The Effect of Human Factors in Aviation Maintenance Safety

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Abstract

With the recent media attention on major airlines such as Southwest and American Airlines, public concerns have greatly increased for aviation maintenance safety. There are several factors that play into the cause of aircraft accidents and some of these factors are known as human factors. The study of how humans can most efficiently interact with technology is known as human factors. According to Boeing, the world’s largest aircraft manufacturer, human error accounts for 70% of commercial airplane accidents. In order to decrease the number of accidents caused by maintenance-related human factors, awareness and training in the field of human factors is critical. This research aims to qualitatively investigate the type of human factor that exist in aviation maintenance as well as the extent to which the factors affect safety performance. Furthermore, the researcher wanted to find the number of accidents that were caused by maintenance-related errors in the ten year span of 1996 through 2006. The results indicate the top three mechanical errors with the highest number of fatalities in order were: a). failure to properly complete tasks, b). improper maintenance, and c). improper installations. In addition, the human factors that were most prevalent among the attitudes of both Aviation Maintenance Technicians (AMT’s) and the Federal Aviation Administration (FAA) officials were demanding deadlines, environmental and personal distractions, and lack of proper use of maintenance manuals or instructions.
Chapter 1

Introduction

In view of affordable air travel prices, a vast majority of the population from the working class to the upper class travel through the air transportation industry and are therefore directly affected by aviation safety. The large scope of individuals concerned with safe air travel forces the constant surveillance of accidents and incidents by the Federal Aviation Administration (FAA) government agency, National Transportation Safety Board (NTSB), researchers, and public attention through media. Most recently, Southwest Airlines gained some unwanted attention when the largest fine in FAA history was issued of 10.2 million dollars for allegedly flying at least 117 of its planes in violation of mandatory safety checks (Levine, 2008; Griffin & Bronstein, 2008). Not only does this place increased attention towards Southwest Airlines, but also places scrutiny ten-fold in maintenance departments within all commercial airlines.

Even with the rapidly increasing advances in technology, humans hold the ultimate responsibility in ensuring the success and safety in the aviation industry. Due to the fact humans are an integral and necessary part of air safety, the study of how humans can most efficiently interact with technology is known as human factors. According to Boeing, the world’s largest aircraft manufacturer, human error accounts for 70% of commercial airplane accidents. Placing extreme importance on the role of human factors in aviation, Boeing studies various human factors and translates it into “design, training, policies, or procedures to help humans perform better” (Graeber, n.d.) Although maintenance-related accidents are far less frequent than accidents caused by pilot error, the end result can be just as fatal. Maintenance personnel, pilots, Air Traffic Control (ATC), and Flight Dispatchers are just a portion of the people dedicated to
ensure a flight travels safely from departure to arrival. While there are several facets impacting the safety of a flight, it begins on the ground with the Aviation Maintenance Technician (AMT), also known as Airframe and Powerplant (A & P) mechanic.

Overarching research questions

1. How many aircraft accidents with at least one fatality have occurred due to maintenance error from 1996 through 2006?

2. What human factors and to what extent do human factors affect a mechanics, AMT, ability to safely conduct maintenance?

3. What are some cost-efficient solutions to decrease the effects of human factors which would result in an increase in aviation safety?

Acronyms

AD- Airworthiness Directive

AMT- Aviation Maintenance Technician

A&P- Airframe and Powerplant mechanic

FAA- Federal Aviation Administration

FAR- Federal Aviation Regulations

IA- Inspection Authorization

NTSB- National Transportation Safety Board
Definitions

1. **Airframe and Powerplant (A&P) mechanic** - a licensed mechanic who has taken Airframe, General and Powerplant computerized FAA exams, as well as an Oral and Practical exam given by an FAA official or a person designated by the FAA known as Designated Maintenance Examiner (DME). A & P mechanic is privileged to perform

2. **Airworthiness Directive (AD)** - FAA issues AD’s informing owner/operator/mechanic that an unsafe condition exists and action must be taken to ensure safety. AD compliance is mandatory and each AD will specify applicability by make and model of aircraft and will also give mandatory compliance procedures. If an AD is not complied with by the specified time noted in an AD that aircraft is considered unairworthy and therefore illegal to fly until appropriately rated mechanic complies with AD instructions.

3. **Aviation Maintenance Technician (AMT)** - same as above definition for Airframe and Powerplant mechanic.

4. **Code of Federal Regulations (CFR)** - codification of general and permanent rules and permanent rules published in the Federal Register. The Code is divided into 50 titles, and Title 14 covers topics pertaining to Aeronautics and Space. Regulatory entities are the Federal Aviation Administration (FAA) and Department of Transportation (DOT).

5. **Corrosion** - a natural occurrence that attacks metal by chemical or electrochemical action and converts it back to a metallic compound. Corrosion that goes untreated and undetected can lead to fatal consequences. (AC 43.131B, chapter 6)
6. **Engine overhaul**- According to FAR 43.2, an engine is overhauled when using methods, techniques, and practices acceptable to the Administrator, it has been disassembled, cleaned, inspected, repaired as necessary, and reassembled; and it has been tested to approved standards and technical data.

7. **Experimental aircraft**- also known as Experimental Amateur-Built or Homebuilt aircraft—builder has built as last 51% of the airplane for recreational or educational purposes. Requires a pilot certificate, but does not require a mechanic certificate. Experimental aircraft are subject to condition inspections every 12 calendar months.

8. **Fatigue cracking**- Fatigue cracks can form in any load-carrying structure during normal use. Corrosion damage leads to cracks in the metal resulting in fatigue cracks which can sometimes lead to catastrophic results. In April 1988, a Boeing 737 in Hawaii brought national attention to the problems of fatigue cracks in aircraft. In this accident, the upper portion of the aircraft was ripped apart in flight due to a fatigue crack in the structure.

9. **Federal Aviation Administration (FAA)** - the federal agency responsible for the safety of civil aviation. With the Federal Aviation Act of 1958, the agency was originally named Federal Aviation Agency; however, when they became part of the Department of Transportation in 1967 they adopted the name Federal Aviation Administration.

10. **Inspections**-

    - **Annual inspection**- aircraft is completely inspected with a checklist every 12 calendar months by a person authorized in FAR 43.7, such as a mechanic holding an Inspection Authorization (IA). An A&P may not perform annual inspections. The annual checklist is derived from various sources depending on the program
the FAA approved for a particular aircraft. A checklist frequently used comes from the 14 CFR part 43 Appendix D, Scope and Detail for 100 hour and annual inspection.

- **100 hr inspection** - differs from annual inspection with regard to the time in which inspection is completed. Every 100 hours time in service an aircraft must undergo a 100 hour inspection. An A&P may perform 100 hour inspection, along with Inspection Authorization (IA), and others authorized by 14 CFR part 43.7

- **Condition inspection** - According to 14 CFR part 65.104, an experimental aircraft must have a condition inspection on the aircraft constructed by the holder in accordance with the operating limitations of that aircraft. An experimental aircraft will not have annual/100 hour inspections, rather the inspection is called a condition inspection.

- **Progressive inspection** - the scope and detail for a progressive inspection is developed by the owner/operator in accordance with 14 CFR part 91.409 and approved by the FAA.

11. **Inspection Authorization (IA)** - According to 14 CFR part 65, in order to obtain the Inspection Authorization rating a mechanic must hold an A&P for at least 3 years and be actively engaged in maintaining aircraft for the previous 2 years before the application. An IA is privileged to return to service any aircraft, airframe, engine, appliance or part after a major repair or major alteration except aircraft in part 121 maintained in a continuous airworthiness program. An IA can perform annual inspections, an A&P cannot perform annual inspections.
12. Kit- experimental aircraft / homebuilt aircraft where some of the airplane is already fabricated and builder purchases the kit.

13. National Transportation Safety Board (NTSB) - an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

14. Accident- includes events in which any person suffers fatal or serious injury, or in which the aircraft receives substantial damage or is destroyed. An event that results in minor or no damage is not classified as an accident.

15. NTSB Definitions for level of injury- (http://www.ntsb.gov/publictn/2004/ARG0401.pdf)

- **Fatal** - Any injury that results in death within 30 days of the accident.
- **Serious** - Any injury which:
  
  1. requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received;
  2. results in a fracture of any bone (except simple fractures of fingers, toes, or nose);
  3. causes severe hemorrhages, nerve, muscle, or tendon damage;
  4. involves any internal organ; or
  5. involves second- or third-degree burns, or any burns affecting more than 5% of the body surface.
• **Minor** - Any injury that is neither fatal nor serious.

16. **Overhaul shop** - mechanic shop that performs overhauls on aircraft, aircraft engine, airframe, component or other parts.

17. **Owner/builder, owner/pilot, mechanic’s, pilot/builder, owner/operator** - describes the roles in which the person played in regard to the aircraft. None of these terms means the person holds a valid mechanics license such as an A&P or IA.

18. **14 CFR Part 91** - Regulations that pertain to operating rules in general aviation

19. **14 CFR Part 121** - Regulations that pertain to operating rules in domestic, flag, and supplemental operations. Major airlines such as Southwest Airlines and American airlines operate under part 121.

20. **14 CFR Part 133** - Regulations that pertain to rotorcraft (helicopter) external -load operations.


22. **14 CFR Part 137** - Regulations that pertain to agricultural aircraft operations.

23. **Service bulletin** - manufacturer issues a notice informing owner/operator an unsafe condition exists that should be addressed in order to safely fly the aircraft. The difference between a service bulletin and an AD is service bulletins are recommended by the manufacturer to comply with, whereas compliance with the FAA issued AD’s are mandatory.
Chapter 2

Review of Related Literature

Various human factors that influence mechanics performance

As far back as the first powered flight by the Wright Brothers flight in 1903, humans have built and flown aircraft which means human error has always played a role in safety. However, it was not until 1988, when the skin of an Aloha airlines Boeing 737 ripped open in flight, did the FAA conduct the first official safety meeting with respect to aircraft maintenance activities (Lu, 2003). Since then, the boom in human factors research proves that researchers, along with the FAA, understand the influence human factors holds on mechanics performance. However, educating researchers on the importance of reducing human error will not improve safety. Aviation safety will be improved when AMT’s and others involved in aircraft maintenance have a full understanding of the effects of human factors and can recognize when one or more of these factors affect performance and safety.

Increased awareness of human factors allows mechanics and supervisors to notice when safety is being compromised and can take the appropriate action to correct the situation. In any job position, pressures, stress, and other human factors affect a person’s ability to properly complete a task. Unfortunately, pressures and stress that affect a mechanics job performance can lead to catastrophic results and therefore must be taken seriously within the aviation industry. Due to the fact that human error is inevitable, organizations and companies need to move from blaming an individual worker to implementing a systemic approach to handle maintenance errors (Hackworth, Holcomb, Banks & Schroeder, 2007). In 1996, Boeing developed the Maintenance Error Decision Aid (MEDA) process to “help airlines shift from blaming maintenance personnel
for making errors to systematically investigating and understanding contributing causes” (Graeber, nd). The MEDA process helps an organization learn more about maintenance errors and drastically eliminate costly and unsafe mechanical errors. The three principles behind the MEDA principles are: positive employee intent, contribution of multiple factors that contribute to an error, and manageability of errors. With the MEDA process, the traditional way of investigating errors by finding a person to blame is replaced with the new effective method of learning what factors contributed to the error in order to prevent further mishaps.

While the hope is the desire for safety drives the aviation industry to study the effects of human factors, profit is always a top priority and maintenance errors are extremely costly to an air carrier operator. According to a Boeing survey, as many as 20 percent of all in-flight engine shut downs and up to 50 percent of all engine-related flight delays and cancellations are linked to maintenance error (Allen, Rankin & Sargent, n.d.) The FAA estimates an engine shutdown can cost an airline an alarming $500,000, one flight cancellation around $50,000, and a return to gat cost $15,000 (Fiorino, 2004). With such high costs, it is no surprise the emphasis placed on human factors research along with the development of several human error models within the aviation industry.

In efforts to place top priority on human factors, in the year 2000 the FAA issued an Advisory Circular (AC) 120-72 titled Maintenance Resource Management training. The AC 120-72 is a 74 page suggestive guideline for improving communication, effectiveness, and safety in maintenance operations. Within this document, the FAA defines human factors as the scientific study of the interaction between people and machines. The FAA coined the phrase Dirty Dozen, which identifies the twelve most common maintenance-related causes of errors. Most recently, the FAA published a 2008 Dirty Dozen pocket calendar which reminds a mechanic to avoid the
twelve most frequent human factor errors. There is also a FAA website devoted entirely to research on human factors, [www.hf.faa.gov](http://www.hf.faa.gov). The Dirty Dozen are known as:

**Table 1. Dirty Dozen**

<table>
<thead>
<tr>
<th>Dirty Dozen</th>
<th>Explanation</th>
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<tbody>
<tr>
<td>Lack of communication</td>
<td>failure to communicate effectively in order to complete a task</td>
</tr>
<tr>
<td>Complacency</td>
<td>Overconfidence from repeated experience on a specific activity or situation. A complacent person may fail to fully pay attention to a task which may lead to error.</td>
</tr>
<tr>
<td>Lack of Knowledge</td>
<td>Without the proper knowledge or training a procedure may not be appropriately completed.</td>
</tr>
<tr>
<td>Lack of Teamwork</td>
<td>Failure to work together towards a common goal.</td>
</tr>
<tr>
<td>Distraction</td>
<td>Events or conditions that limit a person’s ability to focus on the task at hand. Distractions can be from noise in the hangar or distractions because of one's personal life.</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Worsens a person’s ability to work effectively. Fatigue can be sleep deprivation, time on duty, time since awake, and even environmental factors such as extreme temperatures, and vibrations.</td>
</tr>
<tr>
<td>Lack of Resources</td>
<td>Lack of appropriate maintenance manuals, tools, parts, etc., to complete a task</td>
</tr>
<tr>
<td>Pressure</td>
<td>Internal or external forces that demand high-level job performance. For example, pressure to complete a task by a deadline.</td>
</tr>
<tr>
<td>Lack of Awareness</td>
<td>Failure to be aware and understand a condition, as well as predict the possible results.</td>
</tr>
<tr>
<td>Lack of Assertiveness</td>
<td>Failure to voice concerns about instructions or actions of others.</td>
</tr>
<tr>
<td>Stress</td>
<td>Physical or mental condition resulting from the influence of external forces.</td>
</tr>
<tr>
<td>Norms</td>
<td>Behaviors that are not required by the organization, but expected by the team members. For example, taking shortcuts in aircraft maintenance or working from memory.</td>
</tr>
</tbody>
</table>

Adapted by AC 120-72 & 2008 Aviation Maintenance Technician Calendar
In addition to bringing awareness of the most common causes of human factor errors, the FAA also provides a human factors checklist found in the book titled Acceptable Methods, Techniques, and Practices-Aircraft inspection and repair (also known as the AC 43.13-1B). The Airworthiness Aviation Safety Program developed a personal minimums checklist from various human factors reports and incorporated the checklist in Chapter 13 Human Factors. There are 10 questions to read before the task and 10 questions after the task is completed. All questions should be answered yes and if the mechanic answers no to any of the 20 questions, the aircraft should not be returned to service. An example from the before the task checklist reads “Do I have the proper tools and equipment to perform the task?”, and a question for after the task is “Did I perform the job task without pressures, stress, and distractions?” (AC 43.13, p. 13-1). No longer does a mechanic only need the proper tools, data and technical skill to perform maintenance, but also must ensure they are aware of the human factors which impact their performance.

A less common, yet still insightful, cognitive model of maintenance error was developed by Alan Hobbs with the Bureau of Air Safety Investigation (BASI). Mr. Hobbs research identified the following eight types of errors and the frequency in which they occurred: memory lapse, work-arounds, situational awareness, expertise, action slips, work practice, technical inaccuracy, and perceptual difficulties. The most common error, memory lapse, occurred in 24% of the 127 errors reported by maintenance personnel. Both fatigue and work overload can result in an individual simply forgetting a specific aspect of their job resulting in maintenance mistakes.

Following closely behind at 23%, the second most frequent type was the work-around errors. These errors include an individual’s knowledge of the correct procedure, but belief it
would be all right this time. An example is performing a task in a more convenient manner than that specified in the maintenance manual. Pressures to complete a task within a certain time frame also influence how a mechanic does his/her job. When faced with time pressures, many AMT’s decided not to document their actions and failed to perform all the necessary steps in a task (Hobbs, 2000). Unfortunately, there is no way to completely eliminate time pressures because the AMT’s that can perform the tasks quickest receive the most business resulting in higher profit.

**Definition of Safety Culture**

In order to truly combat error, a positive culture or environment of safety must be adopted by all employees including management. In the Advisory Circular 120-72, the FAA advises that senior management take at least three actions to create and maintain a positive safety culture. Upper management must develop standards and expectations that emphasize safe work practices and provide the appropriate resources to continually meet the standards. Furthermore, the FAA suggests implementing incentive programs that reward safe and reliable behavior (AC 120-72). It is unfortunate that safety is not incentive enough, but sometimes people need a little extra drive to make the goal personal rather than an organizational goal.

Safety culture flourishes only when it is a group or organizational goal in which every mechanic strives for a 100% safe working environment. Gibbons, von Thaden, and Wiegmann (2006) and Wiegmann, Zhang, von Thaden, Sharma and Gibbons (2004) found the similarities among existing definitions and constructed a detailed safety culture definition. Safety culture consists of the following prosperities:

- Shared values among a group of people concerning safety within an organization.
- Concern with formal safety issues related to but limited to supervisory positions.
- Must include contributions from everyone at every level of employment.
- Reflected between the rewards program and safety performance.
- Impacts the behavior of employees during all maintenance activities.
- Reflected in the organization’s willingness to learn from errors rather than blame someone for making an error.
- Safety culture is stable and long-lasting.

Fogarty (2004) developed and distributed a survey to 240 Australian Army maintenance engineers. With the goal of measuring a safety climate, Fogarty tailored the survey on various scales applicable to aviation maintenance. The scales within the questionnaire were safety climate, morale, psychological health, outcome variables, and affectivity. The results indicated that workers’ perceptions, such as management’s commitment to safety and availability of resources have links with safety outcomes. Additionally, the proof of “indirect links between climate and errors (via psychological health and morale) suggest that the mere presence of unfavorable perceptions of organizational facts is not sufficient in itself to lead to errors” (Fogarty, 2004, p. 86). Rather, the unfavorable conditions place unwanted pressure on the mechanic which may then lead to a chain of events resulting in the occurrence of errors.
Chapter 3

Methodology

Participants

During the 2008 Mid-South Aviation Maintenance seminar, an FAA official announced the purpose of the research and informed the audience the location in which the researcher was located for voluntary participation in a human factors mechanic survey. AMT’s approached the researcher to obtain the survey and was instructed to drop off the survey in an assigned container. Attached to the top of each survey was a university approved consent form along with an explanation for the need of the research. In addition, contact information was provided if the participant had questions regarding the survey or the study. There were 18 surveys collected with the participant average age approximately 46 years old, ranging from 26 through 67 years old. The research process also included open-ended interviews with FAA officials in which the researcher recorded notes in a journal along with tape-record of interviews.

Design Approach and Instruments

The purpose of the study was to learn what type of human factors affect AMT’s performance and to what extent have human factors impacted the safety of the aviation industry. Due to the nature of the inquiry process, the researcher determined that a qualitative approach was necessary for the study. Wiersma and Jurs (2005) describe qualitative research as an inductive inquiry process without any preconceived theories or hypotheses for the data collection. The inquiry process included: a) designing and collecting human factors AMT survey, b). conducting interviews with FAA officials, and c). collecting and reviewing the NTSB online aviation accident database. Qualitative data analysis included condensing and organizing the data
sets into categories that can be analyzed and placed in emerging categories, themes, and patterns (Gough & Scott, 2000, Wiersma & Jurs, 2005). After all the data was collected, the qualitative data coding began, and the key categories, themes, and patterns are reported in the findings and conclusions of the study. To ensure organization, a research timeline was developed at the beginning of the study (Table 2.)

Table 2. Research Timeline

<table>
<thead>
<tr>
<th>Research Activity</th>
<th>Explanation</th>
<th>Date of Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRB Proposal</td>
<td>Submit my proposal, along with human subjects training</td>
<td>Feb. 11</td>
</tr>
<tr>
<td>Introduction</td>
<td>Write the introduction</td>
<td>Feb. 18</td>
</tr>
<tr>
<td>Literature Review</td>
<td>Find research relevant to human factors in maintenance and write the literature review</td>
<td>March 3</td>
</tr>
<tr>
<td>Collect data</td>
<td>Pass out surveys to the AMT maintenance seminar. Review the surveys and categorize answers.</td>
<td>March 10</td>
</tr>
<tr>
<td>Collect data</td>
<td>Search on ntsb.gov for maintenance-related accidents and keep a log of date, aircraft type, and reason for accident</td>
<td>March 5</td>
</tr>
<tr>
<td>Conduct Interviews</td>
<td>Interview 5 FAA employees (day off of work)</td>
<td>March 14</td>
</tr>
<tr>
<td>Methodology</td>
<td>Write methodology for triangulation matrix of: online ntsb research, surveys, and interviews</td>
<td>March 17</td>
</tr>
<tr>
<td>Analyze Data</td>
<td>Data analysis for online ntsb database, surveys, and interviews.</td>
<td>March 31</td>
</tr>
<tr>
<td>Results</td>
<td>Begin writing the results and drawing conclusions for the data concerning ntsb accidents, surveys, and interviews.</td>
<td>April 14</td>
</tr>
</tbody>
</table>
The researcher took on the role as the participant-observer with both interactive and noninteractive collection of data. In a qualitative study, the most commonly used methods of data collection include observation, interview, and collection and review of related documents (Wiersma & Jurs, 2005). During data analysis, a triangulation matrix was utilized to ensure focus on the three overarching research questions. The triangulation matrix is listed in Table 3.

<table>
<thead>
<tr>
<th>Overarching Question</th>
<th>Data set</th>
<th>Data Set</th>
<th>Data Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many aircraft accidents with at least one fatality have occurred due to maintenance error from 1996 through 2006?</td>
<td><strong>NTSB online aviation accident database</strong></td>
<td>Researcher field journal</td>
<td>AMT Human factors survey</td>
</tr>
<tr>
<td>What human factors and to what extent do human factors affect a mechanics, AMT, ability to safely conduct maintenance?</td>
<td><strong>AMT Human factors survey</strong></td>
<td>Interviews with FAA officials</td>
<td>Researcher field journal</td>
</tr>
<tr>
<td>What are some cost-efficient solutions to decrease the effects of human factors which would result in an increase in aviation safety?</td>
<td><strong>Interview with FAA officials</strong></td>
<td>Researcher field journal</td>
<td>AMT Human factors survey</td>
</tr>
</tbody>
</table>

**Indicates the data set largely responsible for answering the overarching question**

All participants in the study were in the field of aviation maintenance to ensure the highest level of insight into the effects of human factors in maintenance-related errors. According to Devers and Frankel (2000), qualitative research most often uses purposive, rather than random sampling strategies to enhance understandings of selected individuals or groups’ experience or for developing theories. While the level of experience may have varied for participants answering the survey or participating in the interviews, all subjects were licensed aircraft mechanics.
Data sets were collected based on the AMT human factors surveys, FAA interviews, researcher field journal, and NTSB online database search. According to Wiersma and Jurs (2005), the collection and review of related documents without any preconceived theories of hypotheses is considered qualitative type of research. Once collected, the data were organized into possible codes with relation to the research questions. Unique findings and intriguing comments were noted. At the last stages of the data collection process, the researcher reviewed the initial codes and refined them as necessary to reflect any changes discovered through the inquiry process.

Chapter 4

Data analysis

Once all the data was collected, the researcher began the qualitative data analysis. Given that qualitative research analyzes words, not numbers, it is critical to carefully analyze the data and then revisit the data for further analysis for possible categories, trends, and connections between categories (Ratcliff, 2008). In order to stay on course, data was organized into categories relating to the overarching research questions. Quantitative descriptive statistics was incorporated with the analysis of the AMT human factors survey. For example, some questions were yes/no answers and the percentages were calculated based on the participant responses. Otherwise, a qualitative stance was taken with the open-ended questions within the survey and participant responses organized into key categories or themes. The procedure for analyzing the data from the interviews with the FAA were also analyzed for common themes as well as any other important responses the researcher felt would address the research questions.
To determine the number of maintenance-related aircraft accidents that resulted in at least one fatality for the ten year span of 1996 through 2006, a review of the National Transportation of Safety Board’s (NTSB) aviation accident database was necessary. The NTSB website, http://www.ntsb.gov/ntsb/query.asp provides public access of accident reports including but not limited to: probable causes, contributing factors, type of aircraft, number of people and level of injury for persons on board the aircraft. Each maintenance-related accident was copied from the website into a computer document and reviewed for emerging themes and categories. Just because a mechanical failure occurs during flight does not indicate it was the error of an AMT. Unfortunately, sometimes parts fail for unknown reasons and could not be traced back to the AMT’s actions or lack of appropriate actions. For example, there were several accidents caused because of engine failure, in-flight separation of parts, and fatigue cracks. These were not accounted for as maintenance-related accidents unless the report specifically cited the fault of maintenance, such as improper or inadequate maintenance.

While this study focused on licensed AMT’s, some of the accidents were caused by owner/pilot that operates as a mechanic but is not necessarily a licensed aircraft mechanic (AMT). Even so, because a mechanical error led to fatal consequences the researcher deemed it necessary to include in the research. It is also important to note the NTSB reports both the probable cause along with the contributing factors in which the researcher did not separate for the purpose of reporting the findings. Whether maintenance was the primary or secondary cause is irrelevant when discussing the safety of a person’s life.

Embarking upon the task of data analysis, the researcher followed the suggested guidelines by Maykut and Morehouse (1994). The process is as follows:
1. Organizing the data by creating a system to utilize as data are collected.

2. Initial coding of each set of data as it aligns with overarching research questions.

3. Unitizing the data which means to separate or classify the data into units. Further data analysis may require re-organizing as needed.

4. Discovering any emerging patterns, themes, or categories relevant to the study.

5. Defining the discovered categories and the assigning attributes to each category.

6. Exploring patterns and relationships across all the data sets.

The Maykut and Morehouse (1994) guidelines for qualitative research provided a means for the researcher to conduct the study in an organized fashion producing descriptive results.

Chapter 5

Findings

As the data was collected and organized, the discovery process began and the data coded into various categories. Next, the categories were assigned defining attributes and then reviewed for further analysis and re-coding if necessary. Once the coding process was complete, the researcher explored patterns and relationships across all the data sets as they aligned with the overarching research questions. The following findings are organized by overarching questions along with the triangulation matrix, and categories that emerged from the data collection and analysis (See Figure 1)
Overarching Question #1- How many aircraft accidents with at least one fatality have occurred due to maintenance error from 1996 through 2006?

Data analysis of the three data sets revealed the following twelve categories along with the attributes assigned for each category:

1. I goofed: Accidents that fall under this category listed the probable cause or contributing factors as failure to properly complete the maintenance task. This category includes failure to properly torque, lubricate, attach, secure, tighten, adjust, rebalance or balance, and failure to install various parts.

2. Failure to maintain: Indicates an accident occurred due to improper maintenance by maintenance person(s) or person acting as a mechanic such as owner/builder. Attributes for this category are as follows:
• improper maintenance
• improper replacement
• misrouting of fuel lines
• improper assembly
• improper construction
• improper shimmying
• misalignments
• improper modification
• improper repair

3. **Who needs directions?:** Accidents that occurred from improper installations indicates the maintenance instructions or directions were not properly followed by the mechanic. A few examples include: improper installation of cylinders, fuel line, oil pump, and magneto contact points.

4. **Detective needed:** The researcher discovered there were several accidents that occurred from failure to detect or identify problems that occurred over an extended period of time. While these issues are not always easy to detect, failure to notice these often subtle issues during inspections can lead to serious repercussions. The accidents occurred from failure to detect or identify fatigue cracks, corrosion, erosion, worn cables, and fretting in propeller blade.

5. **Sloppy Joes:** Indicates an accident occurring as a result of inadequate maintenance/repair. In other words, the maintenance task was completed in a sloppy manner. This category did not provide much detail, but rather listed inadequate maintenance as a cause or factor contributing to the aircraft accident.

6. **Unfinished business:** Accidents dealing with the inspection of an aircraft fall under the Unfinished business category. Some accidents occurred as a result of inadequate inspections performed on the aircraft or complete lack of the proper inspections. The majority of these cases were the cause of inadequate inspections which indicates the inspection process was
completed but not thorough. The inspections include annual, 100 hour, conditions, or progressive inspections (See explanations in Chapter 1, definitions section).

7. **Breaking the rules**: Category indicates noncompliance with an Airworthiness Directive (see Chapter 1, definitions section), manufacturer’s instructions, notice, or recommendations. Noncompliance indicates the mechanic is not complying with certain procedures and is hence breaking the rules.

8. **Overhaul issues**: This category was developed for accidents involving the improper maintenance or inspection during the overhaul of an engine.

9. **It’s all wrong!**: Attributes for this category included both inadequate maintenance and inadequate inspections. In other words, it combines the categories of I goofed (inadequate maintenance) with Unfinished business (inadequate inspections).

10. **Missing in action**: Parts were completely missing from the aircraft which resulted in accidents. Examples include missing nut, push-pull control rod bolt, and valve keeper.

11. **What were you thinking?**: In some accidents, the mechanic installed a part that was considered to be unairworthy or not approved for use with the certain type of aircraft. Unairworthy means it is not in the proper condition to safely fly.

12. **I screwed up!**: There was only one accident that occurred because a screwdriver was left inside the airplane’s fuselage.

Once the researcher put the accidents into the twelve categories and listed the attributes for each category, the next step was to determine the number of fatalities in each category along with the type of operations. With a total of 123 fatalities, the highest number of fatalities
occurred in the category of I goofed. This had the highest number of fatalities because of the part 121 Alaska Airlines accident on January 31, 2000 in Port Hueneme, California. The probable cause was insufficient lubrication of the jackscrew assembly resulting in 88 deaths. The second highest category was Failure to maintain with a total of 69 deaths. Again, one particular accident had a large number of fatalities and was also part 121 Air Carrier operator. On January 8, 2003, Air Midwest crashed in Charlotte, NC because of improper maintenance procedures killing 21 persons on board. Table 4 and 5 lists the categories along with the number of fatalities and type of operations for each category.

Table 4. *Number of fatalities and type of operation for each accident category*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Number of fatalities</th>
<th>Type of operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I goofed</td>
<td>123</td>
<td>Part 91 General Aviation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 121 Air Carrier Operator</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 135 Air Taxi &amp; Commuter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 137 Agricultural</td>
</tr>
<tr>
<td>Failure to maintain</td>
<td>69</td>
<td>Part 91 General Aviation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 121 Air Carrier Operator</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 135 Air Taxi &amp; Commuter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 137 Agricultural</td>
</tr>
<tr>
<td>Who needs directions?</td>
<td>53</td>
<td>Part 91 General Aviation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 135 Air Carrier Operator</td>
</tr>
<tr>
<td>Detective needed</td>
<td>43</td>
<td>Part 91 General Aviation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 121 Air Carrier Operator</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 133 Rotorcraft External Load</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 135 Air Taxi &amp; Commuter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 137 Agricultural</td>
</tr>
<tr>
<td>Sloppy Joes</td>
<td>31</td>
<td>Part 91 General Aviation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 135 Air Taxi &amp; Commuter</td>
</tr>
</tbody>
</table>
Table 5. *Number of fatalities and type of operation for each accident category*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Number of fatalities</th>
<th>Type of operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfinished business</td>
<td>21</td>
<td>Part 91 General Aviation, Part 133 Rotorcraft External Load, Part 135 Air Taxi &amp; Commuter</td>
</tr>
<tr>
<td>Breaking the rules</td>
<td>16</td>
<td>Part 91 General Aviation, Part 121 Air Carrier Operator, Part 135 Air Taxi &amp; Commuter, Part 137 Agricultural</td>
</tr>
<tr>
<td>Overhaul issues</td>
<td>11</td>
<td>Part 91 General Aviation</td>
</tr>
<tr>
<td>It’s all wrong!</td>
<td>4</td>
<td>Part 91 General Aviation</td>
</tr>
<tr>
<td>Missing in action</td>
<td>4</td>
<td>Part 91 General Aviation</td>
</tr>
<tr>
<td>What were you thinking?</td>
<td>3</td>
<td>Part 91 General Aviation, Part 137 Agricultural</td>
</tr>
<tr>
<td>I screwed up!</td>
<td>1</td>
<td>Part 91 General Aviation</td>
</tr>
</tbody>
</table>

The findings indicate from 1996 through 2006 there were 379 fatalities as a result of accidents caused by maintenance-related error. The majority of these fatalities, 215, occurred in Part 91 General Aviation operators. Second highest was 132 fatalities that occurred within Part 121 Air Carrier Operators. Table 6 shows the number of fatalities and accidents that occurred within different type of operations.
Table 6. *Number of fatalities within the type of operation*

<table>
<thead>
<tr>
<th>Number of fatalities</th>
<th>Type of operation</th>
<th>Number of accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>215</td>
<td>Part 91 General Aviation</td>
<td>141</td>
</tr>
<tr>
<td>132</td>
<td>Part 121 Air Carrier Operator</td>
<td>5</td>
</tr>
<tr>
<td>25</td>
<td>Part 135 Air Taxi &amp; Commuter</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Part 137 Agricultural</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Part 133 Rotorcraft External Load</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 2. *Overarching Research Question #2 Triangulation*

What human factors and to what extent do human factors affect a mechanics, AMT, ability to safely conduct maintenance?

- Interviews with FAA officials
- AMT Human Factors survey
- Researcher field journal
- Interview with FAA officials
- AMT Human Factors survey

Overarching research question #2: What human factors and to what extent do human factors affect a mechanics, AMT, ability to safely conduct maintenance?

The researcher analyzed the AMT human factors survey, separate interviews with 3 FAA officials, and researcher field journal. To protect the anonymity of individuals, the FAA officials will be named Mr. Grumpy, Mr. Workout, and Mr. Round. The data was analyzed and coded by referring back to the overarching research question and the triangulation matrices. The following findings show the overall perception of what human factors exist in the maintenance arena and to what extent do human factors affect an AMT’s ability to safely conduct maintenance.

Theme #1: “Back off with the demands!”- The AMT human factors survey participants were given different types of stresses and asked to circle all that apply. Furthermore, they were also given an opportunity to list any other stresses in which the researcher did not already list in the survey. Responses to the survey shows that the highest number of respondents, 61 percent, experienced stress as a result of demanding deadlines. The stress from placing demanding deadlines on an AMT made it difficult to properly perform certain maintenance tasks. In addition, 77 percent of survey participants have felt pressure to rush through a task because of work deadlines. One of the FAA officials, Mr. Workout, also felt that demanding schedules or deadlines is one of the top human factors issues affecting the safety of maintenance. The top four most frequent stresses experienced at work are as follows:

- 61% Demanding Deadlines
- 50% Sick while at work
- 50% Tension among employees and/or employer
- 38% Excessive workloads

Theme #2: “I’m sorry what did you say?”- Analysis of the data shows that another top human factors issue affecting aviation maintenance safety is various types of distractions encountered
within the workplace. These distractions make it difficult to pay attention and could lead to error. The FAA official, Mr. Grumpy, believes not paying attention is a very big problem at maintenance facilities which could and have caused accidents. Mr. Grumpy stated that the environment in which the AMT works affects the ability of a mechanic to pay attention to the task on hand. Providing various examples, Mr. Grumpy stated that personal problems, physically sick while at work, lack of proper training, and nervousness are all distractions that can cause lack of awareness or attention.

Within the AMT human factors survey, participants were asked to circle all the types of distractions encountered within the workplace. If a distraction was not already listed, the participants were given the choice to list any other types of distractions they have experienced. The most frequently circled distraction was a tie between cold or hot hangar temperatures and interruptions while performing. Extreme weather conditions in a maintenance facility would make it difficult to completely focus on tasks because of the level of personal discomfort. During the interview with the FAA, Mr. Round stated extreme temperatures, especially cold temperatures, are one of the top human factors affecting maintenance safety.

In addition, any interruption while performing work forces the AMT to stop and restart. Restarting the task can lead to missed steps in the procedures because he or she was interrupted during the process. According to the AMT human factors survey the top four distractions are as follows:

- 66% Cold/hot hangar temperatures
- 66% Interruptions while performing a task
- 44% Disorganization (having to track down proper manuals, tools, etc.)
- 38% Lack of resources
Theme #3: “I don’t need no stinking manual!”- Whenever a mechanic performs a repair or alteration they are suppose to follow the maintenance instructions that address the specific repair or alteration. While the instructions can be found in various manuals, some common examples are a FAA approved manufacturer’s manual, maintenance instructions, or book titled Acceptable Methods, Techniques, and Practices-Aircraft inspection and repair (also known as the AC 43.13-1B). Combing the survey results and FAA interviews, the researcher discovered AMT’s are not always following the appropriate manuals and rather performing tasks my memory. When asked how frequently do you perform a task from memory if it is a familiar task here were the scary responses:

- 61%  Yes, I perform a task from memory if it is a familiar task.
- 16%  No, I do not perform a task from memory even if it is a familiar task.
- 22%  On occasion I perform a task from memory if it is a familiar task.

Mr. Round believes the number one issue that gets people into trouble with the FAA is lack of proper use of maintenance instructions. AMT’s are not rigidly following the maintenance instructions and as a result making unnecessary mistakes. These unnecessary mistakes could lead to unnecessary accidents resulting in injuries or fatalities.
Overarching research question #3: What are some cost-efficient solutions to decrease the effects of human factors which would result in an increase in aviation safety?

After careful analysis of the data, the researcher found there were two different categories that emerged within the study. One category identified the issues that need to be addressed to improve safety and the second category provided suggestions for solutions to various problems. The AMT human factors survey participants were eager to list all the issues they feel need to be addressed in order to improve safety, and the FAA officials provided some suggestions to decrease the effects of human factors towards aviation safety. The following findings are offered.
Category #1: Issues that need to be addressed in the aircraft maintenance industry to improve air safety. The participants listed the following on the AMT’s human factor’s survey:

- Hands on current training done every year.
- Better error reporting and shared knowledge or error causal factors.
- FAA required recurrent training
- Improved training.
- Non-airmen in management and/or leadership position in the industry, or those people who are rated airmen with college degrees but little or no actual practical experience in fixing, servicing or flying aircraft being in leadership positions.
- Complacency.
- Check attitude.
- Current service information.
- Human factors awareness.
- Mandatory crew rest
- Lack of sleep on midnight shift, technician fatigue
- Extended work shifts.
- Pay and benefits- it is hard to get young people in the industry due to pay and working conditions.
- Cost of maintenance manuals to ensure all repair stations and/or personnel can obtain current approved data. It would reduce the likelihood of noncompliance in the industry.
- Pressure to finish work.
- More safety checks so it is done right the first time.

Category #2: FAA officials suggestions to improve maintenance safety

Mr. Grumpy suggested that awareness of human factors training would help improve aviation maintenance safety. They must be aware of what human factors are in order to recognize when human factors are affecting mechanical performance. Furthermore, Mr. Grumpy strongly believes anytime a mechanic goes through some type of trauma, such as death of a loved one, that person should not be working alone in a critical area. Any work completed should be checked by another mechanic to ensure no mistakes were made throughout the process. Ideally, the AMT should take some time off and return when they are emotional healthy and prepared to focus while at work. The last suggestion from Mr. Grumpy focused on communication.
Communication between the crew both down and up the chain of command is essential for achieving a safe maintenance record.

According to Mr. Workout, human factors training will be ineffective unless you change corporate culture. Corporate culture is set by managements’ philosophy which is usually focused on profit not safety. The goal is to satisfy the customer and make a profit which places a lot of pressure on mechanics to get the job done as quickly as possible. Mr. Workout made a very interesting statement in that “sales is driving the train when it should be the caboose”. In a perfect world, there would never be time restraints on ability to perform maintenance. Safety cannot truly be the focus if a person is instructed to complete a task by a certain date or else they will lose the customer’s business. All efforts to reduce the effects of human factors in aircraft maintenance will be in vain until higher emphasis is place on safety and less emphasis on profitability.

Mr. Round believes improvements in aviation maintenance safety can occur with constant and repetitive training. Due to the fact recurrent training is not currently mandatory but rather voluntary, training must be affordable or the company will not place safety training as a priority. Especially with part 121 Air Carrier operators, cost is a major issue affecting both profit and shareholder investments. To reduce the cost of training, Mr. Round suggests in-house training rather than sending employees off to flight safety training in various locations. In other words, send one or two maintenance technicians (AMT’s) to some type of training course and then allow those AMT’s to train the rest of the maintenance crew. With the more economical choice of in-house training, increased awareness of human factors would result in increased safety.
Conclusions

With the extensive research of the National Transportation of Safety Board’s (NTSB) aircraft accident online database, the most accidents and fatalities occurred within part 91 General Aviation operators. From 1996 through 2006, there were 141 accidents resulting in a tragic 215 fatalities. This should serve as a warning that general aviation needs to improve aircraft maintenance programs. While there were 132 fatalities in part 121 Air Carrier operator, this occurred in only five accidents over a ten year span. Unfortunately, when a part 121 aircraft has an accident the results are generally more severe because of the large number of passengers on board. It is my hope that general aviation pilots and mechanics learn from the past accidents that occurred due to various mechanical errors and improve the overall safety of general aviation.

The human factors that were most prevalent among the attitudes of both AMT’s and the FAA officials were demanding deadlines, environmental and personal distractions, and lack of proper use of maintenance manuals or instructions. All of the aforementioned human factors, as well as any other human factor that affects a mechanic’s ability to safely perform tasks, must be taken seriously by mechanics, supervisors, FAA and NTSB officials, the United States government, and the general public. Safety should longer be compromised because of the desire to make profit.

The top three mechanical errors with the highest number of fatalities in order were: a).failure to properly complete tasks, b).improper maintenance, and c).improper installations. Perhaps these errors occurred because of pressure from management to complete the task and release the aircraft to the owner, or the AMT had some type or personal distraction that took his focus off of correctly installing a part. The NTSB accident database does not report what caused
the mechanic to make the error, but rather reports the error linked to the accident. Simply put—because mechanics are human there will always be human factors affecting their performance. The more awareness and training a person receives the more likely they are to recognize when human factors is affecting performance and take proper action to handle the situation.

**Suggestions for Improving Practice**

Training, training, and more training is the number one suggestion for improving aviation safety. Unfortunately, it seems profit is the top priority in the aviation industry and it needs to be further down the list in order to ensure people’s safety is always the most important consideration. Safety training should no longer voluntary, but rather be made mandatory by Federal Aviation Regulations (FAR’s). If the majority of corporations feel training is too expensive or not within their budget, the training will be cut from the program. It is the responsibility of the U.S. government and citizens to demand safety take the lead and make initial as well as recurrent training mandatory for every licensed aircraft mechanic. No longer should the decision be placed in corporate management hands to ensure awareness of human factors. Safety is a concern of everyone and the only way to achieve safety is with some type of mandatory human factors training.
References


Lu, C. (2003). An inductive study regarding nonregulatory maintenance resource management (MRM) training (Dissertation, The University of Nebraska at Omaha, 2003 UMI No. 3087733)


