigation in large-scale systems: Lessons from high reliability organizations. *California Management Review, 39*(4), 152-162.

Gherardi, S., Nicolini, D., & Odella, F. (1998). Toward a social understanding of how people learn in organizations: The notion of situated curriculum. *Management Learning*, *29*(3), 273-297.

Hawkins, F. H., & Orlady, H. W. (1993). *Human factors in flight.*

Heinrich, H. W. (1941). Industrial accident prevention: A scientific approach. *Industrial Accident Prevention. A Scientific Approach,* (Second Edition).

Hinrichs, K. T., & Hinrichs, A. T. (2014). Comparing followers and subordinates: Accounting for the effects of organizational hierarchy. *Followership: What is it and what do people follow*, 89-105.

Hobbs, A. & Williamson, A. (2003). Associations between errors and contributing factors in aircraft maintenance. *Human Factors*, *45*(2), 186-201.

La Porte, T. R., Roberts, K., & Rochlin, G. (1987). High reliability organizations: The research challenge. Revision of La Porte, T. R. High reliability organizations:

The problem and its research dimensions. Institute of Governmental Studies. University of California at Berkeley, Working Paper.

Lipshitz, R., & Strauss, O. (1997). Coping with uncertainty: A naturalistic decision-making analysis. *Organizational behavior and human decision processes, 69(2),* 149-163.

Marais, K., Dulac, N., & Leveson, N. (2004, March). Beyond normal accidents and high reliability organizations: The need for an alternative approach to safety in complex systems. *In Engineering Systems Division Symposium (pp. 1-16).*

Martin, J., 2002. Organizational Culture. Mapping the Terrain. Sage, Thousand Oaks, London.

Marx, D. A., & Graeber, R. C. (1994). Human errors in aircraft maintenance. Aviation psychology in practice (A 96-10209 01-53), Aldershot, United Kingdom, Avebury Technical, 1994,, 87-104.

McDonald, N., Corrigan, S., Daly, C., & Cromie, S. (2000). Safety management systems and safety culture in aircraft maintenance organisations. *Safety Science, 34*(1), 151-176.

Perrow, C. (1999). Normal accidents, updated edition. Princeton University Press

Reason, J. (1990). Human error. Cambridge university press.

Reason, J., & Hobbs, A. (2003). Managing Maintenance Error: A Practical Guide.

Richter, A., & Koch, C. (2004). Integration, differentiation and ambiguity in safety cultures. *Safety Science, 42*(8), 703-722.

Robbins, S. P., & Judge, T. (2013). *Organizational behavior.*

Roberts, K. H. (1990). Some characteristics of one type of high reliability organization. Organization Science, 1(2), 160-176.

Rochlin, Gene I., La Porte, Todd R., and Roberts, Karlene H. The Self-Designing High Reliability Organization. Naval War College Review, Autumn, 1987.

Schacter, D. L. (2011). Psychology Second Edition, 41 Madison Avenue, New York, NY 10010.

Sexton, J. B., Thomas, E. J., & Helmreich, R. L. (2000). Error, stress, and teamwork in medicine and aviation: Cross sectional surveys. *Bmj, 320*(7237), 745-749.

Sharit, J. (2006). Human error. *Handbook of human factors and ergonomics, Third Edition*, 708-760.

Smithson, M. (2008). The many faces and masks of uncertainty. *Uncertainty and risk: Multidisciplinary perspectives*, 13-25.

Weick, K. E. (1987). Organizational culture as a source of high reliability. *California Management Review, 29*(2), 112-127.

Weick, K., & Sutcliffe, K. (2001). Managing the unexpected: Assuring high performance in an age of uncertainty. San Francisco: Wiley, 1(3), 5.

Wickens, C. D., Gordon, S. E., Liu, Y., & Lee, J. (1998). An introduction to human factors engineering.

Wiegmann, D. A., & Shappell, S. A. (2001). Human error analysis of commercial aviation accidents: Application of the Human Factors Analysis and Classification System (HFACS). *Aviation, Space, and Environmental Medicine, 72*(11), 1006-1016.