JUST CULTURE: A STUDY ON HOW TO IMPROVE RISK MITIGATION BY APPLYING A JUST CULTURE IN AN AIRLINE LINE-MAINTENANCE ENVIORNMENT

by

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This Capstone Project was prepared and approved under the direction of the Group's Capstone Project Chair, Dr. Leila Halawi
It was submitted to Embry-Riddle Aeronautical University in partial fulfillment of the requirements for the Aviation Management Certificate Program

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Abstract

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This research aims at improving the risk management of line-maintenance department in a major airline in South America. The method was to tackle three fronts. One is the promotion of a just culture to create a reflective environment and the ability to identify organizational factors. This promotion is done by means of a course dedicated to the subject targeting management positions. The second front was to design a form that would give a proper channel for line-maintenance technicians to voice their concerns in a confidential way. Lastly, the third front was the definition of Safety Performance Indicators that will organize the risks reported. All these fronts are part of a more harmonic integration of the maintenance department with the safety department. Although the research was directed at afore mentioned company, the concepts here are universal enough to be applied to many fields, especially complex socio-technical systems.

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Chapter I

Introduction

This research is dedicated to mitigating maintenance-related safety events in a South American company, where all the researchers are currently employed. Due to the confidentiality agreement (Appendix A), the researchers were granted permission to disclose data about events and pertinent information as long as the company's name is not revealed. Therefore, the company will be referred to as Company 1.

Maintenance interventions are operational necessities during the whole life cycle of any aircraft. Maintenance is crucial for ensuring continued airworthiness due to the natural airframe wear as well as aircraft engines and is considered vital for aircraft safety purposes (McDonald, Corrigan, Daly, & Cromie, 2000). Maintenance errors can cause catastrophic events; therefore, their risks must be mitigated. A couple of examples of maintenance direct contribution to catastrophic events are the accidents of Air Midwest 5481 in 2003 (Hobbs, 2008) and Air Alaska 261 (NTSB, 2002).

There are also examples of affirmative maintenance actions that contribute to safety, such as a recent event at Company 1. A maintenance technician, after spotting ice on the aircraft, convinced the captain that it was not safe to depart. Such episode is being shared during Corporate Resources Management (CRM) recurrent training and as well as the compliment made by the captain to the technician.

However, from the researchers' observations, there has been a strong bias by the industry towards focusing on the pilots as the ones ultimately responsible for the safety of a flight. One example of this is Company 1's Safety department structure: there are thirty-five pilots and only one maintenance representative even though there are about one thousand and eight hundred pilots and one thousand and three hundred maintenance technicians in accordance with the company's learning management system database. Another aspect that illustrates the bias towards the pilots is the evolution of CRM. It started as a methodology for the captain to manage the resources, progressed into several levels that branched out to the rest of the company, including maintenance professionals (Helmreich, Merritt, & Wilhelm, 1999).

Safety departments usually have many pilots, but not enough representatives of the other areas, such as maintenance experts. This causes a significant difference between how Flight Operations tackle safety and how a Maintenance department does. At Company 1, this gap between technicians opposed to pilots in the Safety department can be observed by an outdated safety culture, lack of efficient maintenance safety reporting tools as well as a lack of organized safety data related to maintenance. Company 1 has recently had a few maintenance-driven events that have forced the Maintenance department to seek improvements in order to avoid and prevent future cases effectively. There was one event during unscheduled maintenance which required an engine run-up procedure. This event happened at a remote base where the maintenance technician, although trained on the procedure, was not current and such run-up test ended in an engine severely damaged. The cost for the company was at least USD 1.2 million. This value is just for the engine repair and does not account for the man-hour expenses to replace the engine, crew re-positioning, aircraft productivity loss and other additional factors.

Research Definition

The researchers are closely associated with and perform routine activities involving the Maintenance department. These activities involve:

- Managing the training (initial and recurrent) of maintenance technicians as well as elaborating and writing training curricula;
- Identifying human and organizational factors that involve maintenance;
- Investigating maintenance-related safety issues;
- Managing maintenance engineering and assuring airworthiness; and
- Managing internal cost demands.

This direct contact with the Maintenance department gives the researchers a unique view of the issues related to maintenance from a safety, management and shop floor levels of perception. From a safety point of view, Company 1's Safety department has detected an increase in maintenance related events and their severities while carrying event investigations. For example, there has been an engine cowling that separated from an aircraft engine during take-off, and on another event, a screwdriver was left inside an engine. Both of these events caused operational delays, indirect costs due to repairs and customer relocation as well as decreasing the safety margins, thus impacting the company's maintenance team reputation. According to Schmidt, Lawson, & Figlock (2015), these maintenance events can produce serious incidents or accidents, and 15% of airlines mishaps are caused by maintenance errors and cost over a USD 1,000,000,000 per year. At Company 1, a flight canceled can cause USD 10,000 just in customer compensation (hotel, meal, and transportation) on a half-full 118-passenger seat aircraft.

Apart from the costs, these events can have catastrophic outcomes similar to Air Midwest 5481 and Air Alaska 261, where everybody onboard were killed.

These unexpected expenses and reduced margins have caught the attention of Maintenance mid and high-level management. In addition to these events, the feedback from front-line level employees received during recurrent training indicates a lack of morale, a sensation of no support from leadership, blame culture, a perception of promotion not based on merit and a general perception of abandonment. This perception of abandonment comes from seeing other employees such as pilots who have dedicated safety reports, a strong just-culture from their leadership and management support.

Since there are no specific safety reporting tools for maintenance, other than an all-purpose form known as RELPREV, it is hard for the Safety department to produce meaningful safety performance indicators, especially with only one maintenance official. Therefore, Maintenance management does not have efficient safety data and statistics to work with.

To mitigate these errors, there should be proactive safety culture based on the principles of just culture as well as reliable information about events and errors by cultivating a robust safety database and useful safety performance indicators of the airline maintenance departments.

This research seeks to guide Company 1's Maintenance management staff in improving these safety records as well as reducing unnecessary operational costs. Although this research is directed at Company 1, the proposed roadmap can be applied to other organizations with a few adjustments due to the underlying principles being based on the proven concepts of ICAO DOC 9859, Human Factors Analysis and Classification System, and just culture. The two quintessential questions that need to be answered are:

1. How to create an efficient maintenance report form that will build a database robust enough to produce representative safety performance indicators related to maintenance activities?
2. How to create a just culture environment that will mature the safety attitude of the people involved within all levels of the maintenance system?

Research Goals and Scope

At Company 1, Maintenance management staff needs a roadmap and toolset to be able to answer the research questions. The researchers firmly believe that there is a need for an effective maintenance safety standard system together with a robust structure and position of the Quality Assurance and Safety departments. In addition to that, Maintenance management should have a clear understanding and alignment with both the safety standards and the operational and commercial interests. In this way, this research proposes a just culture framework to facilitate the alignment of both safety and production of a Maintenance department in a commercial aviation company.

The purpose of this research is to create a roadmap to improve Company 1's Maintenance safety culture by using the four components of a Safety Management System (SMS) as defined by ICAO DOC 9859:

- Safety Policy/ Objectives
- Safety Risk Management
- Safety Assurance

- Safety Promotion

This research will clearly deliver: (1) a new risk management report for line-maintenance technicians to fill out, (2) a recommendation of safety performance indicators for safety assurance that will come as the result of the report, and (3) a training roadmap program for safety promotion.

This research will promote the understanding of the just culture concept and applicability in a maintenance department. The status of a safety culture of a company can be improved after using the deliverables proposed in this research, primarily due to the event reporting form and the indicators that can be produced with that data.

Maintenance managers, as the major stakeholders, will be able to compare the results and make the changes directly connected with an improved organizational environment.

Definitions of Terms

JUST CULTURE	A general term used to reference the balance between learning from mistakes and the accountability for their outcomes.

List of Acronyms

ADDIE	Analysis, Design, Development, Implementation, Evaluation
AQD	Aviation Query Database
CRM	Corporate Resources Management
FAA ASRS	Federal Aviation Administration Aviation Safety Reporting System
FDM	Flight Data Monitoring

FOQA	Flight Operations Quality Assurance
FRMS	Fatigue Risk Management System
HFACS	Human Factors Analysis and Classification System
ICAO	International Civil Aviation Organization
LOSA	Line Observation Safety Audit
MCC	Maintenance Control Center
MEL	Minimum Equipment List
MIS	Maintenance Information System
RELPREV	RELatório de PREVenção (Safety Prevention Report)
SMS	Safety Management System
SPI	Safety Performance Indicators
TLB	Technical Log Book

Chapter II

Review of the Relevant Literature

As mentioned in the introduction, two issues need attending: an efficient safety reporting system that provides a tool that can help maintenance technicians voice their safety-related concerns and provide useful safety performance indicators for management, and the building of a robust safety culture across all maintenance levels. These are two challenging goals and aviation, being a highly regulated industry, has rough guidelines for research like this one. This literature review will cover what safety culture and just culture are essentially about, provide foundations for which to develop maintenance directed safety reporting forms, what safety indicators are to be extracted from the form and the tracking of this data. It will also cover the ADDIE methodology chosen by the researchers for the development of a just culture training program.

The researchers believe that the topics of Safety Culture, Maintenance Safety Culture, Just Culture, Complex Systems, New View of Human Error, Safety Reporting and Safety Performance Indicators, and Training and Delivery are parts of creating more robust risk management in maintenance. These topics will be discussed in more depth in this Chapter.

As discussed below, aviation is a complex system. To have a healthy safety culture, it needs a strong reporting system that generates robust SPIs. In the researchers' understanding, this helps comprehend how unexpected factors affect the system as a whole. In order to create an open environment for reporting, the organization needs to practice and understand what a just culture is. This process is clearer when the organization, and especially managers, are introduced to the new view of human error.

However, the safety culture in Company 1's Maintenance department needs to be understood to map the points of improvements and strengths, and tailor a successful reporting form, SPI and a training program.

Safety Culture

In order to promote a strong safety culture, the definitions of what safety and just culture are, need to be clear. The guidelines to build, run and improve a safety management system are written in the Safety Management Manual and referred to as ICAO DOC 9859. Given the safety-related reformative purpose of this research, the foundation of the required measures comes from this manual. The most critical aspects in this manual for the advancement of Company 1's maintenance safety management are safety culture, safety performance management, and safety data collection. Since it is a very technical book that is tested and established, there are few weaknesses to the propositions, most of which manifest due to the particularities of the institution that is attempting to apply the guidelines from the manual.

ICAO DOC 9859 (2018) identifies a safety culture as being "how people behave in relation to safety and risk when no one is watching" (p. 3-1). The definition is expressing that the values of the people involved make up a culture. It is difficult to efficiently define what culture and precisely, what safety culture is. Carsten Busch synthesizes the two most prominent approaches: functionalist and interpretive (Safety Myth 101). From a functionalist approach, the culture is made top-down to serve the company's strategic objectives (Glendon & Stanton, 2000). Glendon and Stanton (2000) further explain that the interpretive approach indicates that the members of the organization form the culture. The researchers believe that there needs to be a coexistence between both approaches to building a culture and that it is naïve to expect a culture to be immutable. However, the researchers also believe that a culture can have core values that are the foundations of a company. This idea of a safety culture having layers is discussed by Guldenmund (2010) as well. “The more deeply a layer is located, the more difficult it becomes to change it" (Guldenmund, 2010). To the researchers, what a culture is and what it aims for need to be defined top-down as this process gives the workers a goal to reach. For a safety culture, management needs to show strong support towards the front-line workers so that proper safety actions are understood as the correct way to go, regardless of the operational impact. However, as the interpretive approach suggests, culture is made bottom-up by having workers interpret what makes sense to them and how to manage work or risk (when speaking of a safety culture). ICAO DOC 9859 highlights the importance of this consistency in culture by endorsing that only when leaders reinforce safety as the main value, the whole company will always follow these guidelines and apply safety measures. This endorsement, as ICAO DOC 9859 recommends, starts as a clear safety policy and an educational program tailored to high and mid-level management.

Maintenance Safety Culture. It seems that safety culture has a close relationship with operational performance and productivity of the airline. In practice, some conflicts may exist between safety and production and the same process involves the maintenance departments. Safety culture and the economic interests may have a paradoxical relationship (Atak & Kingma, 2010).

In aviation organizational culture, one usually realizes that both quality and production departments have their safety-related practices. In practical terms, maintenance technicians usually tend to be flexible and desire to have the tasks done. On the other hand, quality assurance people want the technicians to work under technical maintenance manuals and internal procedures despite the operational demands and pressures. When the safety culture is not robust enough, maintenance management tend to be more flexible and as long as the maintenance technician completes the job, the process to complete a task is not as important. In some maintenance organizations, when there are commercial pressures to release the airplane for flight, it can be considered “normal” for maintenance management to interfere with the technicians. This causes management to press them to release the aircraft back to revenue service, regardless of the risks (Atak & Kingma, 2010).

Also, in accordance with Atak and Kingma (2010), there are basically two types of safety culture in maintenance organizations: one is production-oriented, and the other is profession-oriented. In the first type, productivity is the primary goal and people take risks on a routine basis. In the second type, the work is oriented by safety standards and people do not take risks. In production-oriented organizations, policies and procedures can be easily bypassed under commercial and time pressures. In this case, the organizational culture corrodes the safety culture.

In accordance with McDonald et al. (2000), maintenance technicians form “a strong professional sub-culture, which is relatively independent of the organization” (p. 173). This culture also tries to balance and find a solution between the official organizational safety system and the current operational practices. However, the authors note that in a maintenance organization that is profession-oriented, production environment molds safety and the production environment is very much affected by safety standards.

Atak & Kingma (2010) analyzed one maintenance organization, and they pointed out how a new relationship between safety and productivity can be built in which safety and production interests are aligned. However, at the same time, they showed that this cultural change takes time and it is not smooth. Also, they state “the paradoxical relationship between safety culture and its production context, and what this paradox in practice means for the everyday work of aircraft maintenance technicians who, often under great time pressure, have to creatively deal with conflicting interests” (p.277).

Safety culture within Company 1. After having a general idea of what safety culture is and the particularities of maintenance culture, it is important to understand how the safety culture within Company 1's maintenance department is compared to the industry because others might have gone through the same problem. McDonald et al. (2000) compared different safety model systems in maintenance organizations. Although this is not the objective of this research, it provides interesting views on safety culture in maintenance organizations, such as the existence of sub-cultures and its different view of safety. McDonald et al. (2000) also stated that fundamental issues in management and the organization have led to recent accidents and incidents instead of direct technical and operator task failures. These observations are important to this research because, at Company 1, there is little evidence that the Maintenance department looks at failures as an organizational problem due to the perception of a blame culture from the technicians. Thus, it is necessary to introduce Company 1's Maintenance department to what a just culture means.

Just Culture. According to Dekker (2007), a just culture needs to define a clear line between the acceptable and the unacceptable. However, the key is who draws this line. Since incidents can have different points of view, this will generate different countermeasure recommendations which will rely on the approach towards the human component that could be blame or accountability-driven. The key is to create a progressive and change-oriented culture while not exempting the individual from accountability.

The advantages to applying an accountability mindset in lieu of a finger pointing one are significant if the company seeks to map out organizational weaknesses. The problem with blame is the tunnel vision it creates on the individual's performance. It will force a defensive stance from the individuals in the organization as well as entrenchment from the workers, as well as a useless reporting system (Dekker, 2005). In summary, people will be afraid to speak up. When practicing accountability, the organization gives the worker a chance to explain themselves and let them tell their point of view of what happened. People will not make mistakes in a vacuum (Dekker, 2002); therefore, it is plausible to believe that something in the work environment influenced the mistake. For example, poor lighting conditions can lead to faulty services. The important factor the organization needs to keep in mind is to avoid the hindsight bias when investigating the mistakes and understand why the chain of events made sense to the worker (Dekker, 2007). If the organization can learn what influenced the individual to make a mistake, it can fix this on a grand level and prevent other individuals from falling into the same trap. Safety will only progress if an organization learns from its failures (Dekker, 2010).

A just culture is necessary to maintain report levels high due to the perception that the workers will be treated fairly and that honest mistakes will not lead to negative consequences (Ruitenberg, 2002). The ability for line-maintenance workers for reporting a problem without fear of being judged or blamed for this error is one of the objectives the researchers have for Company 1.

The beginning of this section talked about the key being who gets to draw the line. This requires a change in the leadership mindset from shifting the line from blaming to understanding the organizational factors that caused a failure, error or violation. Instead of looking at the people making mistakes, the focus needs to be in dissecting the system in which they are inserted into (Dekker, 2006). To fully understand how human errors are a symptom of a systemic failure, there needs to be an understanding of how complex systems work.

Complex Systems. According to Perrow (1984) and Lofquist (2010), aviation is a complex system. In broad terms, aviation is a complex system due to its level of unpredictability. Aviation maintenance has a series of unplanned sequences, such as weather interfering with proper aircraft services and limited substitution of resources, such as technician and parts shortage. It is also an exhaustively planned operation that requires technicians to follow checklists and procedures in sequence, which according to reports from Company 1, are not always followed. This "complacency" with procedures as well as commercial pressure and other factors, further add to the level of unpredictability to the system. Complex systems are defined, but not limited to the factors stated above: unpredictability, unplanned sequences, and limited substitution of resources.

Another example of aviation being a complex system is the Operations Control Center. Also known as the nervous center of the airlines, it serves to run and provide resilience to the operation by managing unexpected interactions, such as weather, unscheduled grounded aircraft, and absent crewmembers. Maintenance is a part of the aviation system. Nevertheless, it is a subsystem itself with its own processes, such as engine changes and particular couplings and interactions as the ones stated in the first paragraph of this subsection. As Hobbs (2008) stated, aviation maintenance is a vital sub-system that keeps the aviation system reliable and safe.

In addition to that, maintenance as a system can have tightly coupled and loosely coupled interactions. Tightly coupled components have no buffer between interactions (Perrow, 1984). An engine replacement is a good example. This replacement requires a spare engine to be mounted on the plane. However, if there is no spare engine available, no service will be possible. Loosely coupled components, on the other hand, have a buffer between interactions, this means there can be more than one way to accomplish a task. Take the same engine replacement service. This task requires five maintenance technicians, and there are five scheduled for the job and another one for normal ramp duties. However, an aircraft lands at the airport with an unexpected complex failure due to a bird strike that will require three technicians on the ramp to fix it. This aircraft arrival time coincides with the scheduled hour for the engine change. In order to keep the operation going, the maintenance leader diverts two of his/ her engine technicians to the ramp and begins the engine service with only three technicians. Therefore, although the system requires five technicians, the task has been done with only three. What would happen if one of the fuel lines to the engine was hastily assembled causing a leak, causing a fire and consequently the loss of the engine? What if everything went fine and high-level leadership noticed that the task could be done with only three technicians? Thus, cutting resources on an already strangled department?

Since this research talks about practicing a just culture, let's suppose that the engine fire happened due to a human error. Leadership could fire this technician or try to understand how her/ his error was a systemic failure. This conundrum is why it is essential to have a new view of human error.

New View of Human Error. Continuing with the engine replacement example, with the information available from Company 1 blame-driven culture, the maintenance technicians would probably receive some sort of reprimand. According to Dekker (2006), "errors and accidents are only remoted related" (p.17). As mentioned above, unpredictability is part of what defines a system as complex. A simple bird with bad timing was able to result in millions of damages. Is it the bird's fault? Is it the technicians' fault for following their leader? Is it the leader's fault for pushing the task with fewer resources? Those questions involving fault and blame are pointless.

A more productive one would be using local rationality: why did it make sense to the leader and her/his team to accomplish a task requiring five technicians with only three? It is essential to ask this question because of two factors. One is that it is unlikely that an individual would be solely responsible for this and there are more systemic factors at work (Dekker, 2010). The other is that errors and accidents are loosely related (Dekker, 2010).

An excellent way to guide the understanding of the engine mishap is to reflect on the points presented in Dekker's "Two views on human error" 2006 (Table 1).

Table 1

"Two views on human error"

The Old view of human error on what goes wrong.	**The New view of human error on what goes wrong.**
Human error is a cause of trouble.	Human error is a symptom of trouble deeper inside the system.
To explain failures, you must seek failures (errors, violations, incompetence, mistakes).	To explain failure, do not try to explain where people went wrong.
You must find people's inaccurate assessments, wrong decisions, bad judgements.	Instead, find how people's assessment and actions made sense at the time, given the circumstance that surrounded them.
The Old view of human error on how to make it right	**The New view of human error on how to make it right**
Complex systems are basically safe.	Complex systems are not basically safe.
Unreliable, erratic humans undermine defenses, rules and regulations.	Complex systems are trade-offs between multiple irreconcilable goals (e.g. safety and efficiency).
To make systems safer, restrict the human contributions by tighter procedures, automations, supervision.	People have to create safety through practice at all levels of an organization.

Transcribed from “The Field Guide to Understanding Human Error,” by Sydney Dekker, 2006.

When investigating this case, leadership needs to ask the proper questions to understand what the motivations at the time were and what drove the improper connection of the fuel line. Was the technician in poor lighting conditions or was she or he under pressure from the leader? Why was the leader putting pressure on his/ her team? Did this come from the company and his/ her superiors or did the leader feel the need to prove himself/herself? Was this rush and under-resourced task accomplishment a normal situation? Failures are usually a consequence of people doing normal work (Dekker, 2010) and it is one of the main topics of Normal Accidents by Perrow (1984). Other examples include the Challenger launch decision (Vaughan, 1996) and the shoot down of U.S. Blackhawks in Iraq by friendly fire in 1994 (Snook, 2000).

It is essential for managers to understand why the system is not working according to prescription. Complex system accidents are not the result of one factor only, and therefore it is necessary to understand human error as the tip of the iceberg of more profound systemic failures. By using Dekker's table (table 1) as a guide to conduct investigations and inquiries, managers can grasp a more transparent image on what is genuinely affecting the system they are accountable for.

By having this deeper systemic view, the company will be able to have a clearer picture of itself. It will identify that the sources of errors are not personal, but are engrained into the system (Dekker, 2010), and it will be clearer that the events or mishaps are not the consequence of a breakdown but were a consequence of a faulty system (Dekker, 2010).

Safety reports and indicators. Since part of this research will recommend a safety reporting form to the organization as well as SPIs to measure safety effectiveness, it needs to be integrated to already existing programs and databases. A few references are available to be used to integrate the maintenance form results into Company 1's HFACS (Human Factors Aviation Classification System), AQD (Aviation Query Database) and LOSA (Line Operations Safety Audit) taxonomy seamlessly. This integration can help provide a realistic and broad organizational risk map. The Root Cause Analysis of Rule Violations by Aviation Maintenance Technicians research provided an interesting base for the taxonomy integration (Patankar, 2002). The study cross-mapped some maintenance failure taxonomies: General Failure Types (Reason, 1997) that measure disruptive processes independently from the outcome; Boeing's Maintenance Event Decision Aid form that helps map the factors that led to an event (Rankin and Allen, 1996); and Transport Canada's Dirty Dozen items which aim at raising awareness towards unsafe factors related to maintenance. This cross-mapping is useful because Company 1's Maintenance department has familiarity with them, thus tending to make the acceptance of the proposals in this research clearer. The taxonomy proposed will facilitate the creation of the form and following performance indicators by providing maintenance-related safety terms that are adapted easily to Company 1's maintenance safety mindset.

Apart from the cross-mapping, Patankar (2002) proposes the troubleshooting of anonymous terms, such as "Lack of Knowledge". Terms like this can be ambiguous to an unprepared reader or out of context. It provokes ambiguity in where the knowledge is lacking or what kind of knowledge is lacking. This clarification will be useful when explaining the terms to managers and front-line maintenance employees.

As discussed before, safety management is dependent on information and its analysis. The basis for this is identifying and measuring safety performance indicators (Safety Management Manual, 2013). It is essential for management to define what kind of indicators are required so that there is enough information to make decisions towards improving safety culture. These indicators should help the company understand why, how and where a maintenance mistake, error or failure is happening. The indicators should also help map if there is a common factor for events to happen or if they happen more frequently during certain types of services or stations. These are only a few examples of useful indicators.

In accordance with Rashid, Place, & Braithwaite (2012), maintenance errors can have several different causes, and there are important factors that need monitoring. Such factors can be tracked as indicators that are related to maintenance documentation availability, written communication, maintenance planning, task assignment, maintenance task complexity, equipment, and tools provision, supervisory errors and violations, and workplace conditions. The authors also highlight the weight of importance of some causal factors in maintenance errors, such as task assignment and delegation, as well as supervisors' failure to inspect.

Risk factors and scorecards sometimes can be used as the basis to develop safety performance indicators. Also, since significant human risk factors may contribute to maintenance technicians' errors, they can be weighed and used to drive and build useful indicators. With this approach, Chang and Wang (2010) developed an interesting analysis which shows the relative importance of some risk factors, such as stress, revision of maintenance manual, workplace norms, paperwork, correct equipment and tools availability, pressure management, communication between technicians and workforce planning, among others.

Safety Management International Collaboration Group (SM ICG) issued a paper in 2013 which provide guidelines for the definition of safety performance indicators. Based on this paper, maintenance organizations may use as indicators the percentage of work orders with a difference of more than 10% between the estimated workforce and the actual needs, percentage of work-orders that required re-work, and number of duplicated inspections that identified maintenance errors.

Øien et all (2010) showed some maintenance indicators to be monitored to evaluate the management of flight safety in maintenance organizations. Between the metrics, the number of reported deviations per year, the number of internal and external audits per year, the number of recurrent training per technician per year, and the number of maintenance tasks that have not been accomplished as planned per 100,000 flight hours (this last indicator may represent the ability to do preventive maintenance) were available. In addition to that, Øien et al (2010) also mentioned the number of inoperative Minimum Equipment List (MEL) items as a metric related to the technical condition of the aircraft on critical systems (MEL is a list that has conditions under which an aircraft can fly with inoperative equipment at the time of dispatch).

While examining a combination of different safety performance indicators, Herrera et al. (2009) demonstrated that some metrics, such as air safety reports or flight occurrence reports, represent only some accidents. At the same time, they trigger considerable efforts to investigate and learn. On the other hand, some metrics, such as MEL items or technical reports represent a vast opportunity, however little effort to investigate and learn.

Some of the previously mentioned metrics are good safety indicators since they can capture the safety level and overall performance of the maintenance department at different core activities and areas. However, the researchers understand that those indicators do not reveal some important aspects of the maintenance department, especially the ones associated with human factors and their intricate latent conditions. Therefore, it is necessary to have an additional set of indicators that represent a straightforward metric to help management better understand the triggers to maintenance errors.

Adequately defined indicators will also help monitor the status of risk mitigation actions as well as the overall risk of the company. For example, if a new toolset is implemented, a proper "hardware" indicator can show if this tool is causing problems. The indicators regarding maintenance safety at Company 1 require a vast improvement, and the guidelines on how to do this are present in DOC 9859. However, they need some adaptation to the company's particularities as well as its targets.

To be able to generate these SPIs, the Safety Management System needs effective data. As DOC 9859 states, this is quintessential to the proper functioning of the SMS as well as the effective collection and management of this data (Safety Management Manual, 2013). To collect data, the Maintenance department needs a robust report that can feed the indicators as well as provide a direct channel for maintenance personnel to report what they observe. DOC 9859 divides these reports into few sections, out of which this research will focus on the voluntary reports since this is where the widest room for improvement is as well as being the kind of reports that will: "tend to illuminate latent conditions, such as inappropriate safety procedures or regulations, human error, etc." (Safety Management Manual, 2018,5-5).

Lander and Braithwaite (2016) proposed an adaptation of the Line Operations Safety Audit (LOSA) program to the maintenance environment, and since it uses a lot of Hobbs's work for Australian Civil Aviation Agency, they are both under the same division of this literature review (Hobbs, 2004).

Although adapting LOSA to maintenance is not the objective of this research, there are some interesting insights on how safety is perceived in the maintenance environment as well as useful breakdowns of maintenance tasks to fit the observation reports. Hobbs (2008) stated that maintenance errors and violations in a complex social-technical system are the readily perceivable failures of embedded problems in the organization. This perception, along with, the incomplete understanding of the organizational aspects that lead to failures in the maintenance department (Hobbs, 2008) is shared by the researchers.

One interesting insight cited is that "mistakes of maintenance personnel can be more difficult to detect, and have the potential to remain latent" (Hobbs, 2008, p.vii). This further corroborates to the need of progressing the safety culture within maintenance by using predictive methods geared towards risk mitigation. Hobbs (2008) also mentioned that there are still signs of blame culture in maintenance and may reflect on a tendency of maintenance reports being ten times less than flight operations in the FAA Aviation Safety Rerpoting System database. This significant difference in reports is also observed at Company 1 and reducing this difference in reports is one of the objectives of this research (Gaynor et al., 2010).

One of the challenges of building a report specifically for maintenance crews is that the dynamics of the job are very different from that of a normal flight: ground, taxi, takeoff, climb, cruise, and landing. This linear progression of a flight is always the same. However, a maintenance service can have different progressions. The division proposed by Langer and Braithwaite (2016) is as such "scheduled tasks are usually organized into a check (e.g., transit, daily, weekly) and unscheduled tasks, such as troubleshooting and defect rectification, may be performed outside of a scheduled check" (p.988). These divisions are adequate for a reporting system as well and provide a logical unit of observation to classify the risks. Company 1's Line Operation Safety Audit uses a similar division for flight observations, and it has proven effective.

Training Development and Delivery

Developing a training footprint that addresses non-technical knowledge and skills, which will promote cultural changes in perceptions and attitudes to highly technical personnel, can be a challenge. Maintenance people tend to value airplane and procedural knowledge more than cultural issues, which seem subjective at first hand. According to Haines (2008), there are very few studies on how maintenance technicians best learn even for technical knowledge and skills. Consequently, a structured training requires a development methodology so that the course can address subjects, which will later be evaluated and implemented.

Seel and Lehmann (2017) regard ADDIE (Analysis, Design, Development, Implementation, and Evaluation) as a set of instructional design steps. These procedures structure how training will be disposed of since ADDIE offers a systematic approach that guide training designers tackle all relevant points and reflect on course participants' profiles and needs.

During the Analysis Phase of ADDIE, the instructional challenge is detailed, learning objectives documented, and the training target population and needs mapped. In the Design Phase, the instructional designer will plan what the training will look like. The Development Phase serves to establish instructional materials and learning tasks. The Implementation involves training both facilitators and trainees for trials. The Evaluation

Phase will map those training objects that work and those who should be improved. Then, the course is ready for delivery.

Summary

This literature review is only a broad scope of the available material. However, the researchers believe that they captured the essence of just culture, culture, safety culture, and practical training strategies. For a research of this time frame and objective, the researchers believe that the concepts above provide a decent and sustainable foundation to develop the safety form, relevant SPIs, and a practical just culture course.

Chapter III

Methodology

This chapter presents the methodology that the researchers used for writing a line maintenance reporting form and a training program. The form is a tool to provide line technicians with a way to report issues as well as provide pertinent SPIs to maintenance leadership. These SPIs are explored in Chapter IV – Outcomes. For the training program, the researchers applied the method known as ADDIE.

Reporting Form

To clarify the roadmap for the form, the following aspects will be discussed: Sampling, Data Collection Methods, Form Validation, General Form Considerations, Form Objectives, Specific Data Points, Target Audience, Specific Tabs (Introduction, General Data, Task Related Issues, Non-Task Related Issues, Description and Attachments), and Integration into HFACS.

Sampling. In order to have a comprehension of what data is required for performance indicators, the researchers have chosen two parties to be the participants for this research: the researchers and the maintenance focal point for safety issues. By being in a senior management position and a subject matter expert, one of the researchers has a clear view of where the data gaps are and what kind of information the company needs to have a better idea of the safety-related issues regarding maintenance. The maintenance focal point has interesting insights into what the needs of maintenance technicians are and what they need to expose their problems. In addition to this, these parties were chosen by sampling by convenience (Sedgwick, 2013).

Data Collection Mechanism. The platform to host the form is Company 1's reporting system. This is a web-based software that is accessed by the employee by using her/ his corporate login and password to access safety reporting forms. This software can be accessed via mobile platforms as well and is already well established within the company.

This software automatically compiles information from the filed reports and tabulates that into a database. The access to this database is restricted to Company 1's safety department. In order to read this database, the safety department uses data business intelligence software to process the data. The business intelligence software can be programed to display the proposed SPIs outcoming from the submitted forms. The form will only be based on this software and is not meant to be printed or distributed in any other way.

Form Validation. Due to time restrictions, the form was not tested with members of the target audience. Instead, the researchers will pre-test it within a focus group for ease of usage and comprehensibility. The focus group is comprised of the people mentioned in the sampling paragraph and the researchers. The results of these tests, as well as recommendations for further studies, are discussed in Chapter V.

General Form Considerations. The form contains the following tabs: Introduction, General Data, Task-Related Issues, Non-Task Related Issues, Description, and Attachments. Each section is explained in thorough detail below. All fields are optional unless specifically stated as mandatory. The reasons for them being mandatory are discussed as they appear. There are two mandatory fields, eleven Boolean questions, and one descriptive field. The form target completion time is five minutes.

Form Objectives. As stated before, the objective of the form is to provide a specific formal channel for the line-maintenance technicians to report the risk factors they perceive and create a database to translate that data into formal SPIs, leadership can act upon. For the form to work, it needs to be self-explanatory, easy to fill-out, and relatable to the technician while providing the relevant SPIs to maintenance leadership. Therefore, the criteria for the structuring of this form comes from the SPIs demands from maintenance leadership provided by the researchers' insights, Company 1's safety data taxonomy and feedback from maintenance safety training. Where each criterion was applied will be described further down in this research. Another general aspect to consider is that Company 1 is not based in an English-speaking country. This means that the terms here will need to be translated before publishing the form.

Specific Data Points. An important data point is the level of knowledge and skills of the maintenance technicians assigned to the several different tasks during the maintenance activities. The form aims to map this and helps correlate it with other issues explored in the form. This data can be used to improve training programs and courses.

Another point is that sometimes maintenance tasks need to be repeated because they were performed incorrectly or inappropriately, consequently reducing efficiency. In these cases, the maintenance technical logbook will show the repetitive items, and the data should be tracked in order to reveal the abnormal maintenance actions. This can help show how many times the aircraft was released to flight in an un-airworthy condition. The form will aim at this un-airworthy issue as well with questions that target incorrect maintenance actions.

There are also issues with maintenance technical logbooks missing data, incomplete or wrong information leading to the lack of understanding of the technical issues and those cases need tracking. These issues can further lead to a breakdown of communication between accountable parties when discussing technical issues. The form aims to map this as well with specific questions on the Task-Related and Non-Task Related tabs. A mapping of all of these factors will help increase efficiency and reduce risk.

Form Target Audience. There are usually two main types of maintenance services: line-maintenance that takes care of the day to day inspections as well as troubleshooting, and heavy maintenance where the aircraft stops for an extended period of time for more intricate and specific checks. Due to the time restrictions of this project, the line-maintenance technicians are the target audience of the reporting form.

Specific Tabs. Due to the form's software platform, its physical space is limited, so the sections have been divided into tabs. They are discussed below.

Introduction. This section of the form contains general guidelines on how to fill out the form and has a frequently-asked-questions section as the form matures and adapts throughout its usage. This helps the form be "self-sustaining" by clarifying points that may turn out to be unclear. The following text is in the present on the first edition of the form:

"Thank you for your commitment to safety!

This form was created by your peers in collaboration with the Safety Department for you.

Please keep in mind that this form is confidential!

In case you choose to identify yourself, only the Safety Department will have access to your identification.

Any disclosure of your identification requires YOUR approval."

General Information:

- If you need to describe something, use the "description tab".
- If you have any opinions or improvement suggestions for this form, please use the description tab.
- Please feel free to call or contact us on XXXX-XXXX or at xxxx@company1.com"

General Data. This tab of the form has the objective of establishing who, where, and when an event or risk happened or is present. It aims to provide a general understanding of the reported issue.

It is essential to the researchers to establish "who" is reporting. The reason is not to identify the individual, although that option is given, but to understand the hierarchical level which indicates the experience the user has. This information is relevant because it helps establish how many recurrent trainings, meetings and other company related processes she or he has passed. It can also help understand, among other factors, if more experienced individuals are skipping tasks because they already know them by heart or if there is a problem in the transition between training and the actual work for new hires.

To establish the "who" in the event, the primary information necessary is what role the individual has in the organization. This field is mandatory. Due to the maintenance hierarchy, there are ten outcomes: trainee, technician I through IV, shift-leader, supervisor, coordinator, base manager, and engineer (who usually conducts audits and oversights). Engineers are stated here because although they do not conduct direct line-maintenance activities, they can supervise as well as audit a task. These options are available in a drop-down menu and help reduce errors and typos.

In addition to that, there is a field for the technician to fill-out his/ her employee number if he/ she is willing to disclose that information. Another aspect explored is time on duty/ shift. This is important to measure in order to understand if fatigue might be an issue. Fatigue may be caused by back of the clock operations as well as time awake (DOC 9966). Therefore, there is a field where the technician may fill out the duty check-in time and a separate one to describe how long one's current duty has been going on for at the time of the reported issue. Both fields are drop-down menus. The duties start in fixed times: 00:00/06:00/12:00/18:00 and the options are presented as such. For the duty time, the following time-frames are presented as options: 1-3(hrs), 4-6(hrs), 7-9(hrs), 10-12(hrs), more than 13hrs. These numbers were chosen for convenience purposes and naturally incorporate half-shifts (1-3), full shifts (4-6), overtime (7-9), double shifts (10-12), and extreme contingencies or duty-limit violations (more than 13hrs). To further address the "who", there is a simple checkbox with the question "Did you feel physically fit for duty at the time of the event"? This is important for establishing the state of mind of the technician and can help understand if one is reporting for duty unfit. It also contributes to understanding if there are organizational pressures that are forcing the technicians to show up unfit for duty.

After the "who", it is important to establish the "where". The location of where the event or risk has happened can help track if a cost-cutting measure affected a specific station or if recent organizational changes may have unbalanced a particular maintenance team's workflow. This data is crucial to the SPIs because of the myriad of information it can provide. For example, if an incorrect installation happened because of rain or poor lighting, it can help pinpoint the exact location where this happened and provide strong arguments for a change in infrastructure at the station. This environmental problem maintenance is having may be the same the airport staff suffers from and solving one issue helps two different areas. To identify the base, there is a menu with all the airports Company 1 flies into. This airport database is already integrated into the company's safety data set, creating a data link point with other reports data sets.

Another aspect of the "where" is the aircraft type serviced. This can help identify various organizational factors that might be specific to the aircraft type, such as ease of comprehension of manuals/ task cards, maintenance manual availability, aircraft systems friendliness, customer support, and other factors. This data can also generate SPIs to request better customer service from the aircraft manufacturers by tracing a relation between an unsafe event and a poorly written manual. For this field, there is a simple drop-down menu with all aircraft types serviced by Company 1.

The next point is the "when". To the researchers, it is important to establish this because it can help understand the environment at the time of the event or perceived risk. There is a simple field asking for the "Hour of the event or risk perceived". The acceptable answer for this is a time reference written in the 24-hour "HH:MM" format. It is optional because "non-task" related issues might be based on a perception built over a period of time. Due to the various answers that can be available through this information, to clean the data for the SPIs, a simple histogram with the desired time-frames can be set-up.

The last point to establish in the "General Data" section is what kind of report one is filling out. Regarding SPIs, it is critical to understand if the event or risk was perceived or happened in a scheduled, unscheduled task or if it was not task-related. This is crucial because if the task was scheduled, it might mean that it was planned inappropriately. If it was unscheduled, it can mean a mistake could have happened due to organizational pressures. However, if it was non-task related, it can demonstrate a more engrained problem within the line-maintenance system. To discern between these scenarios, a mandatory field is available asking the type of issue reported. The options: Scheduled, Unscheduled and Non-Task Related will be available through a drop-down menu.

Task Related Issues. This tab serves to identify the risks and events that happened during a maintenance task. It aims to cover all aspects of the workflow of the tasks as well as provide SPIs that are in sync with Company 1's Safety department taxonomy. Company 1 has a maintenance information system (MIS) to control, plan and oversee maintenance and engineering actions. All maintenance departments use the same system to assure fleet airworthiness.

First, it is important to discern between the types of line-maintenance. According to Company 1's description, a task can have two origins: Scheduled and Unscheduled. The difference between both is the motivation for a task to happen. In a scheduled task, the company's fleet planners schedule and allocate resources at the station where the aircraft will be when that task needs to be performed. It can be done the other way around as well by scheduling an aircraft to land at a specific station that has the resources available for the required task to be performed. An example of this is a routine windshield inspection that needs to be done at every 750 hours. This planning is subject to many unexpected setbacks, such as aircraft diversions, airport closures, and other factors thus contributing to the complexity of the maintenance services system.

An unscheduled task happens when the aircraft has a failure or issue during its line operation. These tasks can be simple like a bird-strike that in some cases requires only a visual inspection. However, it can be more complex like an engine reverse failure during landing that requires a component replacement or a more elaborate maintenance task to dispatch the aircraft. The unscheduled tasks are more prone to organizational pressures due to the time constraints available during aircraft turn-around. As an example, an aircraft at Company 1 has a scheduled turn-around of 30 minutes. This pressure increases in delayed flights.

Apart from the expected and unexpected differences between scheduled and unscheduled, the tasks follow the same process once they are defined: task planning, execution, task closing, and aircraft release. The planning of the task for scheduled operations will be dealt with more depth because it will involve different areas of the maintenance department, such as supply chain and engineering. This planning phase is where the organizational and supervisory aspects may be identified more clearly. These organizational and supervisory maintenance aspects are mostly the ones that don't involve actual contact with the aircraft. An example of an organizational aspect would be an ambiguously written policy or a lack of allocation of workforce. A supervisory aspect mostly involves how a superior handle hers/his team. At Company 1's database taxonomy, these aspects are in the spirit of the HFACS methodology as developed by Wiegmann and Shapell (2003). For the unscheduled task, the task assignment can be done by who identifies the issue first. This is done by writing the snag on the Technical

Log Book (TLB) of the aircraft. The TLB snag entry can be done by the maintenance staff or the pilots and has an identification number for each reported issue.

The execution is done by the maintenance technicians after task is planning and assignment. It usually is done by following a procedure described in a task card, maintenance manual, troubleshooting manual, service bulletin or airworthiness directive. All these tasks have a dedicated numerical reference that needs description in the TLB. The execution is the most detailed and complicated part of the task. It is when the technician physically interacts with the aircraft. This is also where a lot of unexpected factors may come into play, such as tools and spare parts issues, inadequate man-power, environmental issues, and others. It is also the stage when a pre-condition for unsafe acts will most likely occur, and the form is adapted to that. According to Wiegmann and Shappell (2003), a pre-condition for unsafe acts are the underlying causes of a mishap, error or failure.

Once the execution is finished, the tasks are signed, the TLB is filled out by describing the actions taken and is registered into the maintenance information system. Both the tasks and TLB are signed by the accountable technician responsible for executing the job. This is a great deal of work and involves a lot of paperwork. During recurrent training, there are constant complaints about the amount of paperwork to be completed. For unscheduled tasks, a response on the TLB is enough to release the aircraft for flight. However, during scheduled tasks, there needs to be a release of the aircraft in the maintenance information system in addition to the signatures on the paperwork related to all the completed tasks.

The first part of the Task Related Item tab is to establish on what part of the aircraft the job was performed as well as what kind of technical reference was used to track the execution of the job in the system. There is an open field for the following tracking and identification numbers: TLB, TASK CARD, ATA, and TECH PUBS. ATA (Air Transport Association) Chapters are means of categorization for aircraft systems and areas identification that are used throughout the industry and are common between manufacturers. Task Cards are written technical instructions prepared by the airline to give detailed information on how to accomplish a maintenance task. TECH PUBS are referenced here as any technical instruction prepared by the manufacturer in order to carry out a maintenance task such as Aircraft Maintenance Manuals and Troubleshooting Manuals. All these fields aim to provide tracking numbers relevant to the maintenance task in order to check the processes involved with the reported event or risk. These numbers will also help track the paperwork involved and the service process as a whole. They are not mandatory since other parts of the form may not need this information. Another reason to make it optional is to avoid direct identification of technicians who wish to remain anonymous.

Along with the task identification in the top of the form, there is a field to identify what kind of maintenance process the task required. They can be visual inspection, servicing, functional checks, operational checks, removal/ installation of components, aircraft modifications and structural repairs. These fields will generate an SPI that can help track what kinds of tasks have risks or failures associated with. This field is a drop-down menu where only one option can be chosen. If the task requires more than one kind, the user will need to fill out in what part of the task the risk or failure was identified.

The last header point to be addressed is related to the personal readiness of the user. The following question is asked in the form with a non-mandatory drop-down menu: "Did you feel unprepared to accomplish this service"? The reason the word is "service", not task is because "task" is highly associated to the procedure and not the whole process of executing a task. The following options are available in a drop-down menu: experience, training, and inadequate briefing. These three options aim to address more organizational issues as well as harmonize the responses to fit Company 1's safety taxonomy. This is also included due to the feedback received by the technicians during recurrent training that describes a sensation that they feel ill-prepared for the duties.

Following this question, in the spirit of making the form self-explanatory, the following statement is clearly displayed: “Fill out where the risk, mistake, issue or event was identified. You can fill out more than one phase and choose the options that contributed the most to the risk, mistake or event."

Afterward, the options are divided into the phases of the task: Planning, Execution, Closing, and Release. The phases will be described by headers on top of the corresponding fields.

Planning. The Planning phase is aimed at leadership. The first field aims at reporting the resources available. It simply states: "Where there are resources lacking to execute task" and is followed by three drop-down menus. They have the same options in order to be able to report more than one issue. The options are as follows: Lack of Man-Power, Lack of Tools, Lack of Parts, Man-Power Availability Below Work Package Man-Hours Requirements, Lack of Qualified Technicians and others (describe on description tab). This will provide SPIs that can identify and track if inappropriately planned operations are forcing the system into unsafe state. These inappropriately planned operations usually mean an unbalance between resources and task. These SPIs will require further study from high-level leadership in order to understand what is causing the operations to be planned without adequate resources.

The next field aims to identify organizational pressure by asking: "There was pressure from the Maintenance Control Center to execute the task without proper resources or time". For simplification purposes, the answer is in a checkbox format. This can help understand if the Maintenance Control Center is creating unnecessary pressure or if it comes from higher up.

To address the complexity of unexpected factors that can involve planned tasks, the following checkbox statement is displayed: "The task came from a change in the flight network". Once again, it is in a checkbox format. This way, it is easier for leadership to understand how and if the diversions, weather, and other unexpected network changes are resulting in unsafe conditions.

Execution. The execution section will be more straightforward and is based on a few drop-down menus based on Company 1's established taxonomy. This is done to integrate the data sets created by the maintenance seamlessly with the already established safety data set. This provides a way to map and contribute further to the identification of organizational influences by adding the data from the maintenance form. None of the fields below are mandatory.

The header reads: "Execution. Choose what factors you believed had the most influence". The first question is aimed at hardware and understanding if and why it was an issue. Therefore, it is an optional field. It states: "Tools/ Technology" and is followed by the two identical drop-down menus that comprise: "Inappropriate Tools", "Broken Tools", "Inadequate Material", "Broken Material", "Access to Documentation", "Access to Technical Publications", "Access to Task Procedures", and "others (describe in description tab)".

Hardware is followed by “Environmental Factors”. These are factors that involve the task environment, such as weather and lighting. It follows the same idea of the hardware options and will also consist of two drop-down menus after the following question: "Environmental Factors". These drop-down menus have the following options: "Excessive noise", "Poor lighting conditions", "Access to panels and systems", "Weather", and "others (describe on description tab)".

Following the concept of the two factors above, another area to be explored is the “Personal Factors”. The reason there are various questions throughout the form about the subject is to distinguish it from the different phases of the task. The personal factors in this section are related specifically to the execution of the task. Once again, the form contains a simple label: "Personal Factors" and has two drop-down menus. They contain: "Distraction", "Rush", "Perceptual Error", "Decision Errors", "Skill-Based Errors", "Fatigue", and "others (describe on description tab)". As the data-set builds up and matures, this information can help understand organizational pressures or inappropriately planned operations manifest themselves as an error by correlating and studying the SPIs beyond the numbers.

Following the personal factors identification process, there is one question to address a personal feeling of preparedness by the user. It reads: "Did you feel qualified to execute the task? If not, in case you are comfortable, please describe why in the description tab". It is followed by a "yes" or "no" drop-down menu. This issue is of preparedness, discussed a lot in recurrent training and the researchers felt that this can help voice those concerns in an anonymous environment. The technician's perceptions can help further understand the underlying issues in the Maintenance department.

The next issue to be addressed will be the Communication and Coordination between different members of the team executing the task as well as the comprehension of the job to be done. Following the model for the factors stated above, this part of the form reads: "Comm/Coordination". It has 3 drop-down menus with the following options: "Task comprehension", "Difficulty with English", "Time to complete the task", "Inefficient team-work", "Team communication breakdown", "Shift change interfered with task execution", and "others (describe on description tab)".

Since there are few reports on the RELPREV system regarding tasks executed by memory in lieu of following procedures, the researchers believed it is an important issue to address and map with the SPIs. Therefore, following the same concept of “yes” or “no” answers regarding preparedness, the following question is added: "Did you execute the task by memory?".

Lastly, there is a specific section to further address organizational pressures. It addresses the problem with the following question: "If there was pressure to finish the task, who caused it?". To keep the form consistent, a drop-down menu will be available with following options: "Airport Staff", "Pilots", "MCC", "Maintenance Leadership", "other technicians", and "others (describe on description tab)". This can provide an easy way to track who is being perceived as to be causing the most pressure during task execution.

Closing and Release. The section related to closing and release is comprised of a series of check-box optional questions. These sections are divided by two headers: "CLOSING (check box for yes)" and "RELEASE (check box for yes)".

The first question addresses issues with the maintenance information system (MIS) by stating: "Difficulties with MIS". It is followed by its respective check-box.

To address hurried and rushed closures, the following question is asked: "Did you sign the documentation before closing the task?".

Afterward, the following question addresses task comprehension: "Did you sign the documentation without understanding the task or its execution? If comfortable, please describe why".

Finally, the following two questions address the release phase of the task. They aim at understanding possible rushed releases and verifications. This is included specifically in the form to comprehend why events with these factors happen. Company 1 has faced a series of issues regarding inadequate releases that have resulted in aircraft un-airworthy situation as well as additional maintenance costs related to reworking. It is also a sensitive issue within maintenance leadership. The questions are simple: "Was the aircraft release done before the MIS transaction finished? If comfortable, please describe why.", and "Was the task not inspected before signing the TLB? If comfortable, please describe why". The main objective of these questions is to provide low-level leadership with an anonymous way to voice organizational pressure and its reasons.

Non-Task Related Issues. This tab of the form serves to report the broader organizational issues that technicians have voiced during recurrent training. They start with simple check-box questions followed by two drop-down menu ones. A header explains that the boxes need to be checked for "yes". The questions help have a general sense of the perception that the maintenance employees have.

The following header is written on the form: "This section is for general points you may wish to bring to the Safety Department's attention. They are based on your requests. If you wish to describe anything regarding the questions below, please use the description tab".

Afterward, the following questions are stated and can be answered in the "yes" or "no" format. The first one is aimed at low and mid-level management: "Is the maintenance organizational structure inadequate?". The next one is: "Does maintenance leadership treat and manage people unfairly and inadequately?". A strong "no" answer here can help show the lack of a just culture due to punishment. If this question has a strong response, it can help understand if the just culture training proposed in this research is effective.

The next two questions aim to help voice material resources issues. The first one is: "Is the quality of the tools and hardware inadequate?" and the second: "Are hardware and tools consistently unavailable?".

To map the communication between technicians and the rest of the company, the following field can be answered in the multiple question format: "Choose from the options if you feel there is a communication problem between:". The drop-down menu will have the following options: "Managers and Technicians", "Between Technicians", "Technicians and Pilots", "Technicians and Flight Attendants", "Technicians and Airport Staff", and "Technicians and Inventory".

The last point to be addressed comes from constant complaints from the maintenance technicians regarding communication between the MCC and them. Therefore, the researchers believed that it is adequate to address this with a separate field. "Has MCC been a threat due to:". It can be answered by a drop-down menu containing: "Confusing Communication", "Unclear Directives", “Lack of Technical Knowledge”, "Pressure", and "Others (describe on description tab)".

Description. The description tab is an open text box with no size restrictions for the user to be able to describe different aspects freely. There is no word count restrictions.

Attachments. This tab serves for any file the user may wish to upload and attach to his/ her report. The attachment size is virtually limitless and supports any file format.

Integration into HFCAS. Company 1 is structuring its safety database by using a modified and adapted HFACS taxonomy. It is already working in some parts of the Safety department, such as FDM and on major investigations. The taxonomy is organized per event by creating "safety officer tab" on the form restricted to the Safety department. Although the form facilitates the application of HFACS taxonomy by using already established codes, it will require adaptations, revisions, and alterations in order to harmonize with the existing database. This is crucial so that the SPIs provided are efficient and reliable.

The quantification and qualification are done automatically within the Company 1's safety data structure. The reporting software AQD creates a database that is read by using a business intelligence software. The maintenance form data will fit easily into this environment but will require an elaborate initial configuration by the Safety department's data analyst. Once this is done, due to the standard taxonomy, the data will be integrated into the HFACS reader as well as opening up the possibility of having multiple ways to visualize the SPIs.

Training Development and Delivery

The researchers applied ADDIE questions as the guidelines in order to reflect on how training development and delivery methods will be more effectively conducted. The researchers will answer the following questions as similarly published by Seel & Lehmann (2017):

1. Who is the target population?
2. What are the subjects which need to be covered?
3. What are the obstacles to the training environment?
4. What is the most efficient method to deliver this training?
5. What are other issues that may impact training outcomes?

Target population. The assumption "culture is defined top-down" guided the researchers to identify the course target audience as the line-maintenance top and mid-management down until the person who directly manages a maintenance technician. This requires a review of the company organization chart.

Course Content. For the course subjects, the researchers started by revising Company 1 Safety Management System Manual (SMSM), appropriate SMS guidelines and bibliography regarding just culture. Considering the SMSM, the researchers identified that just culture is defined as the current policy within Company 1. There is then a gap between the written commitment and what is in fact practiced. Consequently, just culture has been established as the first content to be addressed in the class.

Just culture has driven the other subjects: complex systems and the new view of errors. The researchers understand key subjects should be only covered and emphasized.

Course Method. The researchers have studied which course delivery method would be more engaging. Having that assumption in mind, scenario-based training is encouraged in which managers, when as trainees, will be required to put in place just culture principles and the new view of error as if they were dealing with actual circumstances.

Course Constraints. Since the course target population are mid and top management personnel and the researchers are also managers within Company 1, the researchers understand that workload is high and presuppose that their availability to attend the course is low. The researchers have to carefully plan course programmed hours and also where the course is to be held.

The researchers believe that the ADDIE guidelines are practical and simple enough to apply in a rushed and dynamic airline environment. Nevertheless, the researchers feel that this practicality and simplicity do not reduce the quality of the material or compromise the learning experience. ADDIE also helps individuals with little experience in course building to structure an efficient class. This helps with the overall proposition of this research of guiding a just culture driven class.

Chapter IV

Outcomes

As stated in the "Research Goals and Scope" on Chapter 1, this research had the objective of delivering a new risk management report for maintenance technicians to fill out, a recommendation of safety performance indicators for safety assurance that will come as the result of the report, and a training roadmap program for safety promotion. This chapter is divided into the following sections: Safety Reporting Form, Safety Performance Indicators, and Training Course. Each section will explain the results the researchers were able to obtain in the time frame available following the methodology described.

Safety Reporting Form

After following the steps described in the methodology, the form was built and inserted in the test environment of Company 1's safety reporting system. As described, it has six tabs: Introduction, General Data, Task Related Issues, Non-Task Related Issues, Description, and Attachments. Within these tabs, there is a total of two mandatory fields, eleven Boolean questions, and one descriptive field. The focus groups took five minutes to complete the form. These five minutes are within the target of the researchers. Figure 1 is a screenshot of the introduction page.

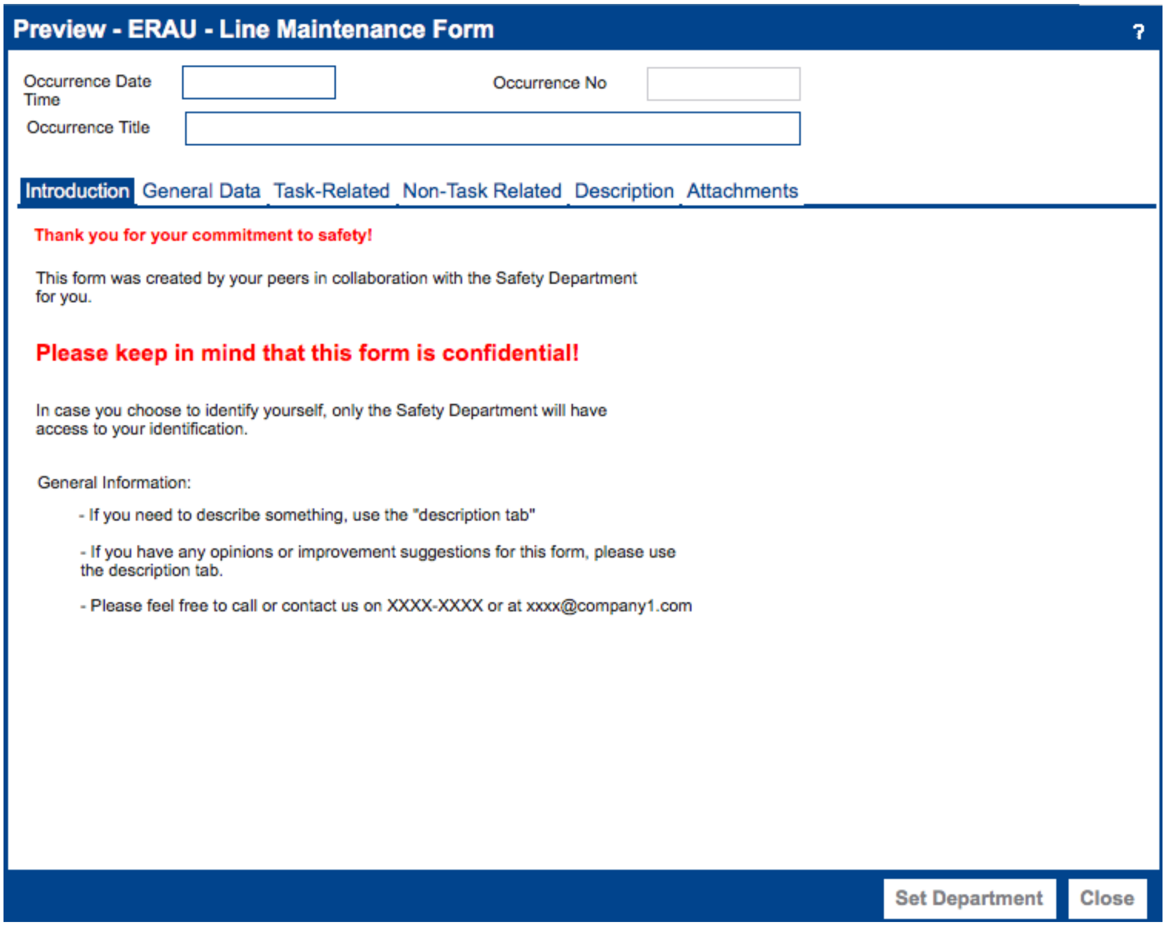


Figure 1. Introduction Page

The remaining of the form can be found in the Appendix pages. The appendixes are divided into tabs and the subdivisions of these tabs are exposed in by figures. The first appendix, Appendix B is the introduction page.

Appendix C has the General Tab and its figures are divided by overview, "Role" drop-down menu overview, "Type of Service" drop-down menu overview, and "Did you feel physically fit for duty" drop-down menu overview.

Appendix D contains the Task Related data tab screenshots. The figures are divided by Task Data tab Overview, "ATA Code menu overview", "Type of Task" drop-down menu overview, "Did you feel unprepared to accomplish this duty service?"

subcategory overview, "Were the resource issues to execute the task?" drop-down menu overview, "Tools and Tech" drop-down menu overview, "Environmental Factors" drop-down menu overview, "Personal Factors" drop-down menu overview, "Comm/Coordination" drop-down menu overview, and "Was the task executed by memory?" drop-down menu overview.

The Non-Task Tab and its drop-down menu are in Appendix E. Appendix F contains the Description tab overview, and Appendix G has the Attachment overview.

Safety Performance Indicators

The researchers have defined the Safety Performance Indicators that have the potential to reflect the state of the Maintenance department in order to provide a clear indication of safety levels. The goal is to help management find out if the organization is likely to achieve its safety objective.

The researchers have realized that the current safety performance indicators on Maintenance departments do not reveal a complete picture in relation with human factors and crucial organizational factors, especially when trying to adapt it to Company 1's safety culture and organizational approach to safety. Thus, it is imperative to have tailored indicators that represent a clear metric to help management better understand the probable maintenance errors.

The indicators proposed in this research were adapted from the current metrics available in the literature. The following SPIs are research outcomes and they are identified below with a description of what they measure, the objective of the indicator, and as the units of measurement. They are identified and broken by categories that represent the main factors involved with the report. It is important to notice that each SPI can provide indications of more than one problem related to the overall aircraft maintenance management process, and each SPI can also be used together with other proposed SPIs in order to provide trends and useful information.

Since the SPIs require data from filed forms as well as the configuration of Company 1's business intelligence software, there are no practical examples discussed in this research. The examples stated below are relevant and practical approaches that can be extracted from the data and fulfill Company 1's initial demands. It is important to note that the form is not limited to only these SPIs and due to its many possibilities of cross-mapping, the potential is immense.

Man-hour planning and scheduling.

1) Number of occurrences per month related to lack of an effective way of detecting and adjusting the available line station manpower to the actual workload on night shifts. The main objective of this metric is to capture the ability of the maintenance planning department to work together with the line-maintenance station leaders. Unbalanced work load can trigger additional time pressure on the maintenance technician work as well as jeopardize the quality of the work and cause deferred maintenance tasks. In addition to that, line-maintenance management should be aware of this issue so as to decide if additional technicians must be hired. The field "Were there resource issues to execute the service" is among other things created to help map this issue.

2) Number of cases per month where the work orders required rework. This indicator can be used to detect issues related to fatigue, related to inappropriate access to maintenance documents, lack of technician skill and training. The form can help identify the causes by mapping the causal factors. Also, it may prevent maintenance planning related incidents (Safety Management International Collaboration Group, 2013).

3) Number of events related to insufficient time allowed for maintenance technicians to accomplish the required operational/ functional checks. Sometimes, although the planned and actual manpower workload was appropriately done, unexpected things can happen during the execution of the tasks leading insufficient time to accomplish critical tests at the end of a task. This metric can point out inadequate coordination between technicians, it can reveal the reasons behind why the technician omitted or bypassed an aircraft system test, and it can reveal inadequate supervision. The fields that ask questions about Communication and Coordination as well as items executed by memory are a great help to map these issues.

4) *Number of overt-time per month the technicians are forced to work.* This indicator may indicate issues related to deficiencies on the maintenance planning process, inappropriate conduct of line-maintenance leaders, and economic constraints of the airline. The duty time fields can help map this problem.

Significant Operational Disruption.

5) Number of air turn backs, aborted take-offs and engine in-flight shutdowns per 1,000 take-offs due to maintenance errors. This indicator is broad in terms of causal factors and can be used for several different approaches including organizational factors, local work condition issues, factors associated to the tasks as well as aircraft design poor reliability.

Fleet Standardization.

6) Number of issues caused by fleet variability for which the technician has been working in different aircraft and engine types. This indicator shows the events directly caused by the lack of standardization of the aircraft fleet within the airline. This is an important indicator because different aircraft and engines types may cause errors due to lack of skill, lack of appropriate training, lack of assertiveness, lack of parts, failure to recognize the aircraft model, among others. By having an aircraft type field, the form can also help map this aircraft type specificity.

Commercial and operational time pressures.

7) Number of cases where flight preparation had to be done by the technician in less than the normally allocated transit time. The objective of this indicator is to show the exposure of the technicians to time pressure that, in addition to other existing problems, can lead to errors. It can also point out the deficiencies on the network planning of the airline as well as some issues with the allocation of manpower. This can be mapped by the specific questions directed at time pressure in the form.

Improper inspection.

8) Number of times that a required inspection item was not properly inspected by a second technician or it was self-inspected. The goal here is to identify events where technicians were overloaded, there was inadequate supervision or technician misconduct. It is also important to identify if this is a routine, supervisory or exceptional violation. If the form data indicates that a lot of bases, in various situations have these issues, it might indicate that improper inspection might have become an unwritten procedure.

9) Number of times the technician sign-off a task without adequate inspection of the aircraft system or part disturbed. This indicator may point out that the sign-offs are rushed or at the very least, improper. It can prove a rich starting point to uncover organizational pressures.

Maintenance task complexity.

10) Number of times an aircraft system does not pass a post-maintenance test. This indicator has the main purpose to show the events where the maintenance procedures were affected by the part quality, tool quality, lack of skill of the technicians, poor maintenance documentation, among others. Although the form alone does not track this, it can help map the aspects that lead to it, such as tool quality.

Maintenance procedure skipped.

11) Number of issues related to accomplish a task without reference to the manuals and relying on memory. This indicator can reveal routine violations and may point out inappropriate access to or availability of the maintenance manuals and ignoring risks from technicians. The form has a specific check-box for this.

Workplace norms.

12) Number of times the jobs were signed-off as completed but post events showed that this was not the case. This metric may reveal that technicians are working without task cards, they are working without reading and understanding task cards or they are signing task cards that they may not have performed. This behavior can lead to serious maintenance errors. There is also a specific field in the form.

Use of unauthorized parts.

13) Number of events of releasing un-airworthy aircraft where technician used non-approved parts. This indicator encompasses the events in which technicians do not use the MIS, Illustrated Parts Catalogue (IPC) and maintenance manuals or when they assume that already installed parts were correct to use as reference to replacement parts. These norms drive the technicians to errors because they must refer to the maintenance manuals, Illustrated Parts Catalogue and MIS system so as to determine the correct part to be installed on the aircraft. This is another SPI that is not directed related to the form but is supported by it. The fields that demonstrate difficulties with English and the MIS are two of the fields that can help.

Lack of assertiveness, ambiguity and diffusion of responsibility in team work.

14) Number of times the technicians assumed a verbal OK condition from MCC without verifying by themselves the accuracy of the information. The main objective of this indicator is to capture the events where maintenance technicians assume that Maintenance Control Center (MCC) is always right regardless of the current and real situation of the local line-maintenance station. These situations can represent a high level of risk and can lead the technicians to release the airplane to flight in an un-airworthy condition. The "aircraft release without the proper documentation" field in the form can help feed this indicator.

Lack of proficiency to accomplish the tasks.

15) Number of times the technicians accomplished a job without adequate knowledge to perform the assigned task and/ or with no real idea about the possible consequences of an error. This indicator may indicate the risks involved when a technician performs a task for the first time or a task that requires specific knowledge of the aircraft. These situations can trigger dangerous situations and can reveal lack of skill, knowledge or experience from the staff. It can also reveal that the training is inefficient or incomplete. There are questions directed at this issue in the form, such as "Did you feel prepared for the service?".

Inadequate tools, equipment and parts.

16) Number of times the technicians accomplished a job without appropriate tools, equipment or parts. The objective of this indicator is to capture the frequency in which the technicians work without the proper resources (tools, equipment, spare parts). This is an important metric because local conditions influence the quality of the work and lack of correct tools, equipment and parts can drive violations due to the use of non-approved alternatives, and it may also constitute a contributing factor for maintenance errors.

Workplace environment issues.

17) *Number of reports related to workplace conditions affecting the quality of the job.* This indicator may reveal serious conditions affecting the quality of the work accomplished by the technicians on the line-maintenance stations and that can lead to maintenance errors. These include poor lighting, noise, extreme temperatures, accessibility for maintenance of the aircraft, and many others.

Poor and/ or not updated technical documentation.

18) Number of monthly reports related to difficulties in accomplishing the maintenance tasks due to technical documentation problems. This indicator can reveal a critical source of maintenance errors that can be produced due to conflicting, poor, and inadequate information as well as lack of data in the aircraft maintenance manuals, task cards, and technical publications in general. This also includes dated technical documentation. This indicator is recommended here to stress the importance of risk factors associated with paperwork and technical publication, and its relative importance was analyzed by Chang and Wang (2010).

Work interruptions.

19) Number of times the technicians are getting distracted from their task or are being asked to perform another task while accomplishing their primary assigned one. This indicator has the objective to capture the frequency in which the technicians are interrupted. This is an important metric because every time the work is disturbed the possibility of a memory lapse is increased and the technicians can leave the tasks incomplete, untagged or unattended.

Awareness and attention.

20) Number of times the technicians accomplished a task without being mentally and/ or physically prepared. The main goal of this indicator is to capture the frequency in which the maintenance tasks were accomplished by tired technicians or impaired by fatigue or adverse mental state. These aspects can significantly increase the chances of making errors.

21) Number of errors made by competent technicians during accomplishment of highly familiar tasks. This metric can point out one of the most common errors in maintenance: slips and memory lapses of the technicians. This is especially true when the technicians accomplish very familiar or highly routine procedures and excessively rely on memory.

Shift turnover.

22) Number of issues related to lack of written and verbal communication during shift change. The main objective of this indicator is to capture inadequate communication motivated by shift change (and as a result, task handover) since the error most likely to occur due to poor communication is omission.

The SPIs can be further categorized in terms of the factors involved in the occurrence of human-related issues, such as Task Factors, Local Factors and Organizational Factors. By proposing these initial indicators that can be mostly extracted from the data resulting from the form and others that will require other sources, the researchers believe that Company 1 will have a clearer picture of its line-maintenance operations.

Training Course

By following the guidelines from the Analysis Phase of ADDIE, the researchers have drawn the following conclusions which are organized in accordance with the questions suggested by the framework.

1. Who are the learners and what are their dispositions to be taken into account?

The target audience will be the high and mid-level managers from the line-maintenance. The respective managers, coordinators, supervisors, and leaders will be required to attend training. The researchers understand the target audience have strong technical skills, generally good interrelationship with maintenance technicians, good capacity to set priorities and are hard-working people. They tend to have operational and mission-driven mindsets. Where a problem is identified, a prompt solution shall be applied; not necessarily a solution which will prevent the root cause from repeating or existing. Since they identify themselves as very pragmatic, those who solve issues, they expect the others to deliver immediate solutions. Those programs which take longer to be accomplished are usually left aside or even started and interrupted at a certain point without measuring its effectiveness. The researchers must set a training course that is engaging and cover all the target audience even if goes overschedule.

2. Which new behaviors, knowledge structures, skills are intended?

The main goals of the class are to introduce the managers to three key concepts: Just Culture, human error based on what Sidney Dekker defines as the "New View of Human Error" (Dekker, 2006), and the concept of aviation as a complex system as defined by the book Normal Accidents (Perrow, 1984). Managers are expected to evaluate errors as organizational breakdowns instead of focusing on the individual.

Company 1’s Safety Manual defines safety culture as "establishing actions for the development of a solid Operational Safety Culture based on a "Just Culture", which prioritizes learning. Company 1 promotes awareness to all its "staff members" that their individual actions can affect the safety of operations as well as the duty to formally share and report occurrences, and any condition that may become or are a risk to the operation. The researchers understand that errors are a natural component of human activity. Only deliberate actions motivated by unacceptable attitudes and behaviors can be subject to disciplinary actions (Just Culture).

3. Which constraints exist with regard to learning?

Some gaps to be addressed include leaders being over-preoccupied with technical problems only, inappropriate supervision and monitoring, lack of knowledge about the importance of teamwork, poor communication skills and lack of real and collective situational awareness related to the current working conditions. Since the target audience are very technically-oriented, soft skills will have to be addressed with a certain technical appeal. Otherwise, theoretical concepts might be left aside and consequently not internalized by our target audience in real situations. The target audience have tight work agendas. When training is delivered, they will have to be far from their work environment in order to avoid interruptions. A turn into just culture will be a great change due to the blame culture addressed in this research been going on for some time. Some managers might not adhere to this type of culture if not properly motivated by senior management.

This cultural shift is a particularly challenging aspect of an organization to measure. The researchers believe this because culture is an ongoing accomplishment, which Weick (1995) calls a process of sense-making. Although there are some proposed models like Hofstede's (2011) and guidelines to measure values, psychological job characteristics, individual perceptions, and organizational core tasks (Reinman and Oedewald, 2004), a safety culture measurement will depend on what the organization defines as safety culture. For example, if one runs a red-light, does this mean that one does not have a proper risk assessment culture (Busch, 2016)? It might mean the opposite. The person could have seen a threat like a burglar when stopping at red-light and decided that it would be safer to run the red light at an empty intersection at two a.m. Another example is a pedestrian that might have looked both ways, assessed all the risks and decided to cross at a red-light since there were no hazards present. This conscious analysis may present a stronger safety culture based on risk assessment as opposed to blindly following the rules (Busch, 2016). The course needs to show the underlying organizational accidents, cannot propose a radical change and must be in baby-steps, playing on corporate strengths like open communication and core values.

4. Which options to deliver instructional materials exist?

The target audience has a busy schedule, so the duration of the course is crucial. In order to maintain engagement, from previous courses done in the company, the total duration has to be of one day. Face-to-face learning is essential for delivering this training since discussions will be great opportunities to assess how much people are willing to adopt these concepts in real-life cases. Problem-solving exercises are also key to success. Managers shall promptly demonstrate the new concepts covered in class.

5. Which more far-reaching educational issues must be taken into consideration?

Since the objective of the course is an introduction and a practical guide, general terms will be introduced and matured with follow-ups by the researchers to assess the practical applications introduced. Although the training itself will be a day only, since there is a paradigm shift in culture, reinforcement campaigns will have to be carried out so that managers are recurrently stimulated to apply the principles of just culture in real situations.

By following ADDIE's guidelines, the course can be quickly organized and set-up defining the key aspects, such as target audience, subject, and structure. To view the lesson plan, refer to Appendix H.

Chapter V

Conclusions and Recommendations

This conclusion chapter discusses the observations from the functionality pre-testing done by the focus group for the form as well as the expectations with the just culture course. In the recommendations section, the following aspects are discussed: further testing for the form, application of the course, and the practicalities for integrating both fronts.

Since the SPIs depend on the form being filled out, as well the configuration of Company 1's business intelligence software to read it, there are no SPIs example or tests. Time restriction also impeded the test-run of one of the just culture courses with the maintenance department. However, since the proposal is based on Company 1's tested dedicated just culture course, the researchers understand that the dynamics and general content have already been pre-tested. The changes required would be to adapt it to the time-frame available to the maintenance managers and use practical examples closer to the maintenance environment. Company 1's safety database is rich with examples to be used and adapted to the course. Further academic testing and improvements were not done due to time restrictions.

The final goal was to build a practical project that would help improve and progress the maintenance safety culture. In addition, the researchers believe a study of the evolution of this research is a promising field for understanding cultural shifts. Nevertheless, Company 1's Safety and Maintenance departments have shown great interest in the initiative and are already planning to execute the form and classes at the beginning of the coming year.

Conclusions

As mentioned before, the focus group was comprised of the researchers and the maintenance focal point for line-maintenance issues. The conclusions mentioned below are based on their observations.

Safety Form. This section will be divided in the following subsections: overview, ease of use, ease of comprehension, and integration into the existing safety database.

Overview. When testing the form, the focus group was unanimous that it was an improvement regarding already existing channels. These channels are general-purpose form and e-mails. The maintenance focal point was enthusiastic about the number of fields available for the user and the division of the tasks and its sub-divisions. He felt that it will help organize the issues into a friendly way that provokes a reflection about where the problem is as well as how it originates. One of the researchers also believes that this organization of the form can help managers improve the mapping of a risk by tracing back its organizational roots.

The focus group also believes that the division between "task-related" and "non-task related" will boost the usage of the form, especially in the early phases. This perception comes from the fact that there is a certain refrain to report one's own mistakes and a bias towards pointing the finger at the organization. Nevertheless, as the just culture classes take effect, and technicians are more open to self-reporting, this dynamic might change. It was also discussed that there needs to be a massive campaign towards emphasizing the confidentiality of the users.

Ease of Use. Although the form fields and its objective are clear, the first step to apply it to Company 1 will be to translate it into the native language. It was also a consensus in the focus group that the form needs to be less visually dense on the "task-related" tab. There are many visual elements which cause an initial overload of information. One of the researchers proposed to divide the "task-related" tab into two. One for planning and execution and the other one for closure and release.

The software where the form is sited also helps users avoid mistakes. The focus group purposely left out mandatory fields and wrote letters instead of numbers in the time fields. When trying to submit the form with these non-compliances, the software promptly warned the user.

Lastly, the focus group felt that the exclusivity of the form as a channel for line-maintenance safety issues will help organize the information and increase the use of the form. This is an improvement to the Safety department because it does not need to organize information from different channels, it helps the target audience because it makes clear that the only channel is the form and helps the maintenance managers who will receive automatically generated clean SPIs.

Ease of Comprehension. The diction was found to be easily comprehensible and aligned with the jargon used in recurrent training. The form was also found fast to fill-out, clocking an average of 5 minutes per user. It is important to note that the form was developed by one of the researchers and pre-tested by the other members of the focus group. The members of the focus group that teach the maintenance courses observed that it is an easy tool to open and explain in class. This generated the idea of integrating it into part of the initial and recurrent maintenance training.

Integration into Company 1's Safety Database. The safety member of the focus group ran a cross-check by using the fields of the form with the HFACS terminology, airport bases database, aircraft type database, and MIS database. The cross-check showed that the data inserted into the form would be integrated into already existing datasets. This will facilitate the future maintenance safety datasets to be integrated into already existing organizational factors mapping and general safety data. Thus, contributing to the general quality and scope of the safety database.

In general, the form was well accepted by the focus group and will be translated. Another necessary change is to make its visual aspect less dense. However, in addition, the researchers will be testing the form with a valid population of line-maintenance technicians to evolve into a next phase and future launch. Another observation was to make a form of promotion material explaining its objectives and reinforcing its confidentiality aspect.

Just Culture Course. As mentioned before, the general structure and themes are based on a proven and active just culture course at Company 1. This course is given to every member of the Safety department as well as other employees, such as CRM instructors, Flight Operation bosses, ground instructors and other members. The key was to adapt the time frame to the one-day requirement and adapt the examples. The researchers believe that this goal has been met.

Recommendations

Safety Form. The safety form requires further testing to be able to go into production. For the next steps, the researchers believe that a focus group that involves the target audience needs to be created in order to validate the form. It would be productive to ask the users how easy it is to use the form, if the terms make sense, if the task division in the form is adequate and valid, and most of all: how to create a solid perception of confidentiality. Another important aspect is to test the form on mobile devices and completion time requirements. To further promote it, the promotional material needs to emphasize that the development was validated by their peers. This may create a sense of pride from the participants and help the technicians take ownership of the form usage and evolution.

SPIs. After the first testing of the form, the database will begin to populate. This can already help the Safety department configure the business intelligence software to read and analyze the data by creating test frames for the SPIs. Once these frames are available, they can be presented to maintenance leadership and high-level management in order to be tested for validity and comprehension. This can help retro-feed the form development process and help adjust it to the needs of the data consumer.

Integration of safety form and just culture course. The researchers believe that this integration of a cultural change promotion and the safety form will help provoke the advancement of a just culture mentality in the Maintenance department. In the researchers' view and experience, the aspects of a just culture mentality are well-accepted in other areas and should not encounter many difficulties in the Maintenance department as long as it is a gradual change. Once this mentality is developed, it can create a need for more accurate data, mostly because the managers will need to map the organizational factors. The form will help generate these SPIs. These SPIs on the one hand will give the line-maintenance managers quality data to work with and on the other will also feed the Safety Department's database with richer information. This will help the company have a clearer image of how its complexity is creating risks, how to map them and ultimately how to manage them.

Key Lesson Learned

Although there are a lot of theoretical and practical studies about how to build forms, SPIs, and courses, the researchers find there is a need to work these ideas in tandem with what the organization needs. Every company has its particularities due to the country they are in, business model, and other factors. This makes every user unique. There is no one-size fits all solution and by aggregating these needs to the literature available while making the concepts digestible for the organization willing to apply them, the researchers feel that this change will have more chances to of success.

Final Considerations

It is of the researchers' consensus that the objectives of this research were completed. Company 1 now has a roadmap that can guide towards improving maintenance risk exposure by means of establishing a just culture, improving tools, and indicators. However, the strategies and concepts discussed in this research such as just culture and safety forms are of universal value. The strategies described can be adapted to any airline or field wishing to improve safety culture and risks management.

References

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

Busch, C. (2016). *Safety Myth 101.* San Bernardino: Mind the Risk.

Chang Y., Wang Y., (2010). Significant human risk factors in aircraft maintenance technicians. *Safety Science (Issue 48)*, 54-62.

Dekker, S. W. A., Linköpings universitet, Industriell arbetsvetenskap, Tekniska högskolan, & Institutionen för ekonomisk och industriell utveckling. (2002). Reconstructing human contributions to accidents: The new view on error and performance. Journal of Safety Research, 33(3), 371-385. doi:10.1016/S0022-4375(02)00032-4

Dekker, S. (2005). Ten questions about human error: A new view of human factors and system safety. Boca Raton, FL: CRC Press.

Dekker, S., & ebrary, I. (2006). *The field guide to understanding human error* (rev. ed.). Aldershot, England; Burlington, Vt;: Ashgate.

Dekker, S. (2007). *Just Culture; who gets to draw the line?* Lund University School of Aviation, Sweden.

Dekker, S., & ebrary, I. (2007). *Just culture: Balancing safety and accountability*. Aldershot, England; Burlington, VT;: Ashgate.

Glendon, A. I., & Stanton, N. A. (2000). Perspectives on safety culture. *Safety Science (Issue 34*), 193-214. doi:10.1016/S0925-7535(00)00013-8

Guldenmund, F. W. (2010). (mis)understanding safety culture and its relationship to safety management. *Risk Analysis: An Official Publication of the Society for Risk Analysis (Issue 30(10))*, 1466. doi:10.1111/j.1539-6924.2010.01452.x

Haines, R. L., Jr. (2008). *The relationship between learning styles and test performance in aviation maintenance technicians.*

Herrera, I. A., Nordskaga A. O., Myhreb G., Halvorsenb K. (2009). Aviation safety and maintenance under major organizational changes, investigating non-existing accidents. *Accident Analysis and Prevention (Issue 41)*, 1155–1163.

Hobbs, A. (2004). Latent Failures in the Hangar: Uncovering Organizational Deficiencies in Maintenance Operations. *Isasi Gold Coast* (p. 11). Nasa Ames Research Center, USA.

Hobbs, A. (2008). *An Overview of Human Factors in Aviation Maintenance.* Australian Transport Safety Bureau. Canberra City, Australia: Australian Transport Safety Bureau.

Hofstede, G. (2011). *Dimensionalizing Cultures: The Hofstede Model in Context.* Maastricht: Online Readings in Psychology and Culture.

Langer, M., & Braithwaite, G. R. (2016). The development and deployment of a maintenance operations safety survey. *Human Factors: The Journal of Human Factors and Ergonomics Society*, 58(7), 986-1006. doi:10.1177/0018720816656085

Lofquist, E. A. (2010). The art of measuring nothing: The paradox of measuring safety in a changing civil aviation industry using traditional safety metrics. *Safety Science, 48*(10), 1520-1529. doi:10.1016/j.ssci.2010.05.006

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

National Transportation Safety Board. 2003. Loss of Control and Impact with Pacific Ocean, Alaska Airlines Flight 261, McDonnell Douglas MD-83, N963AS, About 2.7 Miles North of Anacapa Island, California, January 31, 2000. Aircraft Accident Report NTSB/AAR-02/01. Washington, DC.

Øien K., Utne I. B.,Tinmannsvik R. K., Massaiu S. (2011). Building safety indicators: Part 2 - Application, practices and results. *Safety Science (Issue 49),* 162-171.

Patankar, M. S. (2002). *Root Cause Analysis of Rule Violations by Aviation Maintenance Technicians.* San Jose State University, Department of Aviation. San Jose, CA: FAA Office of Aviation Medicine.

Perrow, C. (1984). *Normal accidents: Living with high-risk technologies.* New York: Basic Books.

Rankin, B., & Allen, J. (1996, April-June). Boeing introduces MEDA, Maintenance Error Decision Aid. *Airliner*, 20-27.

Rashid H. S. J., Place C. S., Braithwaite, G. R. (2012). Investigating the investigation: a retrospective study in the aviation maintenance error causation. *Cognition, Technology & Work*, 15(2), 171-188. doi:10.1007/s10111-011-0210-7

Reason, J. (1997). *Managing the Risks of Organizational Factors.* Aldershot, UK: Ashgate.

Reinman, T., & Oedewald, P. (2004). Measuring maintenance culture and maintenance core task with CULTURE-questionnaire—a case study in the power industry. *Safety Science*, 859-899.

Ruitenberg, B. (2002). Court case against Dutch controllers. *The Controller (Issue 41),* 22–5.

Safety Management Manual (DOC 9859). (2018). Montreal, Quebec: ICAO.

Safety Management International Collaboration Group (2013). *Measuring safety performance - Guidelines for service providers.* Skybrary.

Sedgwick, P. (2013). Convenience sampling. *BMJ: British Medical Journal, 347*doi:10.1136/bmj.f6304

Seel, N. M., Lehmann, T. (. r., Blumschein, P., Podolskiy, O. A., & SpringerLink (Online service). (2017). *Instructional design for learning: Theoretical foundations*. Rotterdam: SensePublishers

Snook, S. A., & Project Muse. (2000). *Friendly fire: The accidental shootdown of U.S. black hawks over Northern Iraq*. Princeton, N.J: Princeton University Press.

Transport Canada 2003. Human Performance Factors for Elementary Work and Servicing. TP14175E. Ottawa, ON

USN, C., Center, N. S., Norfolk, N. S., Lawson, V. M. D., & Figlock, R. HUMAN FACTORS ANALYSIS & CLASSIFICATION SYSTEM–MAINTENANCE EXTENSION (HFACS-ME) REVIEW OF SELECT NTSB MAINTENANCE MISHAPS: AN UPDATE.

Vaughan, D., & ebrary, I. (1996; 1997). *The challenger launch decision: Risky technology, culture, and deviance at NASA*. Chicago: University of Chicago Press.

Ward, M., McDonald, N., Morrison, R., Gaynor, D., & Nugent, T. (2010). A performance improvement case study in aircraft maintenance and its implications for hazard identification. *Ergonomics, 53*(2), 247-267. doi:10.1080/00140130903194138

Weick, K. (1993). *Organizational change and redesign: Ideas and insights for improving performance*. Oxford: Oxford University Press.

Weick, K. (1995). *Sensemaking in organizations.* Thousand Oaks: Sage.

Wiegmann, D. A., & Shappell, S. A. (2003; 2017; 2007). *A human error approach to aviation accident analysis: The human factors analysis and classification system* (1st ed.). Aldershot, Hants, England; Burlington, VT;: Ashgate. doi:10.4324/9781315263878

Appendix A

Company 1 Confidentiality Agreement

Sunday, October 14, 2018 at 2:42:56 PM Brasilia Standard Time

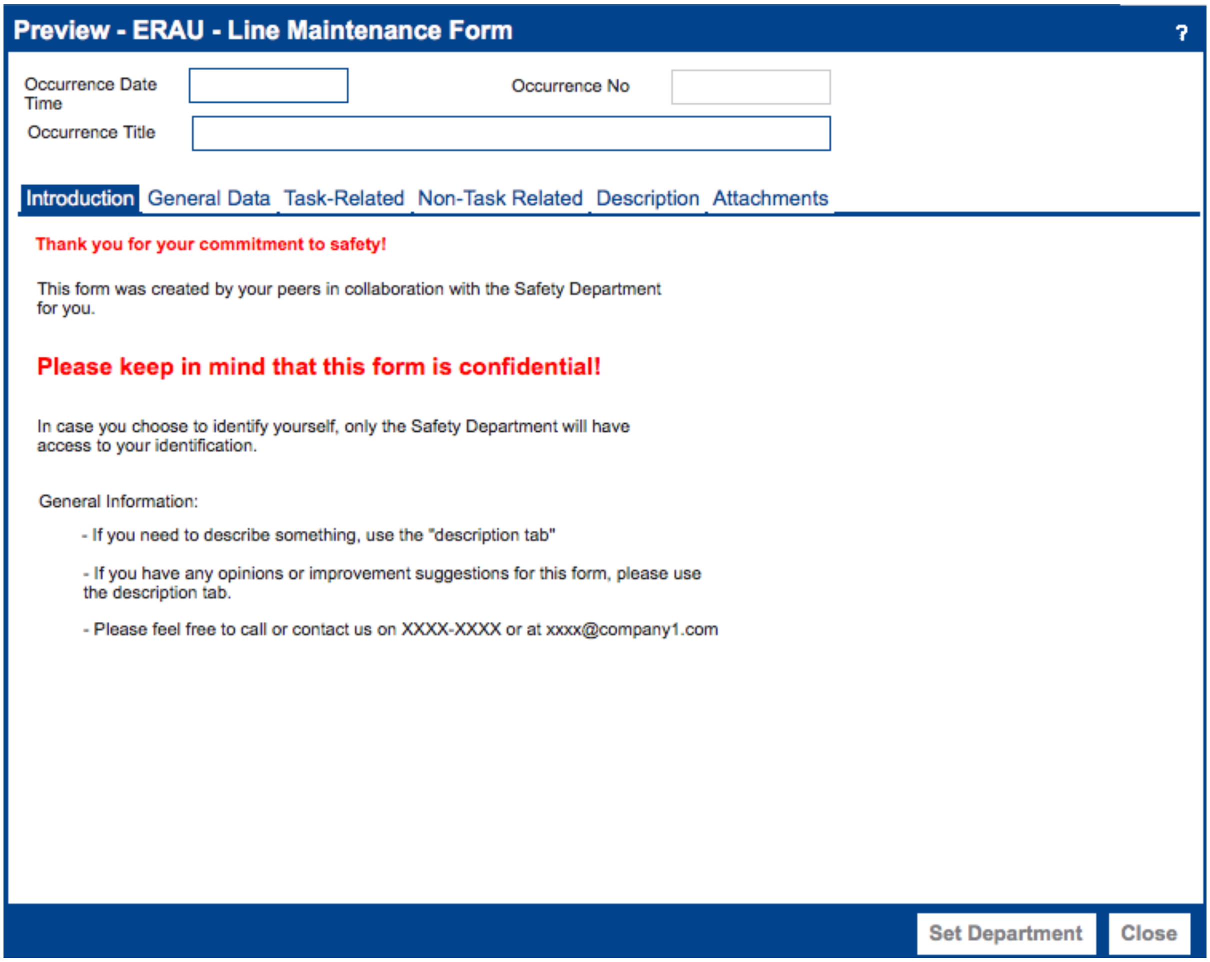
Subject: Event data utilization
Date: Wednesday, 15 August 2018 12:24:59 Brasilia Standard Time
From: [redacted]
To: Caio Rosante Garcia

Caio
We have no restriction in using [redacted] event data for academic purpose as far as the data is completely de-identified.
Regards

[redacted]
Safety [redacted]

Appendix B

Introduction Page


Preview - ERAU - Line Maintenance Form ?

Occurrence Date Time

Occurrence No

Occurrence Title

Introduction | General Data | Task-Related | Non-Task Related | Description | Attachments

Thank you for your commitment to safety!

This form was created by your peers in collaboration with the Safety Department for you.

Please keep in mind that this form is confidential!

In case you choose to identify yourself, only the Safety Department will have access to your identification.

General Information:

- If you need to describe something, use the "description tab"
- If you have any opinions or improvement suggestions for this form, please use the description tab.
- Please feel free to call or contact us on XXXX-XXXX or at xxxx@company1.com

Set Department | Close

Figure 2. Introduction Page

Appendix C

General Data

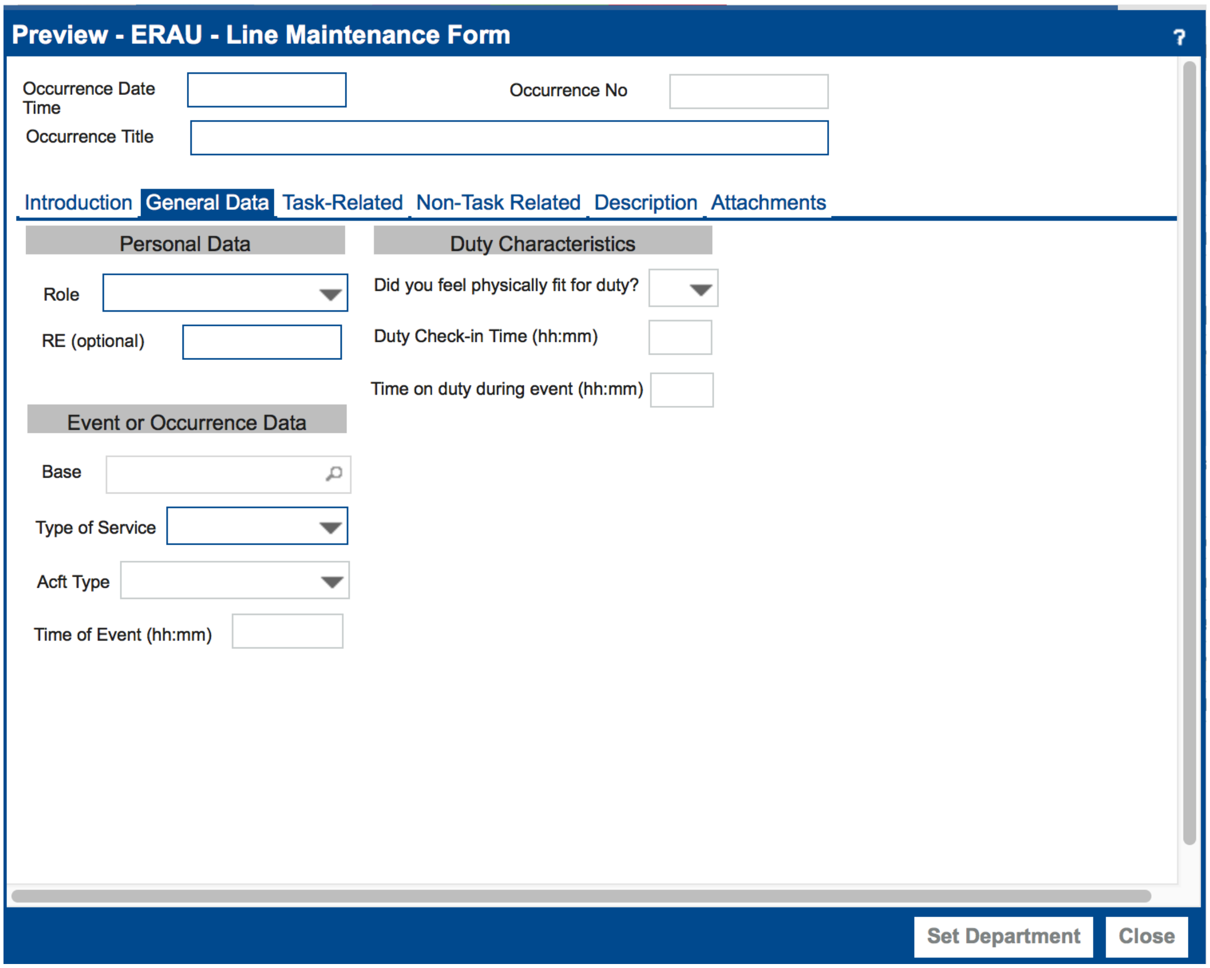


Figure 3. Overview Page

"Role" drop-down menu overview

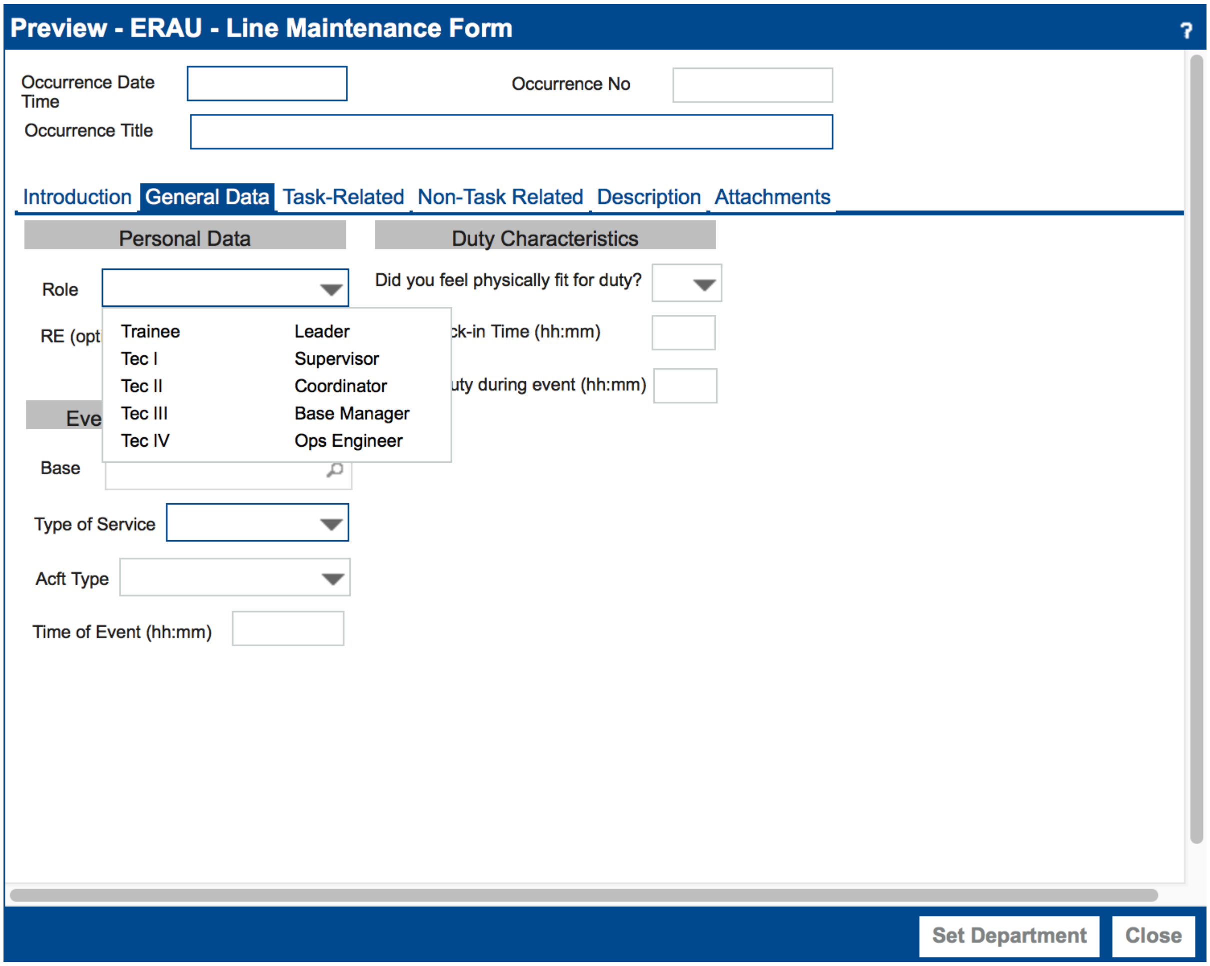


Figure 4. "Role" drop-down menu overview.

“Type of Service" drop-down menu overview

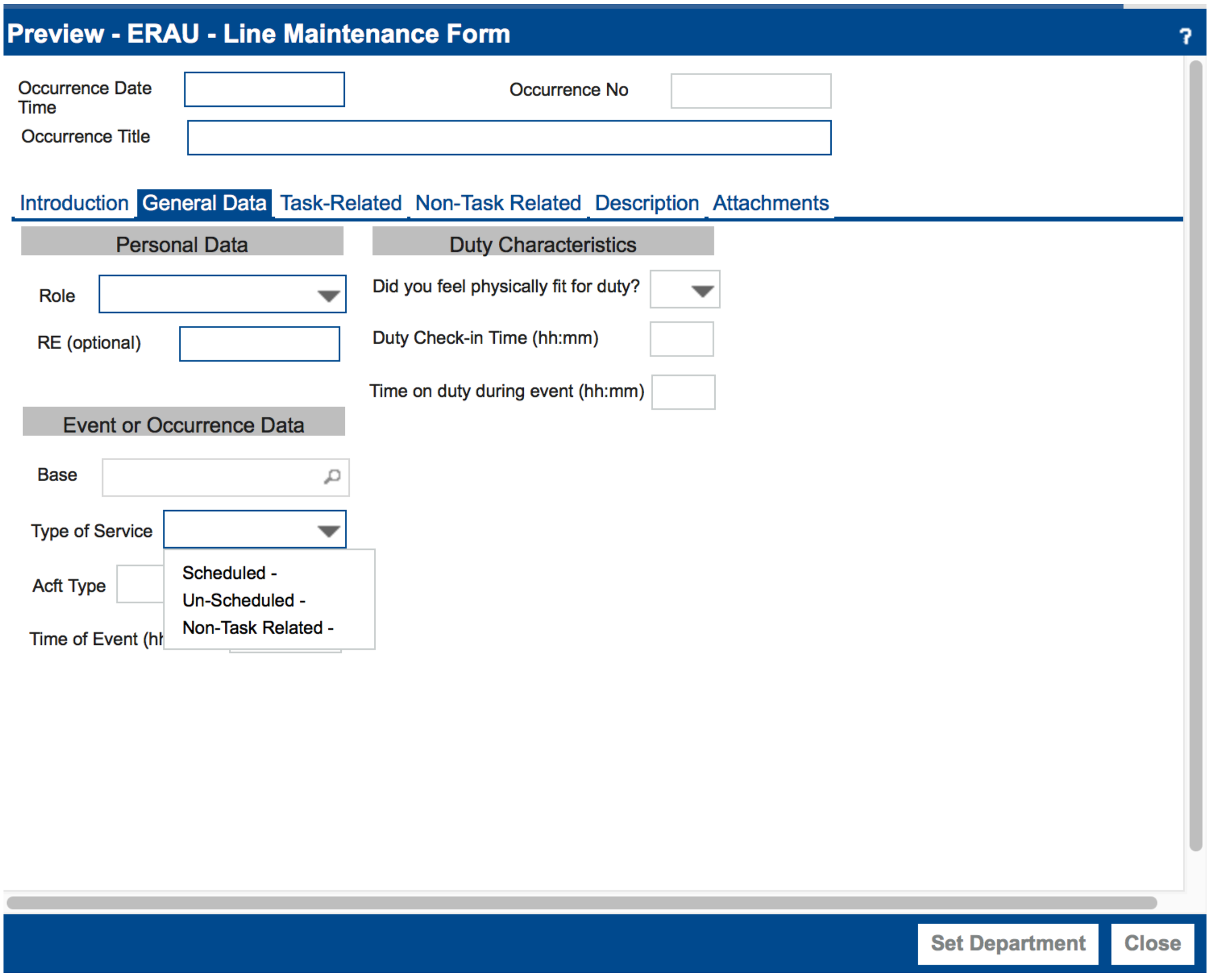


Figure 5. "Type of Service" drop-down menu overview.

"Did you feel physically fit for duty?"

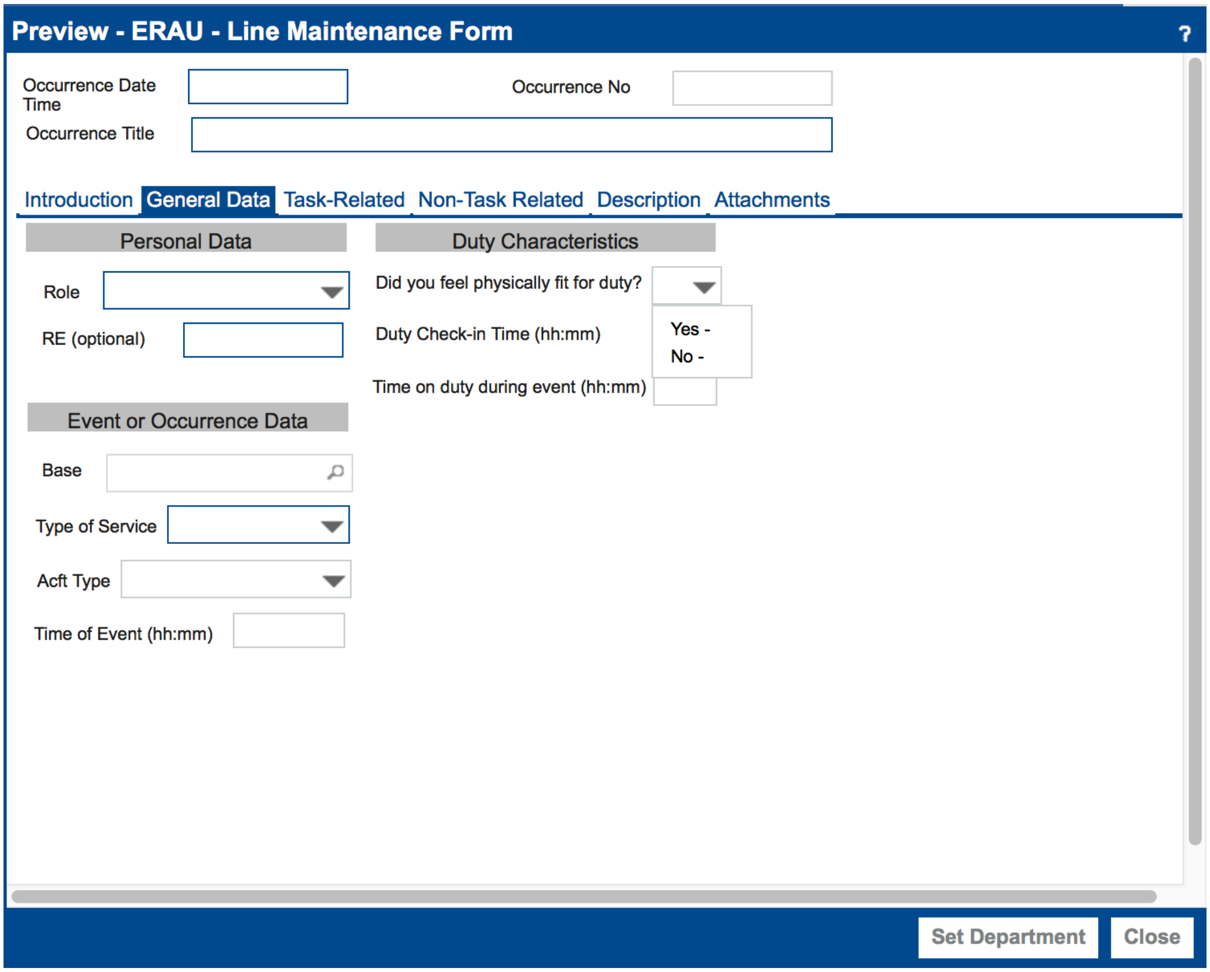


Figure 6. "Did you feel physically fit for duty?" overview

Appendix D

Task Related

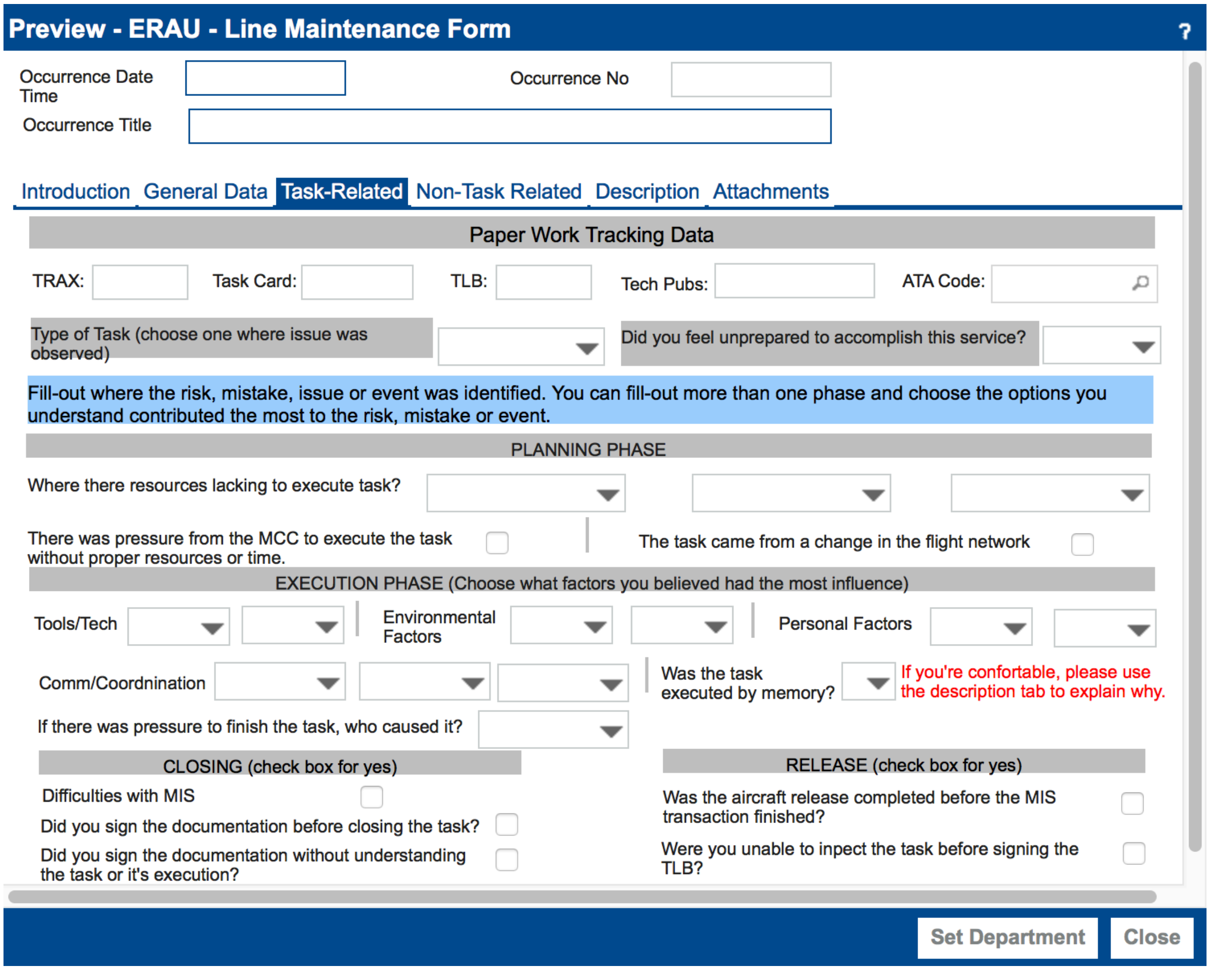


Figure 7. "Task-related" page overview

"ATA Code" menu overview

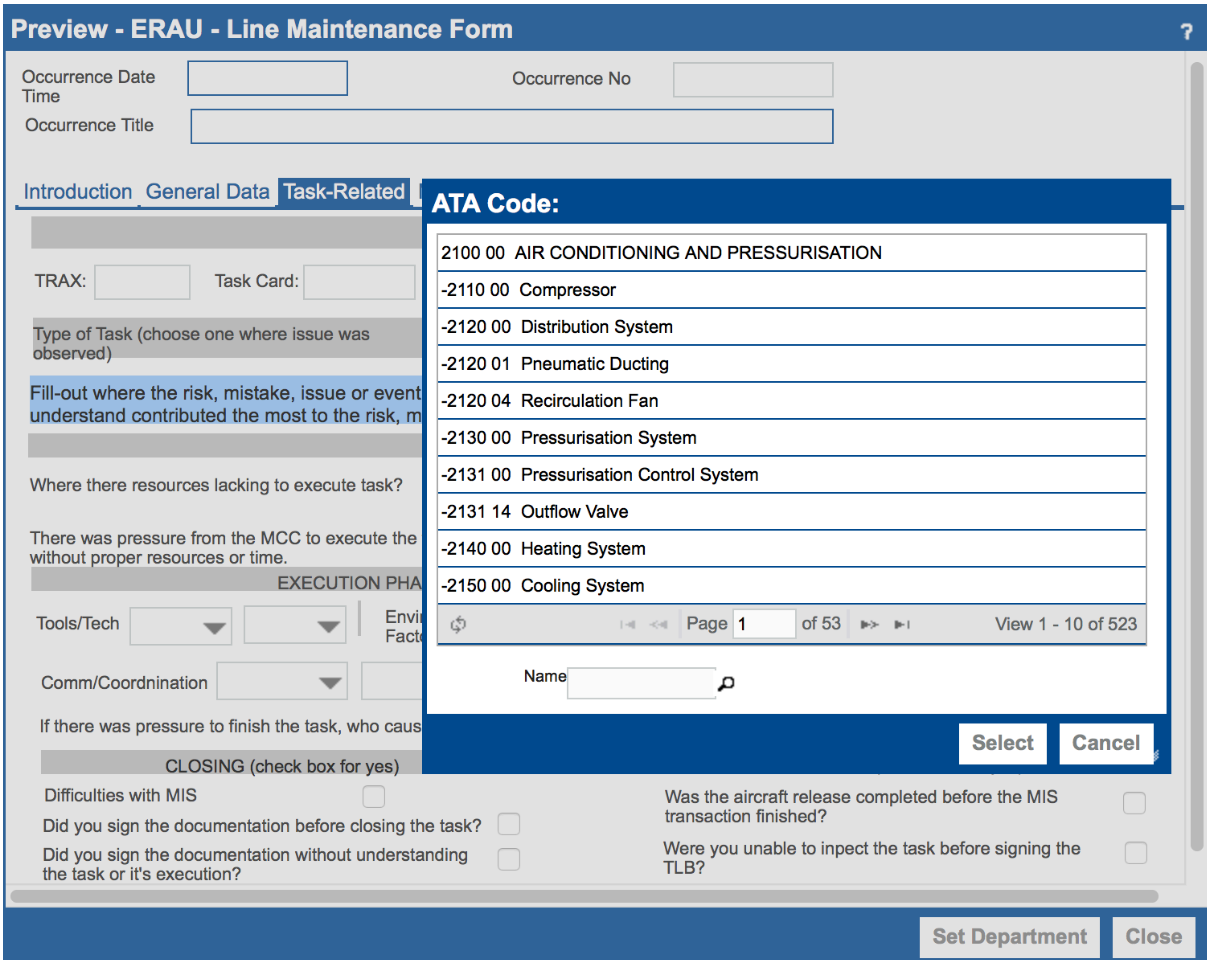


Figure 8. "ATA Code" menu overview

"Type of Task" drop-down menu overview

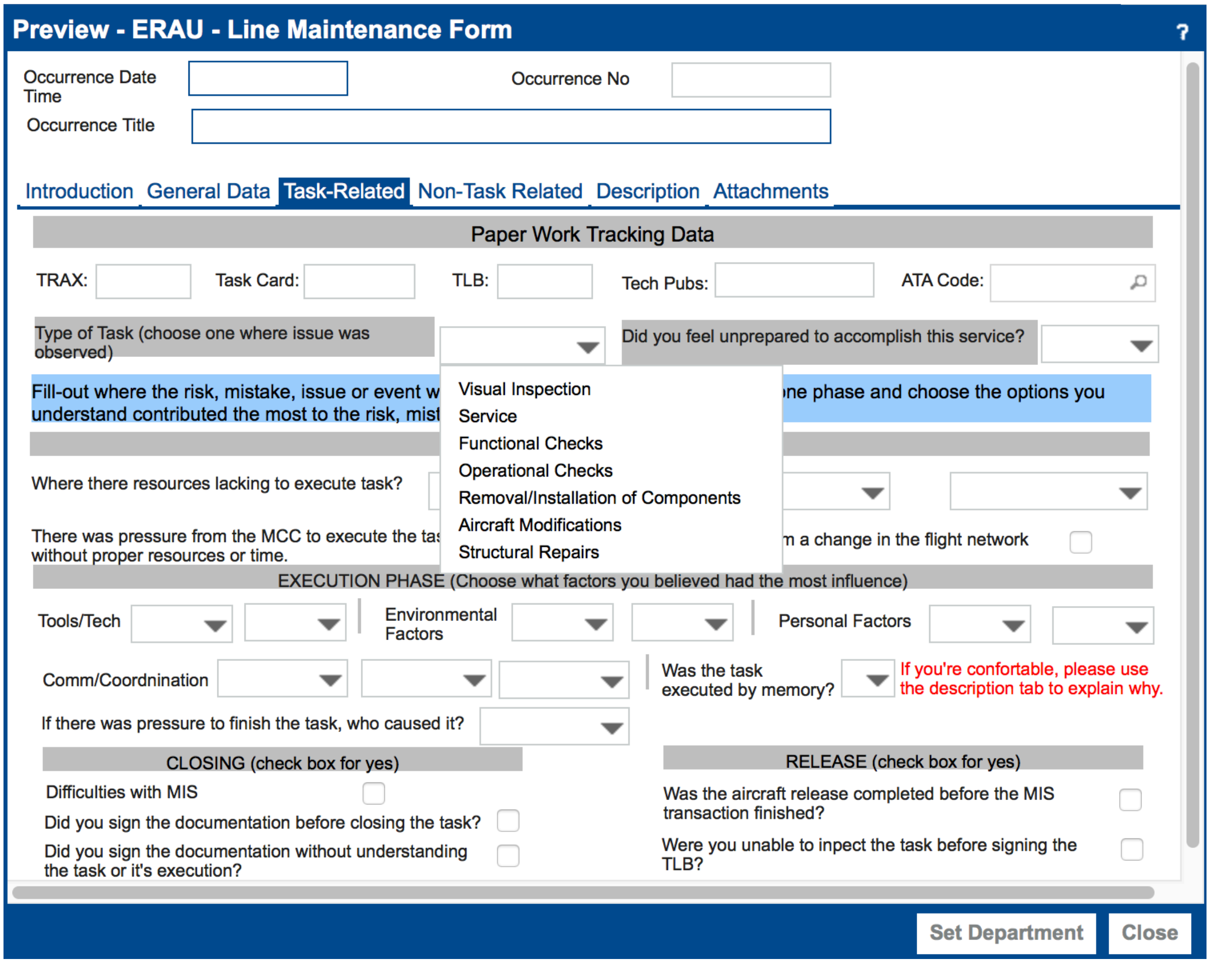


Figure 9. "Type of Task" drop-down menu overview

"Did you feel unprepared to accomplish this duty service?" subcategory overview

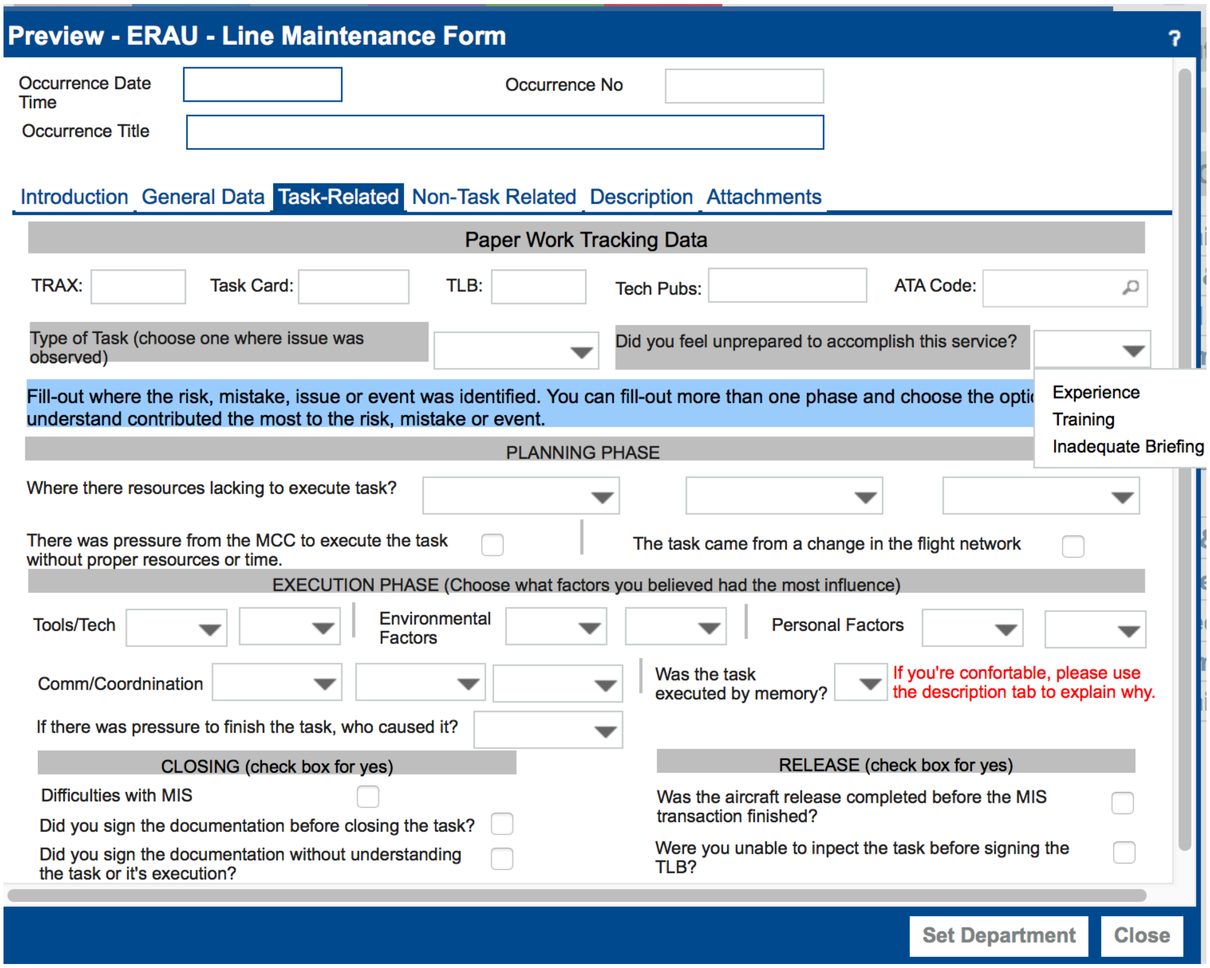


Figure 10. "Did you feel unprepared to accomplish this duty service?" subcategory overview

"Were the resource issues to execute the task?" drop-down menu overview

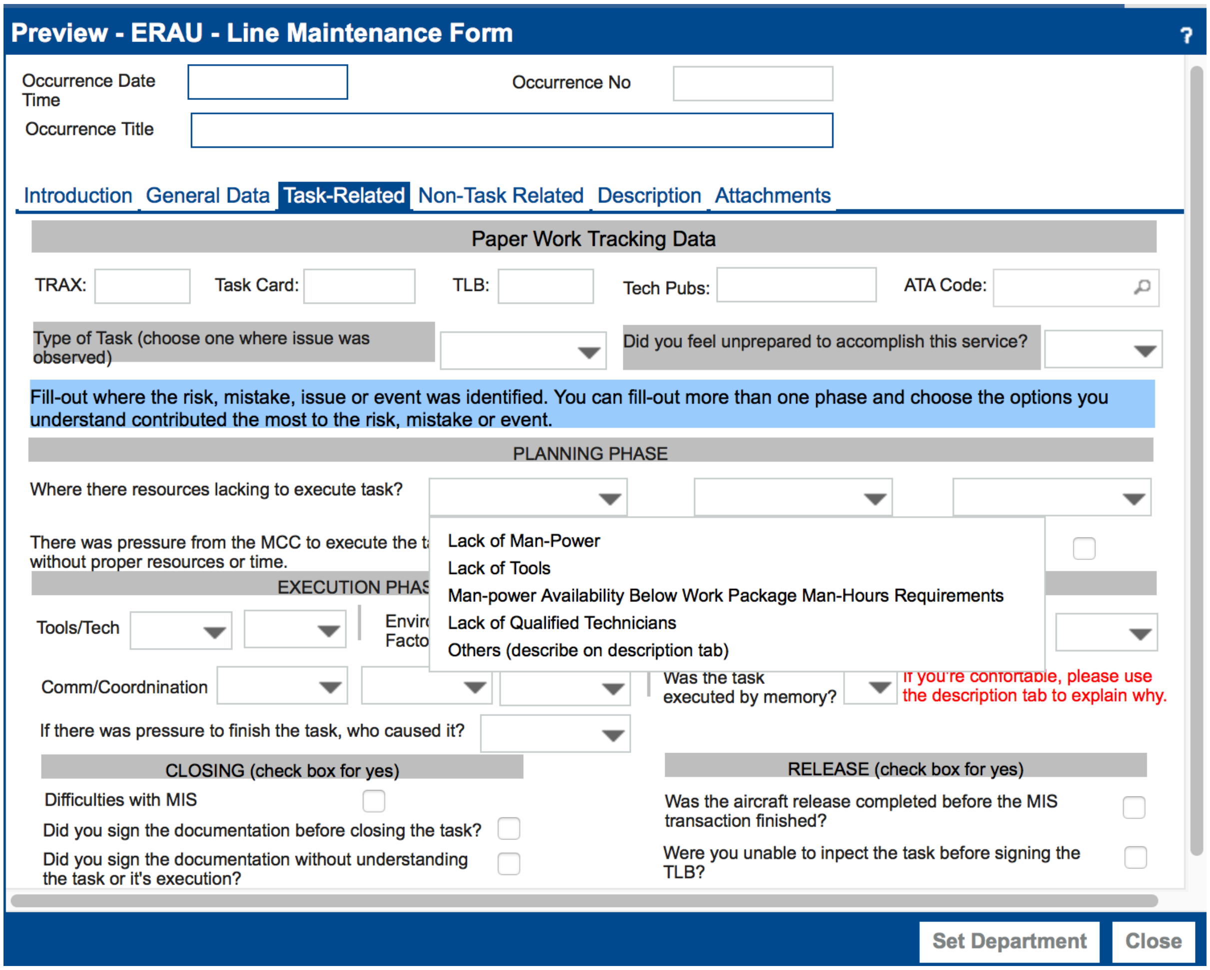


Figure 11. "Were the resource issues to execute the task?" drop-down menu overview

"Tools and Tech" drop-down menu overview

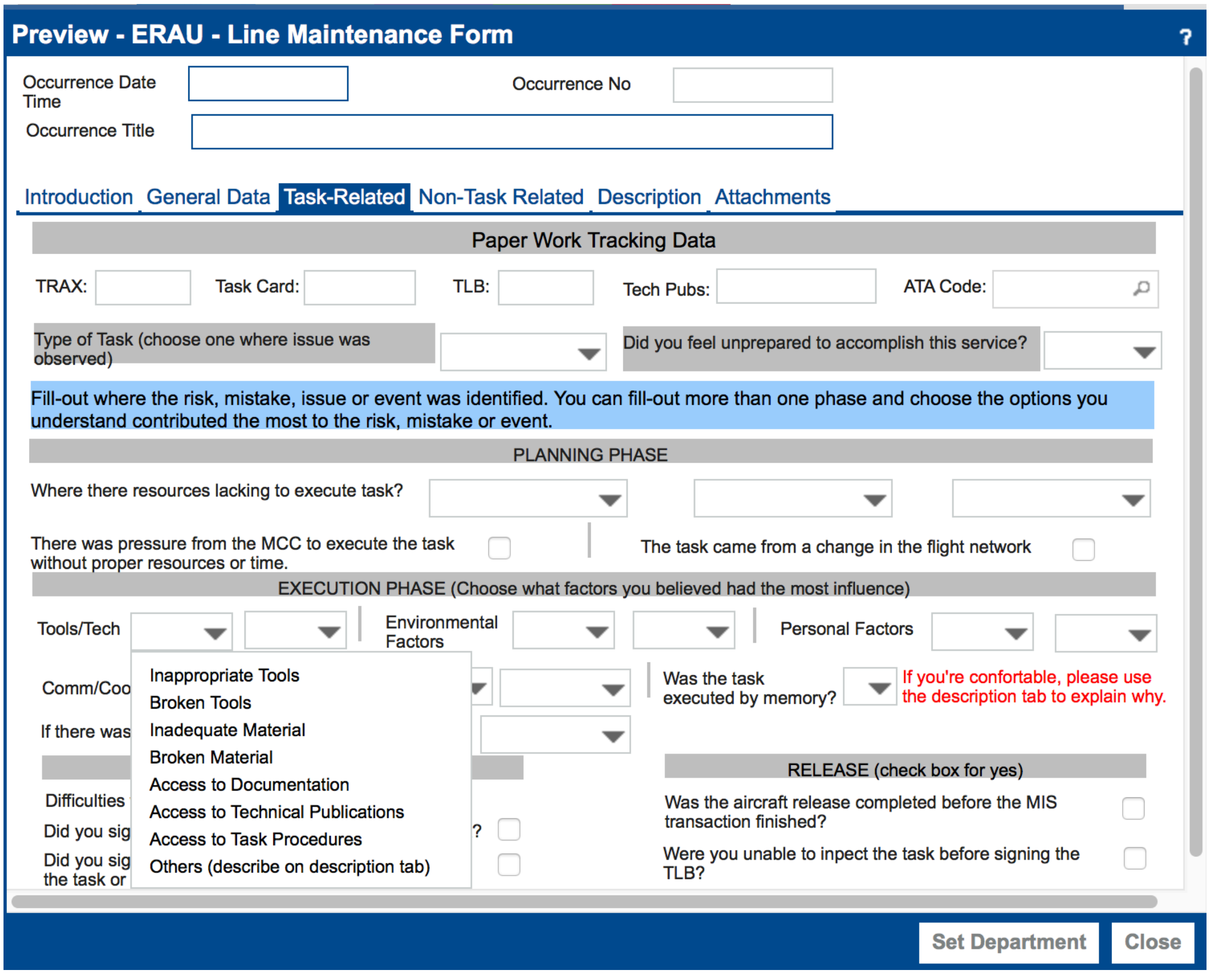
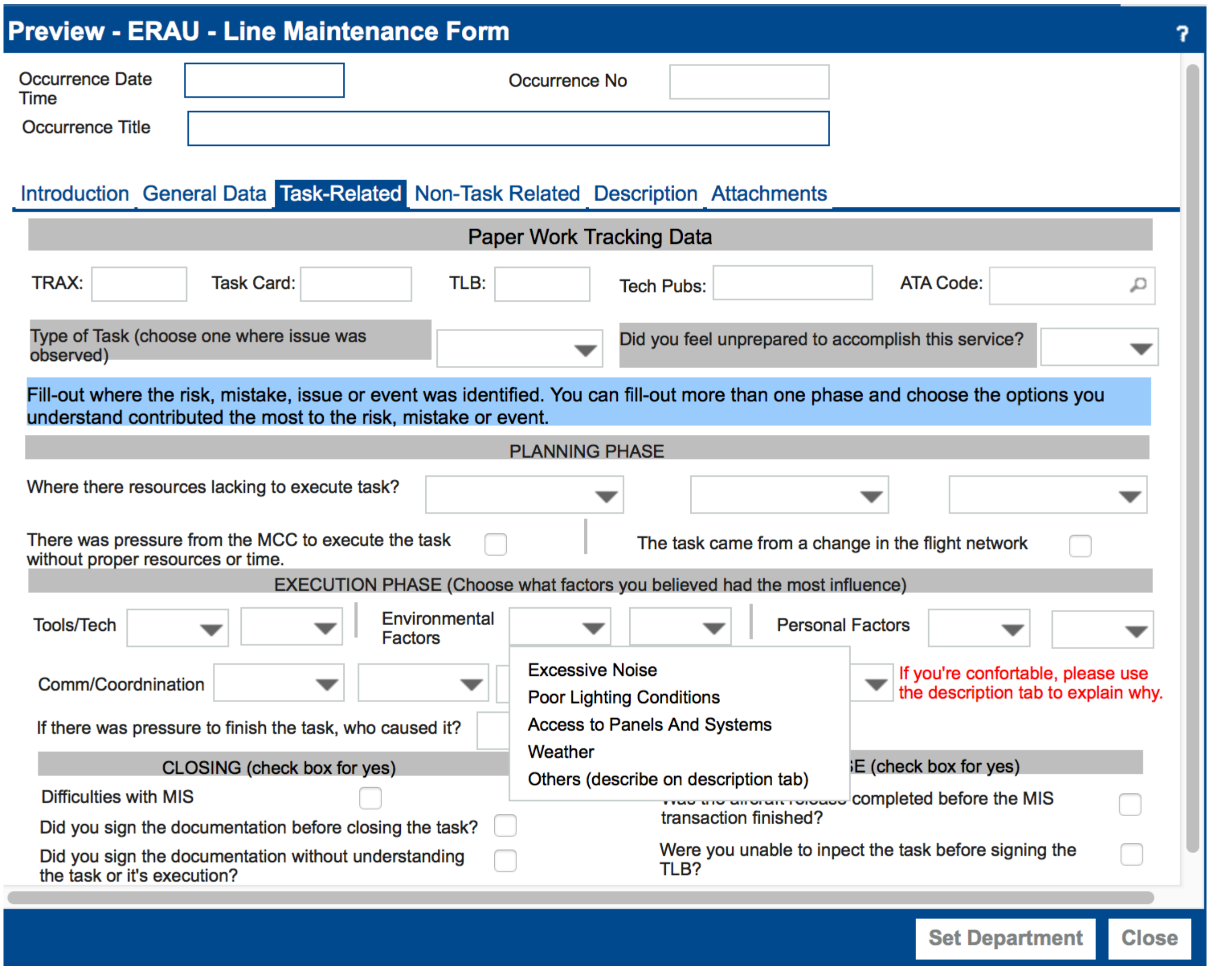


Figure 12. "Tools and Tech" drop-down menu overview

"Environmental Factors" drop-down menu overview



Preview - ERAU - Line Maintenance Form ?

Occurrence Date Time

Occurrence No

Occurrence Title

Introduction General Data Task-Related Non-Task Related Description Attachments

Paper Work Tracking Data

TRAX: Task Card: TLB: Tech Pubs: ATA Code:

Type of Task (choose one where issue was observed)

Did you feel unprepared to accomplish this service?

Fill-out where the risk, mistake, issue or event was identified. You can fill-out more than one phase and choose the options you understand contributed the most to the risk, mistake or event.

PLANNING PHASE

Where there resources lacking to execute task?

There was pressure from the MCC to execute the task without proper resources or time.

The task came from a change in the flight network

EXECUTION PHASE (Choose what factors you believed had the most influence)

Tools/Tech

Environmental Factors

Personal Factors

Excessive Noise

Poor Lighting Conditions

Access to Panels And Systems

Weather

Others (describe on description tab)

Comm/Coordnination

If you're confortable, please use the description tab to explain why.

If there was pressure to finish the task, who caused it?

CLOSING (check box for yes)

E (check box for yes)

Difficulties with MIS

completed before the MIS transaction finished?

Did you sign the documentation before closing the task?

Did you sign the documentation without understanding the task or it's execution?

Were you unable to inpect the task before signing the TLB?

Set Department Close

Figure 13. "Environmental Factors" drop-down menu overview

"Personal Factors" drop-down menu overview

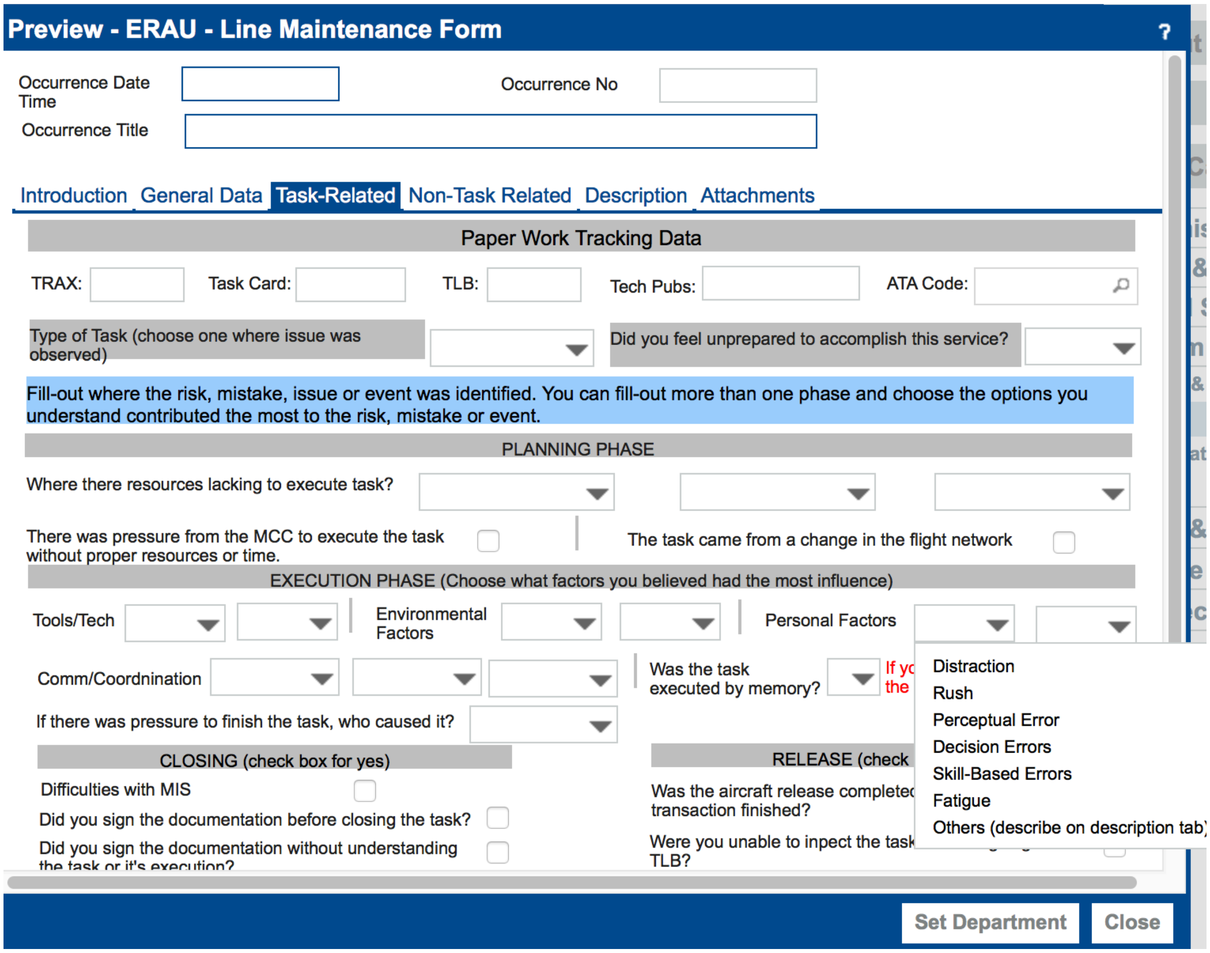


Figure 14. "Personal Factors" drop-down menu overview

"Comm/Coordination" drop-down menu overview

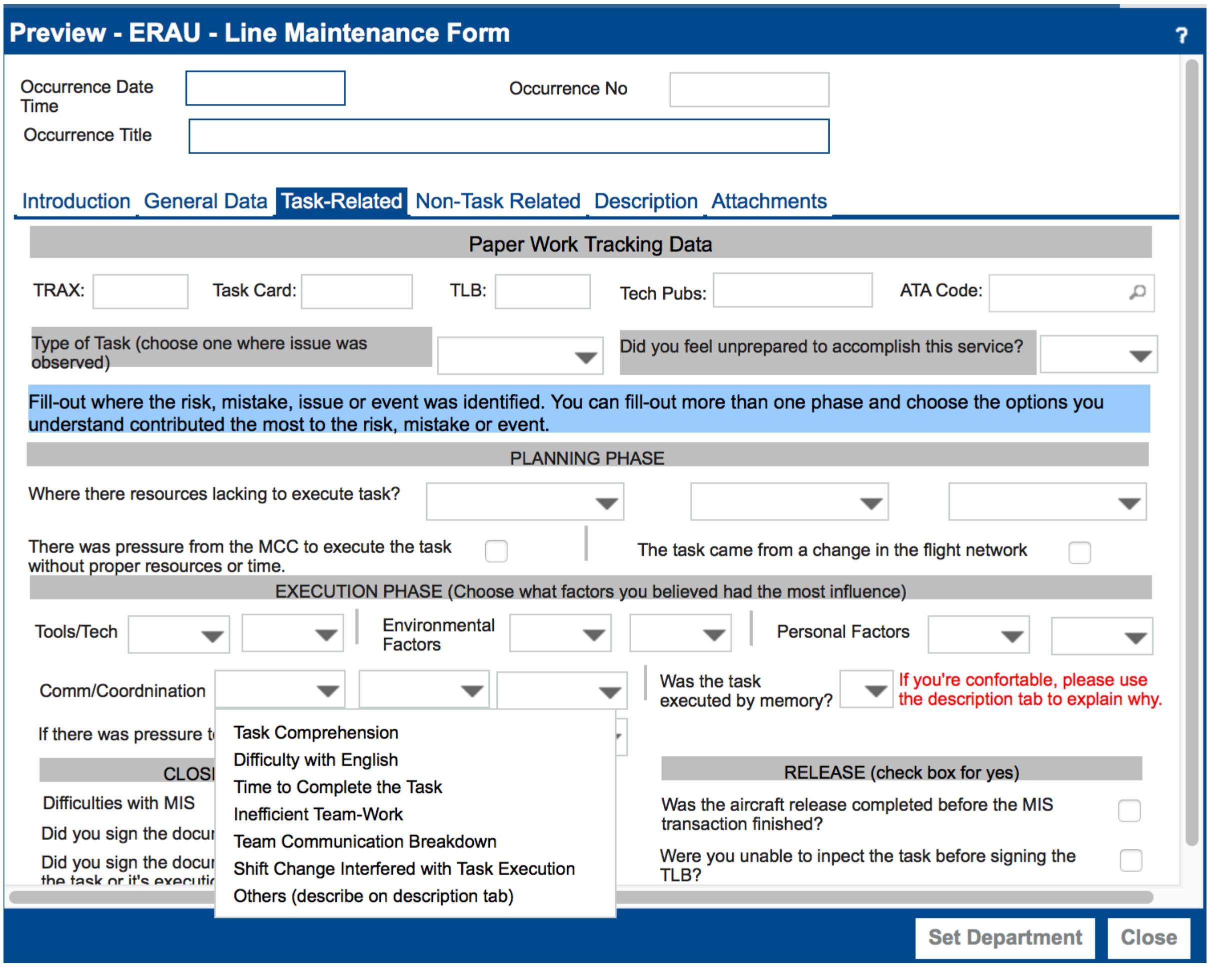
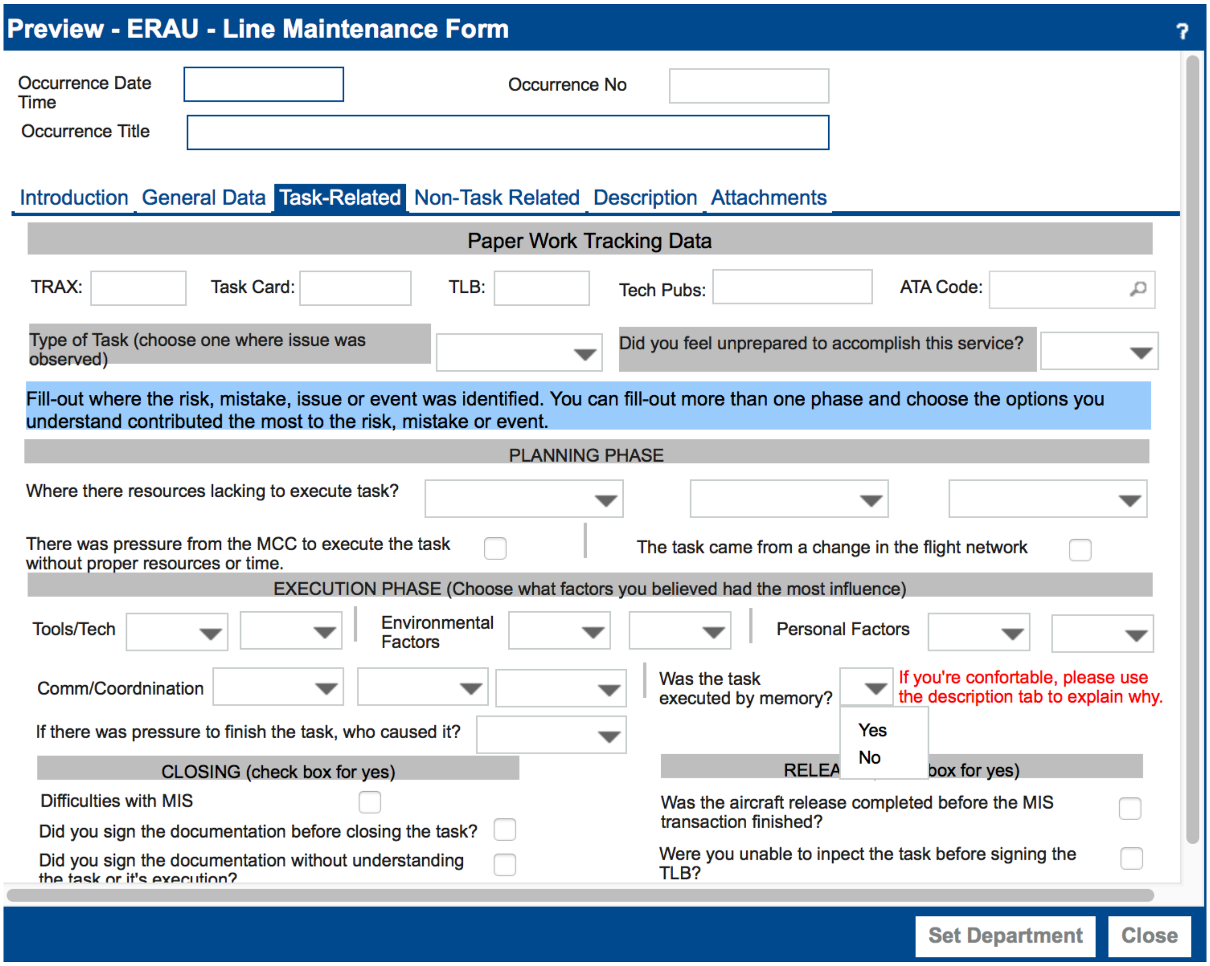


Figure 15. "Comm/Coordination" drop-down menu overview

"Was the task executed by memory?" drop-down menu overview


Preview - ERAU - Line Maintenance Form ?

Occurrence Date Time
Occurrence No
Occurrence Title

Introduction General Data Task-Related Non-Task Related Description Attachments

Paper Work Tracking Data

TRAX: Task Card: TLB: Tech Pubs: ATA Code:

Type of Task (choose one where issue was observed)
Did you feel unprepared to accomplish this service?

Fill-out where the risk, mistake, issue or event was identified. You can fill-out more than one phase and choose the options you understand contributed the most to the risk, mistake or event.

PLANNING PHASE

Where there resources lacking to execute task?

There was pressure from the MCC to execute the task without proper resources or time.
The task came from a change in the flight network

EXECUTION PHASE (Choose what factors you believed had the most influence)

Tools/Tech
Environmental Factors
Personal Factors

Comm/Coordnination
Was the task executed by memory?
If you're confortable, please use the description tab to explain why.

Yes
No

If there was pressure to finish the task, who caused it?

CLOSING (check box for yes)
RELEA box for yes)

Difficulties with MIS
Did you sign the documentation before closing the task?
Did you sign the documentation without understanding the task or it's execution?

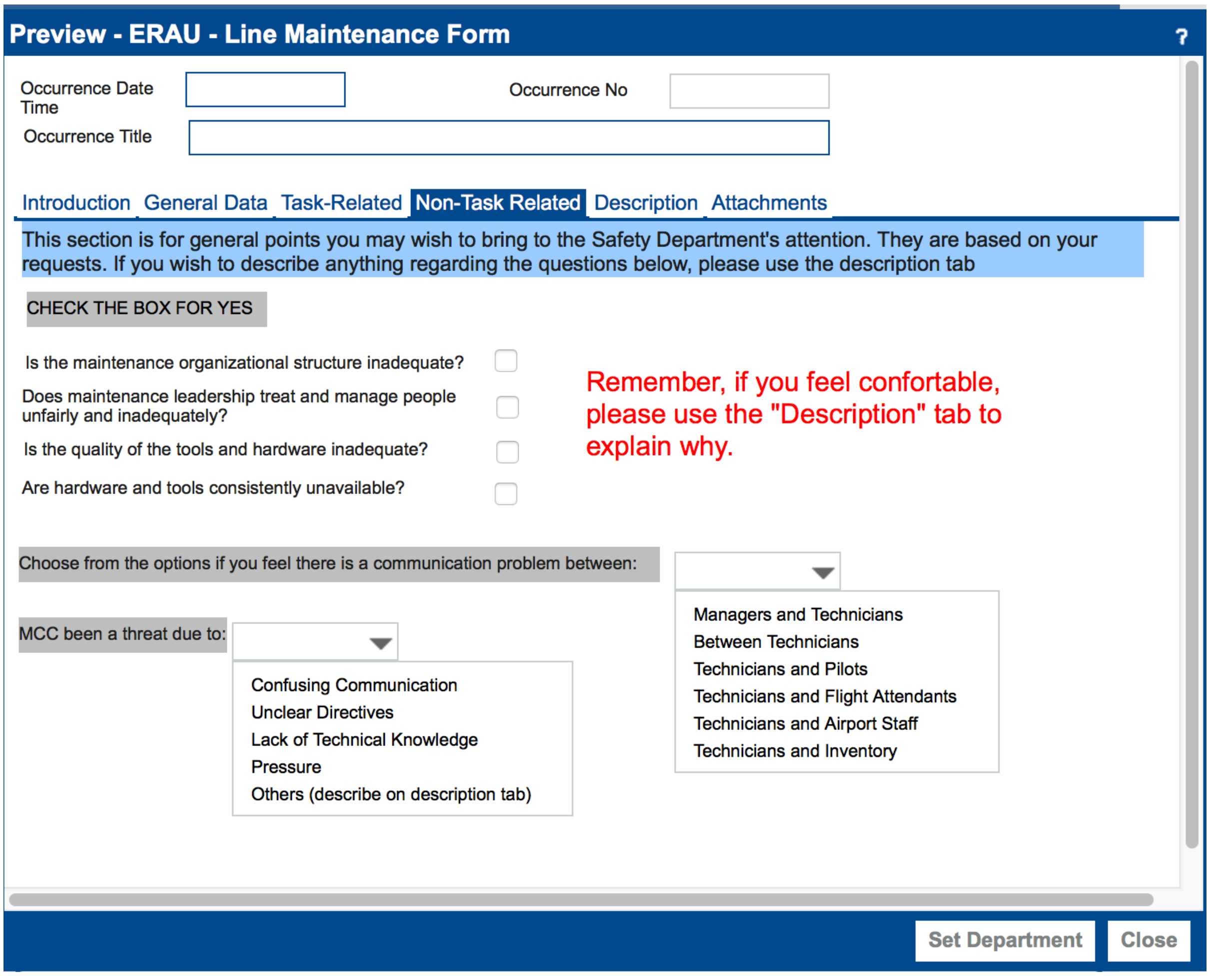
Was the aircraft release completed before the MIS transaction finished?
Were you unable to inpect the task before signing the TLB?

Set Department Close

Figure 16. “Was the task executed by memory?" drop-down menu overview

Appendix E

Non-Task Related



Preview - ERAU - Line Maintenance Form

Occurrence Date Time

Occurrence No

Occurrence Title

Introduction | General Data | Task-Related | Non-Task Related | Description | Attachments

This section is for general points you may wish to bring to the Safety Department's attention. They are based on your requests. If you wish to describe anything regarding the questions below, please use the description tab

CHECK THE BOX FOR YES

Is the maintenance organizational structure inadequate?

Does maintenance leadership treat and manage people unfairly and inadequately?

Is the quality of the tools and hardware inadequate?

Are hardware and tools consistently unavailable?

Remember, if you feel confortable, please use the "Description" tab to explain why.

Choose from the options if you feel there is a communication problem between:

- Managers and Technicians
- Between Technicians
- Technicians and Pilots
- Technicians and Flight Attendants
- Technicians and Airport Staff
- Technicians and Inventory

MCC been a threat due to:

- Confusing Communication
- Unclear Directives
- Lack of Technical Knowledge
- Pressure
- Others (describe on description tab)

Set Department | Close

Figure 17. Non-Task Related

Appendix F

Description

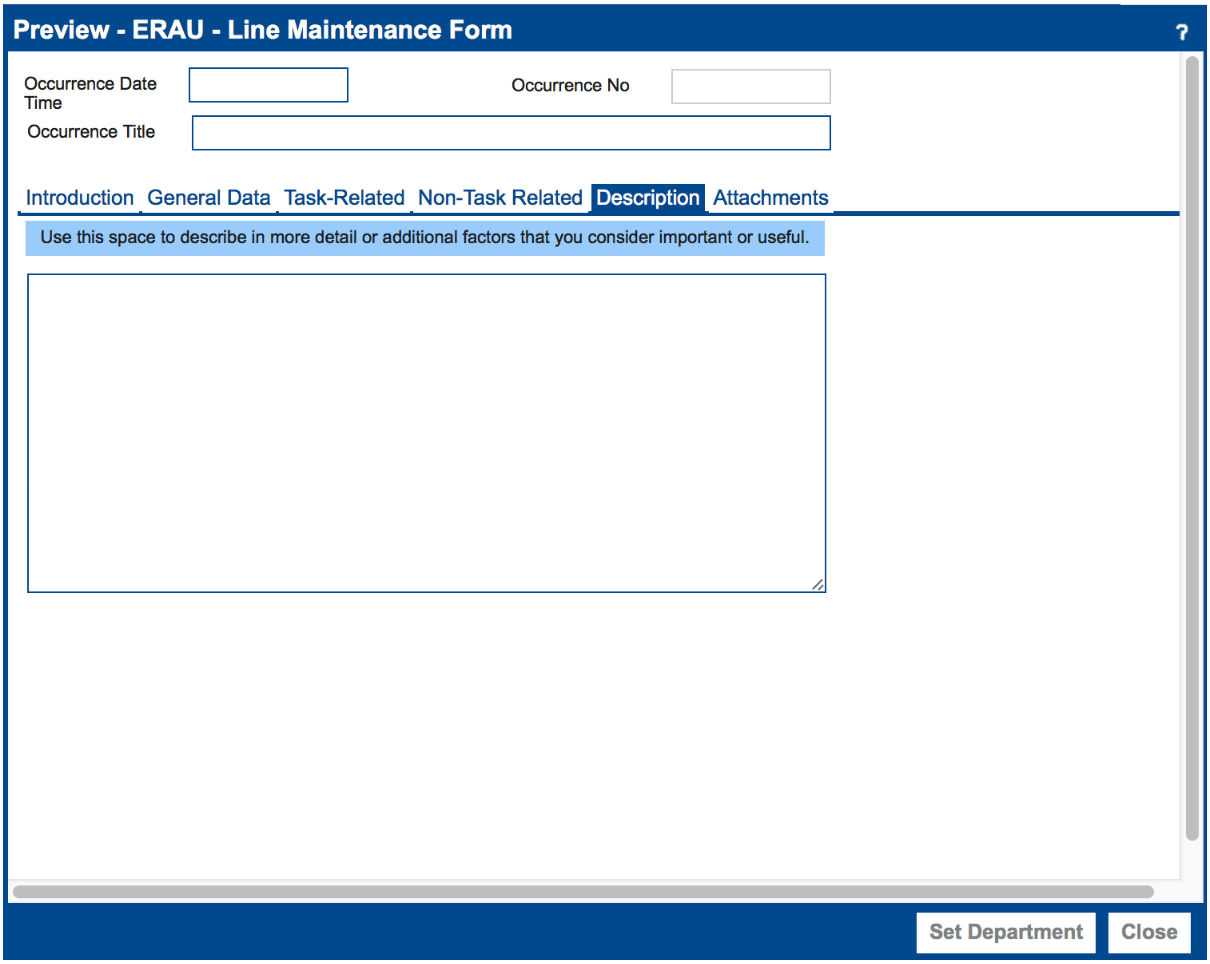


Figure 18. Description

Appendix G

Attachments

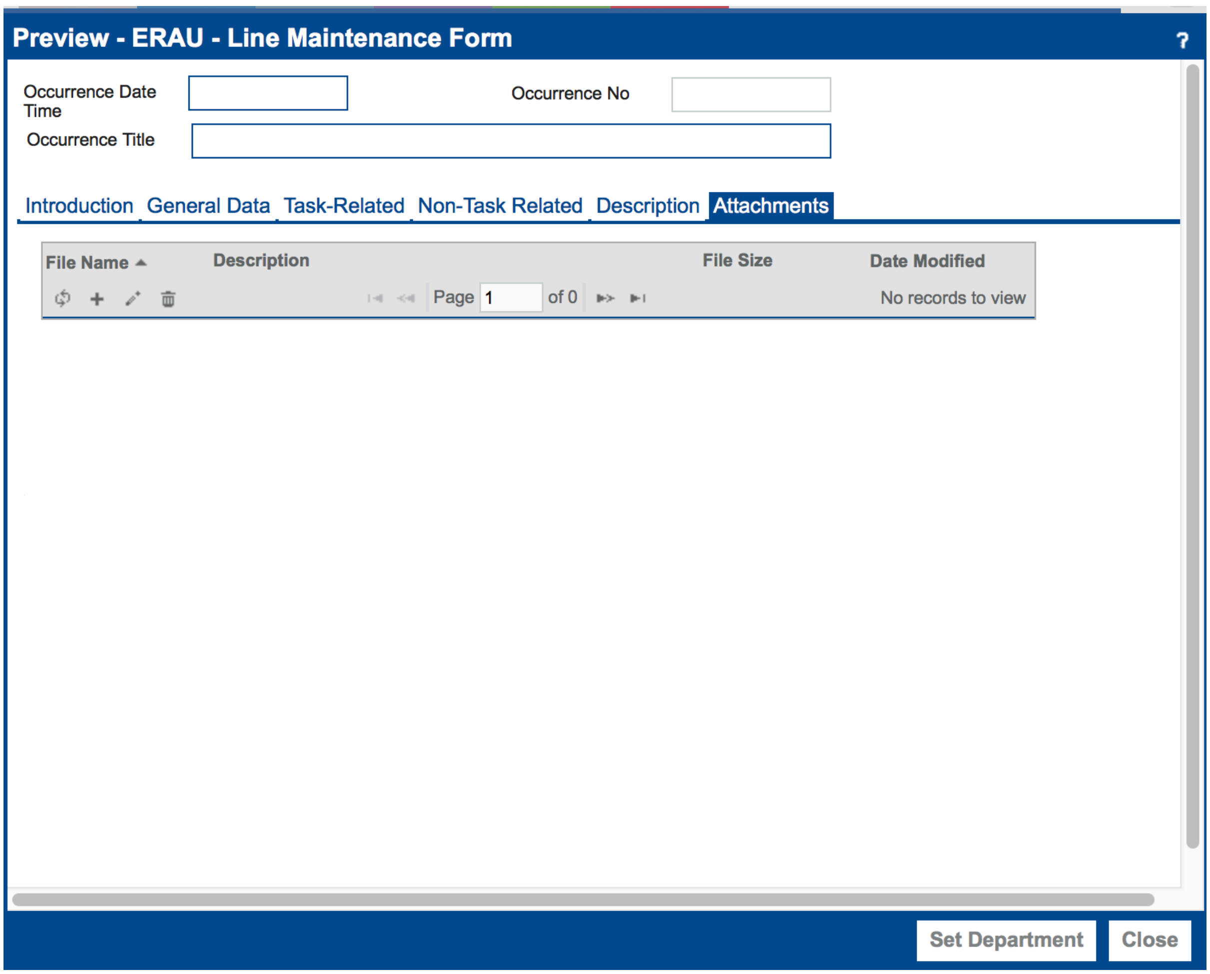


Figure 19. Attachments

Appendix H

Lesson Plan

Course: Just Culture

Training Objectives: At the end of the course, trainees will be able to apply just culture concepts and new concepts of human/ organizational errors

Training Method: Guided-instruction and problem-solving exercises

Duration: 7 programmed-hours

Target Audience: Line Maintenance General Manager, Line Maintenance Manager, Line Maintenance Regional Coordinators

Pre-entry requirements: Trainees shall have previously attended CRM and SMS courses

Training Content:

Module: Complex Systems

Discuss how aviation is a complex system and how coupling and interactions work. Explain the challenges to predict what can happen during an operation and that only by viewing the system, with a focus on the maintenance department, as whole will the company be able to create safety and efficiency. Discuss the pitfalls of treating a human failure as an isolated event and that one of the solutions for this is to see it as a systemic failure.

Module: Just Culture

Present what a just culture is, the importance of developing it, how to practice it. Highlight the difficulty between defining safety and accountability, blame culture vs accountability, cultural changes using functionalist and interpretive approaches. Present the advantages/ disadvantages of a Just Culture. Make a link with how information is crucial in complex systems and how just culture helps retrieve it.

Module: New View of Human Error

Compare and contrast the new views of human error with what Dekker considers the old view. Explain why the new view makes more sense by using examples the lessons and events learned in-house as well as events of significant impact such as the Challenger disaster. Discuss the strategies proposed to reduce human error defined by the new view. Link the need to understand organizational accidents and how it is necessary to have this approach to human error if one is to understand the risks of complex systems.

Training Exercises:

Exercise 1: Trainees will have to apply new concepts studied in real Company 1 cases, reflect how those cases were dealt with and how they succeeded.

Exercise 2: Trainees will read an event told with the old view of error. Trainees will be requested to tell the event in the new view of human error.

Training Assessment: Trainees will be assessed while sorting problem-solving scenarios and applying new concepts of just culture and human errors**.**