Human Factors in Aviation Maintenance

Dr. Bill Johnson, a frequent contributor to this newsletter, is the FAA Chief Scientific and Technical Advisor for Human Factors in Aircraft Maintenance Systems. His comments are based on nearly 50 years of combined experience as a pilot, mechanic, airline engineering and MRO consultant, professor, and FAA scientific executive.

Table of Contents

Meet the Authors

David J. Schroeder, Ph.D., returned to the FAA Civil Aerospace Medical Institute (CAMI) in 1980 as a research psychologist. His research interests have a strong focus on Air Traffic Controller human factors (controller selection, shiftwork/fatigue, anxiety, and personality). He was leader of the research team involved in the development and implementation of the initial FAA employee attitude survey. From 1991 to his retirement in 2008, he served as manager of what is now called the Aerospace Human Factors Research Division. He has also served in leadership roles in the Aerospace Medical Association as well as the APA Division of Applied Experimental and Engineering Psychology. Although retired, he is currently working part time as a research psychologist for Cherokee CRC, LLC on several aviation-related projects including one involving aviation-maintenance safety climate research.

Patricia Davis is a graduate of the University of Central Oklahoma with a BA and MA in psychology, as well as an MBA. While at the university, her research interests included neuropsychology, color vision/perception, and neuromarketing. She is currently an administrative assistant for Cherokee CRC, LLC assisting with multiple aviation-related projects involving safety culture, as well as managing the role of editing the FAA's quarterly newsletter.

Steven J. Landry, Ph.D., is an associate professor in the School of Industrial Engineering at Purdue University, with a courtesy appointment in the School of Aeronautic and Astronautics. He conducts research in air transportation systems engineering and teaches courses in human factors, statistics, and industrial engineering. His research focus is on integrating humans into complex systems such as the air transportation system. His publications include book chapters on human-computer interaction in aerospace, flight deck automation, and aviation human factors. Prior to Purdue, Dr. Landry worked on air traffic control automation at NASA, and was also previously a C-141B pilot with the U.S. Air Force. He has over 2,500 heavy jet flying hours, including extensive international and aerial refueling experience.

Audrey Reinert is a third year Ph.D. student in Industrial Engineering, concentrating in human factors. Her research lies at the intersection of data mining, human computer interaction, and human factors engineering. She has previously participated in the student summer experience program with the Federal Aviation Administration at the William J. Hughes technical center and the Civil Aerospace Medical Institute. Prior to attending Purdue, she obtained a Masters in Human Computer Interaction from the Georgia Institute of Technology.

Just Culture Stories: What can go right and what can go wrong

Dr. Bill Johnson

A Just Culture program encourages voluntary reporting of safety-critical information and reinforces a healthy safety culture. This article will use three stories to describe how a Just Culture can go right or wrong. These stories are as accurate as my memory permits. I describe these stories as the "good, bad, and ugly" in the April/May 2018 issue of AMT Magazine.

Generally Recognized Attributes for a Just Culture

The term *Just Culture* is a household word in aviation safety. It has evolved for over 20 years, from James Reason to David Marx and others. The concept advocates responsibility and accountability for each worker and extends that accountability to the entire organization. Sometimes error is a function of human frailty, or even misfortune. The root cause of an error may extend beyond human performance and rests with the work environment, the expected activity, and the resources necessary to complete work safely, effectively, and efficiently. Rather than immediately blaming the worker for an error, a Just Culture determines root causes that contribute to an error. All investigations and subsequent actions are based on what a reasonable person would consider "fair and just."

Elements of Just Culture include clear communication and trust between labor and management, a shared value of safety, a shared desire to know about errors and to prevent reoccurrence, and a system to report and investigate events. Participation from a cooperative National Aviation Authority also helps. A Just Culture policy is usually documented and well understood. Everyone must be "on board" to achieve the Just Culture.

Just Culture programs can be complemented with investigative tools like Boeing's MEDA© (Maintenance Error Decision Aide); analytic tools like the Outcome Engenuity Just Culture Algorithm™ or the Baines Simmons FAiR® System; regulatory programs like NASA's Aviation Safety Reporting System (ASRS) or the FAA's Aviation Safety Action Program (ASAP); or other voluntary disclosure programs.

The following three examples demonstrate how elements of a voluntary reporting system and a Just Culture can succeed or fail.

## Justice and Fairness without a Formal Program

A large German engineering company expanded their maintenance, repair, and overhaul (MRO) around Europe (West and East), into the Americas, and to Asia. They did this with both organic growth and by acquiring existing MRO facilities. Typically, the German company rotated executives from the parent company into local management roles. Every few years, the key executive role rotated between a local executive and someone from the parent company. This story is about the first rotation of a German executive into the Asian work environment.

As it happened, on one of the German executive's first days on the job at the newly acquired MRO facility, a significant maintenance error occurred. An engineering crew damaged a large engine cowling during removal while using the hangar lift.

The damage to the cowling was extensive. Everyone expected termination of the lift operator since he appeared to be the most culpable party. It was likely that other licensed engineers would also lose their long-time jobs.

The new German executive took the lead on the investigation. There was not an explicit Just Culture policy since this incident happened before the adoption of this concept became popular. Immediately, the executive gathered a team to look at the work environment, how the workers were trained for the engine cowling removal task, the clarity of the procedures, the adequacy of support equipment, and more. The team concluded that some aspects of the work environment – procedures, training, human factors approach, etc. – had not positioned the workers for success and that the maintenance error had been an honest mistake. In a quest for justice, the executive did not fire anyone, but rather, addressed all the contributing factors and installed a replacement cowling.

Later, the German executive asked the same engineer to operate the lift for the new cowling installation. The entire workforce learned of the "damaged engine cowling event" and the fair treatment of the worker. That show of Just Culture influenced the new German-Asian cooperation in a manner that has had an extraordinary long-term impact on the company's safety and efficiency.
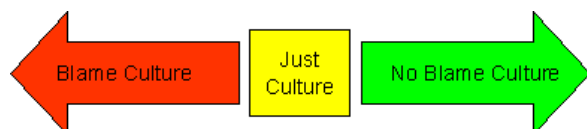
The important moral to this story is that you don't need excessive processes and procedures to achieve justice. While written policy is very important, a Just attitude is most important. However, a Just Culture cannot be dependent on the will of a single executive or manager. The policies must be written, trained, and understood by everyone. That statement leads to the next two stories.

Training and Communication from Day One

This story goes back nearly 8 years, when Airlines for America (A4A) cooperated with the FAA to design, develop, and implement a ground/maintenance version of the Flight Ops Line Operations Safety Audit (LOSA). The maintenance LOSA development process and all related products are available at www.humanfactorsinfo.com.

LOSA is a peer-to-peer assessment that takes place during normal operations. It does not have to be triggered by an event. LOSA permits observers to identify the strengths and weaknesses in the organization. Observations are absolutely non-punitive because no names or identifying characteristics are recorded. Using a threat and error management system, the observer usually identifies safety threats and determines whether the workers are managing the threats, or not.

Training is critical for LOSA programs to succeed. All employees must understand the LOSA concept. The general population of employees must know that LOSA observations are non-threatening. LOSA observers require about 8 hours of training to ensure that protocols are followed and that data are somewhat consistent among observers. Properly trained LOSA observers fully understand the critical nature of data and personnel confidentiality.

A negative event occurred during the initial testing of the LOSA observer training. The LOSA team and trainers were preparing to launch LOSA for a ground operations package carrier. In order to start the LOSA observations, there were extensive deliberations between labor and management. It took nearly 9 months for all to agree to the LOSA test. Because it was still in testing, the necessary LOSA training was not sufficiently delivered to all employees.
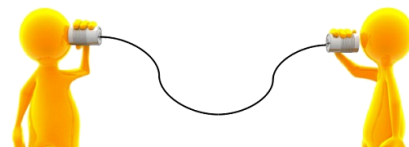
The workforce merely saw people with clipboards walking around the ground operations, which is seldom a welcoming sight. The labor leaders told employees not to worry because it was a test and, in any case, no one would record names.

As fate would have it, one of the LOSA observation trainees noticed that a worker was not wearing protective shoes. Of course, that is a threat to worker safety. It was a valid LOSA observation and the observer noted it. Coincidently, the observer trainee was a friend and next-door neighbor of the manager of that area. During a coffee break, the LOSA trainee saw the manager in the hallway and casually mentioned the improper footwear observation. The manager proceeded to send the worker home for the day without pay. That small incident negated 9 months of planning and set the LOSA implementation back at least an additional year.

The lesson learned is that you cannot halfway implement a critical program. The observer was not ready, the manager was not ready, and what little the workforce knew was proven wrong on the very first day. Complete training and communication is critical from day one.

"Are We All on the Same Page?"

Just Culture implementation is not without growing pains. As early as the mid-1990s, some airlines were listening to or working with leading researchers like James Reason and David Marx.

Early adopters saw the safety, efficiency, and fairness merits of a voluntary reporting system based on Just investigations. One such large carrier decided to test the voluntary reporting system and just culture. The top labor leaders and senior managers saw the potential benefits. When an event occurred, everyone wanted to determine the root cause and find corrective actions.

The company went to great lengths to establish reporting procedures and Just Culture policies by delivering training to everyone. Since it was a radically new program, not all managers were convinced of its value. Some managers were concerned that the new program might lessen employee accountability. Many workers were fearful that a reported error would trigger disciplinary action.

In this scenario, most of the Just Culture champions were at corporate headquarters, where the largest repair facility was based. Leadership decided that the initial implementation would be at a satellite repair facility. The reasonable expectation was that it would be easier, in the first stages, to ensure 100% training coverage for all of management and labor at the smaller facility.

Very early in the Just Culture implementation, there was a maintenance event that resulted in substantive and expensive rework. The workers made a mistake. The supervisors and middle management understood the circumstances contributing to the error and did not take action against the errant workers. When the top manager at the satellite facility saw the cost of the error, he took immediate disciplinary action against not only the workers, but also the managers who followed the Just Culture policy.

The union, at all company facilities, justifiably pulled out of all Just Culture participation. It took years before confidence in Just Culture was restored. Again, the incident demonstrated that a Just Culture must be based on clear, written procedures rather than the whims of individuals.

Summary

When it comes to voluntary reporting, there are many good, bad, and ugly stories. A few years back, I went to my first ASAP Event Review Committee meeting. It was like a courtroom hearing. A representative of the errant mechanic admitted that the mechanic didn't follow a procedure and reported the error. In this case, the company representative felt that there should be a stiff penalty. The labor representative, however, felt that a mild letter of reprimand would be acceptable. The FAA member was the last to vote to achieve the necessary unanimous vote for action against the employee. He firmly stated, "I worked at an airline just like this one, with the same aircraft, for 20 years. Nearly everyone ignored that procedure. Let's stop blaming the worker and fix the procedure." The wisdom and words of that FAA Inspector epitomized the understanding of Fairness and Just Culture.

Dr. David Schroeder, former Civil Aerospace Medical Institute (CAMI) Aerospace Human Factors Research Division Manager, and Patricia Davis of Cherokee CRC, LLC, will discuss the concept of safety culture, which is closely tied to Just Culture, in the next article of this newsletter. Their article summarizes their soon-to-be published extensive literature review. Stay tuned!

"It Doesn't Happen Overnight!" - Improving Safety Culture in the Workplace

David Schroeder, Ph.D.
Patricia Davis, M.B.A, M.A.

Safety culture has been a topic of interest across all industries since the early 1980s, which is when inspectors began pointing a finger at poor safety culture as a cause of a series of high-profile disasters such as Three-Mile Island, Chernobyl, and the Challenger explosion. In the January 2018 Aviation Mx Human Factors Quarterly, Dr. Bill Johnson wrote about the dangerous issue of failure to follow procedures (FFPs). His article described several groups involved in writing maintenance procedures, but his emphasis was on those who use the procedures and the culture that supports those procedures. While many FFPs don't result in negative consequences, others are costly with respect to lives lost, personal injuries, and property damage. In addition, those that require flight delays, cancellations, diversions, and returns have financial consequences. In this article, we will share some findings of our recent research associated with safety culture. First, we must define safety culture and its influences on behaviors, and then we can learn how to measure safety culture and discuss ways to positively change it.

What is Safety Culture?

Everyone has experienced the influence of different work cultures. What is appropriate behavior for work is different from a social gathering or sporting event because there are less strict social constraints. One scientist described organizational culture as enduring values and norms. These values and norms are social "rules" that guide employee interactions with co-workers and supervisors and dictate how tasks are performed. These rules develop both from written policies and procedures and by informal interactions with co-workers and supervisors. Supervisor and management commitment to these guidelines can strengthen or weaken these social rules. Different cultures are present in any organization (safety, creative, innovative, outcome orientation, and team orientation). Safety culture refers to shared perceptions and beliefs that guide employee safety-related behaviors. At times, we may observe that one element of an organization's culture may compete with another. For example, when a supervisor and technician experience time pressure to complete work on an aircraft and yet must comply with safety requirements.

Culture, or more specifically safety culture, is important to those working toward eliminating FFP errors and violations. Addressing how a task is performed is pointless if you didn't also consider the environment where the task is performed. One widely used model captures many of the themes that researchers have found within safety culture. The PEAR (People, Environment, Actions, Resources) model demonstrates four aspects of assessing human factors in aviation maintenance.

Using this model, an organization can assess their level of readiness to support a culture of safe work behavior by asking some questions about each of these aspects.

- Does the organization take the time to ensure employee training?
- Are employees motivated to help others follow procedures?
- Do the supervisors and managers support and reward employees for taking the necessary time to perform tasks safely, or do they push for more production and "turn a blind eye" to cutting corners?
- Does the organization provide the appropriate tools, technical documents, and human resources to perform a job safely and in a timely manner?
- Are employees encouraged to report their errors or near misses (reporting culture)?
- Does management use information from safety audits and self-reports to develop effective improvements or interventions (learning culture)?

Being able to answer these questions favorably indicates a safety culture that is supportive of safe work behaviors.

How do we measure Safety Culture?

Researchers have measured safety culture using surveys by identifying aspects of the organization that influence safe behaviors and asking to rate their perception of these aspects. The surveys also ask questions about employee safety behaviors and safety outcomes.

Special analytical techniques identify the overall level of safety in the organization as well as the relationship between employee perceptions of safety and various safety outcomes. Higher survey scores represent a more positive safety culture and signal higher levels of safety compliance and participation and, as a result, demonstrate a lower number of FFPs. Most researchers refer to these results as a measure of the safety climate, since they represent a "snapshot" of the organization's overall safety culture.

One of the first attempts to measure an organization's safety culture took place in 1980. When five companies participated in a 40-item survey that measured factors related to safety, some factors included the importance of safety training programs, management attitudes toward safety, effects of safe conduct on promotion, level of risk at the workplace, and others. Higher scores represent higher overall perception of safety levels. This study was one of the first to show that companies that had a higher rated safety culture were also behaving in a way that produced safer workplaces. Following the 1980 study, there have been numerous item sets developed to measure safety culture. These sets, also known as scales or dimensions, include management commitment to safety, safety system and procedures, supervisor safety support, communication, training, and competence. An example of a survey that can be used in organizations to assess their current safety culture can be found in Fogarty, Murphy, and Perera (2017)[1].

[1] Fogarty, G.J., Murphy, P.J. and Perera, H.N. (2017). Safety climate in defense explosive ordnance: survey development and model testing. Safety Science, 93, 62-69. https://dx.doi.org/10.1016/j.ssci.2016.11.010

How does Safety Culture influence safety behavior?

At a basic level, the expectation is that organizations with more positive safety cultures will have employees who demonstrate a higher level of compliance with policies and procedures; are more involved; and have fewer accidents, injuries, and near misses. Although there is support for this connection, oftentimes, personal and organizational factors influence the nature of the relationship. Andrew Neal[2] and Mark Griffin are two researchers who have spent a great deal of time studying safety culture and behavior.
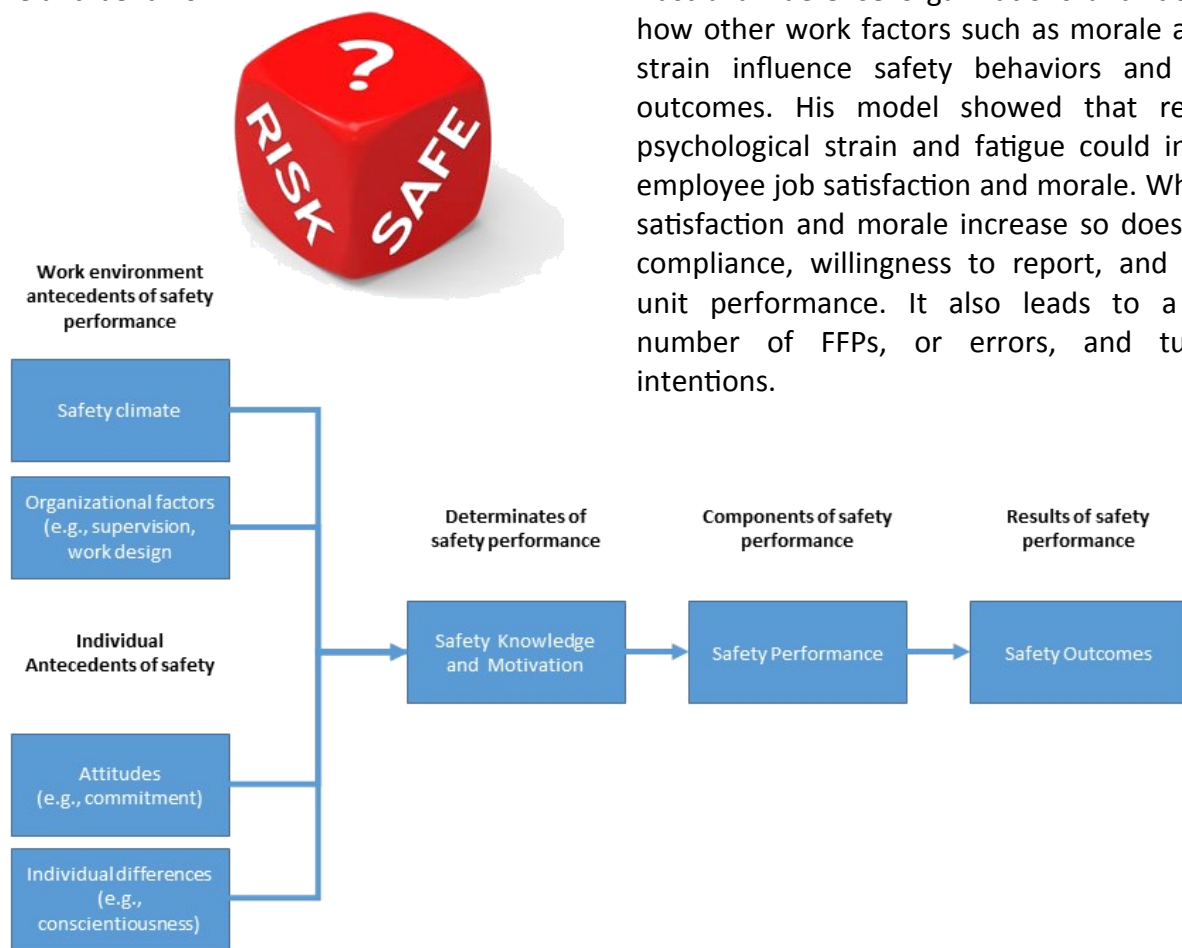
Not only do their studies cover the measures of safety roles, but they also point out the importance of organizational factors such as leadership, training, work design, and work pressures as well as individual differences (conscientiousness) that interact and influence employees' safety knowledge and safety motivation (see Figure 1). Employee safety knowledge and safety motivation determines safety performance and overall safety outcomes. Gerard Fogarty's[3] research also focused on maintenance safety culture. In 2004, he worked with aviation maintainers in Australian defense organizations and identified how other work factors such as morale and job strain influence safety behaviors and safety outcomes. His model showed that reducing psychological strain and fatigue could increase employee job satisfaction and morale. When job satisfaction and morale increase so does safety compliance, willingness to report, and overall unit performance. It also leads to a lower number of FFPs, or errors, and turnover intentions.

Figure 1: Neal and Griffin's (2004) framework for conceptualizing; safety climate and safety behavior.

[2] Neal, A., & Griffin, M. A. (2004). Safety climate and safety at work. In Barling, J., & Frone, M. R. (Eds.). *Psychology of Workplace Safety*. Washington, DC: American Psychological Association, 15-34.

[3]Fogarty, G. J. (2004). The role of organizational and individual differences variables in aircraft maintenance performance. International Journal of Applied Aviation Studies, 4(3), 73-90.

In one study, Fogarty and his colleague demonstrated that while safety climate has a direct influence on violations and errors, psychological strain was the cause of errors. Another feature of work culture is the presence of subcultures. Managers typically have a more positive view of the culture, when compared to the views of front-line employees. In addition, the way in which individual work groups conduct themselves (work norms) plays a strong role in employee intent to comply with procedures and to engage in self-reporting of violations. As you can see, the relationship between organizational factors, safety culture, and safety outcomes is complex and multi-dimensional, so how do we influence culture positively?

Improving Safety Culture

In the past, efforts to increase safety culture have focused around front-line employees. We now know that we need to look at all aspects of the organization. Research by Thomas Krause[4] suggests that efforts must start with the selection and training of leaders because it is their vision, communication, and accountability, among other traits, that support the organization's culture. In a 2002 study, Dov Zohar[5] encouraged safety-based talks between supervisors and front-line employees. After eight weeks, this small change in focus resulted in a dramatic increase in safety-oriented communications, an increase in employee safety behaviors, and a decline in micro-accidents (injuries). This effort is supportive of the role of communication and accountability in supporting safety. Further research is needed to identify the exact nature and importance of different intervention strategies.

Culture change is not easy and it won't happen overnight. Culture is enduring values and norms that are resilient to many change efforts. Yet, studies discussed show that by focusing on the appropriate aspects of your organization, you can positively influence your safety culture. Many of us work in environments where we experience daily challenges to utilize job resources, respond to job demands, and accomplish assigned tasks. Improving the safety culture will require the use of information gained from audits and culture assessments to ensure that leadership, at all levels, provides the necessary training, tools, and resources so that employees have the knowledge and motivation to comply with safety policies and procedures.

[4]Krause, T. R. (2005). Leading with Safety, Hoboken, NJ: John Wiley & Sons, Inc.

[5]Zohar, D. (2002). Modifying supervisory practices to improve subunit safety: A leadership-based intervention model. Journal of Applied Psychology, 87(1), 156-163.

Beyond "Swiss Cheese" – How organizational choices make the holes bigger and accidents more likely

Steven J. Landry, Ph.D.
School of Industrial Engineering
Purdue University

Editor's Note: The information presented in this article is the opinion of the author and is not necessarily endorsed by the FAA by presence in this Newsletter. The author welcomes the variety of opinions that contribute to our ongoing continuation of safety excellence.

Almost everyone is familiar with James Reason's "Swiss cheese" model of accidents. In that model, protections against accidents are slices of Swiss cheese with holes in them. When the holes in all the slices line up – presto, an accident occurs. But a careful review of many accidents reveals a more complex picture.

In this picture, accidents are not random placements of small holes in numerous slices of Swiss cheese protection, but a slow decline of safety buffers over time. They are, in fact, removals of slices of cheese with growth in the holes in the remaining slices. The result is a steady increase in the likelihood of an accident. Eventually, an accident occurs and it seems obvious, in hindsight, that there were organizational safety issues.

To be clear, I am not suggesting anyone intentionally makes systems less safe. A very safe system sometimes seems "too safe." Maybe we can get away with fewer, or less severe, safety precautions without any everyday reduction in safety while saving a lot of money and time. These situations present with good intention and it is not until an accident occurs that criticisms are targeted at the organization. Take, for example, the Alaska Airlines Flight 261 accident in 2000, where excessive wear on the jackscrew assembly that operated the horizontal stabilizer trim system resulted in its failure and a loss of pitch control.

In that accident, 83 passengers and 5 crew were killed when the aircraft crashed into the Pacific Ocean off the coast of California. (This example, and its "drift into failure" is also discussed in Sydney Dekker's 2011 book Drift into Failure: From Hunting Broken Components to Understanding Complex Systems, CRC Press.)
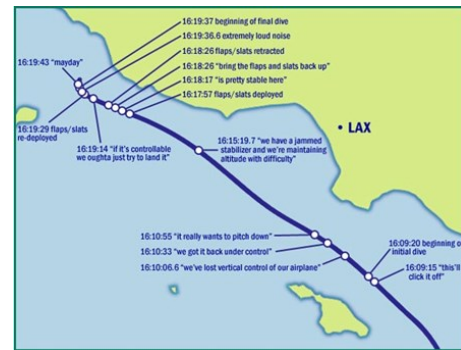

Figure 1. Flight path of Alaska Airlines flight 261. Image courtesy FAA.

I would argue that this accident was not a rare alignment of holes in the layers of safety precautions, but rather a predictable result of, to extend the Swiss cheese analogy, the gradual growth of the holes in the cheese. By that, I mean that over time, Alaska Airlines progressively increased the period between jackscrew lubrication and endplay maintenance checks. And why not? Although Alaska Airlines could not specifically identify the justification for changing the intervals, it seems likely that previous inspections of the jackscrew indicated that the shorter intervals between lubrications were not necessary. (End-play checks were used to evaluate wear.)

Specifically, over the years Alaska Airlines progressively increased the period between lubrication of the jackscrew from every 700 flight hours in 1985 up to 2,550 flight hours in 1996. This was in part a response to the manufacturer changing its recommendation regarding lubrication from every 600—900 flight hours to every 3,600 flight hours in the 1990s.

Alaska Airlines also progressively, increased the end-play check intervals from every 2,500 hours in 1985 to every 9,550 flight hours in 1996.

This is a significantly longer interval than the manufacturer recommendation of every 3,600 flight hours. However, one should not look at these increasing intervals and think that Alaska Airlines was making these changes precipitously. Instead, it is clear that changing general maintenance intervals played a role, and there are records of some of the deliberations, internal to Alaska Airlines, that resulted in the changes.

Alaska Airlines also used internally manufactured, rather than original manufacturer, tools to measure wear of the jackscrew. Again, in hindsight, this may have seemed inappropriate, but at the time, there were probably excellent reasons for this. Overall, there was no clear reason to worry – apart from an Aeroflot Flight 8641 accident in 1982 – the jackscrew had never failed. Plus, there were two independent threads, where failure of one would still leave the assembly fully functional, and no one had seen even one thread fail on a U.S. carrier maintained aircraft.

This situation was not, and is not, unusual. There is a tendency for organizations to "shave a little off the top" of restrictions and maintenance intervals if there are no accidents for a long time. It seems justified, because excessive restrictions cost money and time and, if they are truly excessive, are unnecessary. If it seems like no one ever catches a problem during a 3-month interval, why not stretch it out to 4 months and save some money? The problem, of course, is that no one knows for sure if the restrictions in place are actually excessive. In reducing the restrictions, we are effectively mak-ing the holes in the Swiss cheese bigger and bigger, and thereby making it easier and easier for an accident to occur. Put another way, by increasing maintenance intervals and/or relaxing tolerances, we are creeping closer and closer to the edge of a cliff.

I would argue that this problem is getting worse and not better. As we use more and more complex designs, created by a computer and not particularly understandable by humans, we

Figure 2. Jackscrew assembly recovered from Alaska Airlines flight 261 crash. Image courtesy NTSB.

eliminate the "overbuilt" nature of many of our systems, leaving them with less of a buffer in case we are wrong about our assumptions. As engineers and maintenance personnel, we used to have a natural feel for how the system should work and feel. If something seemed wrong, we could tell what that meant. Modern systems are much more opaque, in that it is much more difficult to get an intuitive sense of how they should be functioning. This suggests we should exercise greater caution when reducing safety margins, even if they seem excessive.

I'll finish by adding that this example is a little misleading, because John Liotine, a lead mechanic for Alaska Airlines in Oakland, CA, identified this problem before it actually occurred. In 1997 he recommended replacement of the very jackscrew assembly that failed, and in 1998 he told the FAA that Alaska Airlines was sidestepping maintenance regulations. There are also other analyses of this accident that identify a number of systemic failures leading to the accident including the existing warnings about wear on the jackscrew on this aircraft. However, I think the lesson still applies – those systemic failures caused this accident because of the slow relaxation of barriers to safety, without an analysis of what effect that relaxation would have on the probability of an accident occurring. Therefore, the Flight 261 accident is not well modeled by the Swiss cheese analogy, unless one considers the effect of the organizational actions taken as changing the layers of cheese and the size of the holes in that cheese.

Data mining in Maintenance Human Factors using wearable devices and text mining

Audrey Reinert
School of Industrial Engineering
Purdue University

Editor's Note: The information presented in this article is the opinion of the author and is not necessarily endorsed by the FAA by presence in this Newsletter. The author welcomes the variety of opinions that contribute to our ongoing continuation of safety excellence.

Technical advances in wearable device design and text processing open a new frontier in understanding the root cause of maintenance human factors incidents. Maintenance experts can use wearable devices to track their heart rate variability, skin conductance, and other physiological measures while processing incident reports using text-mining algorithms can help to identify long-term trends. This article will examine how these technologies can be used to better understand contributors to maintenance incidents.

Wearable Computing

Wearable computing refers to a branch of computer science research that studies the use and design of wearable computers. These devices are designed to be worn on top of or underneath clothing, and can range in size from a head mounted display, to a wristwatch, to a small pin head. Wearable devices have been developed for use in the behavioral modeling research, healthcare monitoring, and service management.

The use of wearable devices as research tools provides a unique opportunity for maintenance human factors professionals. Wearable devices come pre-built with a range of sensors-from accelerometers, to gyroscopes, to heart rate and skin conductance monitors, which permit real time measurement of emotional state and movement. The size of wearable devices is small enough that it is not disturbing in the user's daily activities.

These devices are not without their limitations as research tools. The small size of these wearable devices limits the number of sensors that can be stored within a case. Therefore, each device only records a limited variety of inputs. The sensors in these devices are often built to commercial standards and not research standards. As such, the data from these devices tends to be less reliable.

These limitations do not mean that wearable devices cannot provide unique insights into maintenance human factors problems. Wearable computing devices provide a more complete picture of the wearer's actions. One specific case, in which wearable computing devices have been used, takes the accelerometer data and interprets the position and motion of the wearer's hands throughout a task. These data can be correlated with pulse data to determine the wearer's level of exertion. If the device has camera capability, as is the case in head mounted displays, researchers can estimate where the wearer was looking during the task.

There are specific human factors issues which arise from the use of wearable computing devices. Display sizes are often physically smaller than mobile phone screens. This means that the design must only display task relevant information or display must have a higher information density.

In the case of head mounted displays, the information must be transparent enough to see through, but not so transparent as to be unreadable. There are further design questions of where in the visual field the information should be presented. Presenting information in the center of the visual field increases the likelihood the user will notice and respond, but that placement can interfere with their task performance by obscuring their vision.

Introducing cameras into a work place raises concerns of invasions of privacy. In addition, people tend to alter their actions and behaviors when they are being recorded. Further, video recording may not be permitted in all environment.

Text Mining

Text mining is the process of deriving information from text using statistical pattern recognition. Not all words or phrases in a set of texts are equally informative to an analyst. Some words and phrases are so common that using them in an analysis is meaningless because they would relate with every other term. These terms are called stop terms and are automatically removed from consideration (e.g. "the", "and", and "a").

Once a set of text has been preprocessed, the set will be put into a database for subsequent statistical manipulation. These manipulations include frequency counts to determine the most and least common terms along with trend analyses to determine which terms are correlated with each other. This data set can be analyzed as a network to show the relations between each term.

Text mining can show maintenance human factors researchers the following insights. First, these analyses show how individuals are related to each other and the terms they use to refer to each other.

When a sentiment analysis is conducted, and layered on top of the network, a researcher can see the emotional aspects of the relationships between terms in the network. A sentiment analysis identifies and categorizes opinions expressed in a piece of text to determine if the author feels positively, negatively or neutrally about a topic.

In the context of maintenance human factors, text mining and sentiment analysis can be used to answer the following types of questions. First, are there reoccurring categories of events, and are these events experienced by a certain category of maintenance personnel? Second, is there a source of tension between individuals, and how long has this tension been present? Finally, is there an underlying trend between the time of day that incidents occur, and how the individuals involved in the incident interacted or felt towards each other?

There are a few limitations to using text mining as a research tool. The chief concern is that researchers can only draw conclusions from the texts provided. Further, determining which relationships are truly meaningful requires knowledge about how relationships and interactions typically occur within the space being examined.

What can data tell us?

Researchers should be aware of the following questions when generating and analyzing large datasets from wearable devices or text mining applications.

First, does the research question correspond with the data the device can produce? Second, how easily can the data be extended, through additional analysis and processing, to address the original research question? Finally, what questions are the data simply unable to address?

The answers to these questions have significant impact on research quality. The phenomena being studied will be poorly represented in cases when there is a poor communication between the research question being tested and the device used to collect the data to test that question. While there are software tools and analytic methods to extend a dataset, these tools come with their own limitations and biases. The true power comes from the premediated design, execution, and analysis of the data.

Another consequence of working with large datasets is the dominance of non-informative data and artifacts, which can appear in the data. Some artifact data may be attributable to the type of device, as wearable devices can slip or move on the body. Text data can be incomplete, misspelled or oddly phrased. Data mining techniques can be employed to remove parse statistical noise and artifact data from the clean data. Many commercially available data mining software packages come with these features pre-loaded.

Researchers can compensate for problems by having a focused understanding of their research question, understanding what the data can and cannot tell them, and knowing what their analytic tools can process.

Given all these cautions, analyzing large datasets of text and wearable computing data can produce unique understandings, which analyses of smaller datasets cannot. Large datasets can contain statistically rare events, which smaller datasets may miss. In summary, we no longer have to wait for a negative event to occur. We can address the hazards in our aviation work environment through analysis of data collected through wearable devices, and through text mining to identify potential risks in near real time.

We want you!

We would like to take this opportunity to thank our readers for their continued support of this newsletter. We have received several requests for article submissions, so keep them coming!

Our editors know the best articles and stories come from FAA and industry personnel. Those contributors do not have a primary responsibility writing articles for government newsletters, but they know what they are talking about when it comes to issues related to aviation maintenance. Most importantly, they tell relevant stories that have wide spread interest and value to readers of this document.

Our Request and Promise to You

Every submission will receive prompt feedback from our great editors! With your approval, we will go beyond the Microsoft grammar and spell checker. Before we publish it, we will get your sign-off.

Newsletters come out every 3 months, yes quarterly, starting at the end of March. If you get something to us by the middle of the quarter, then we can usually make the deadline. Send your submissions to janine.ctr.king@faa.gov. If you want to talk about your idea before writing, send an E-Mail to Dr. Bill Johnson and he will call with advice (bill-dr.johnson@faa.gov). If you have an interesting maintenance safety picture, please send it along and provide a caption for the photo. We thank you for your input!

Thank you

- *21st World Aviation Training Summit, **April 17-19, 2018**. Orlando, Florida. www.wats-event.com*

- *Aviation Technician Education Council, Webinar on Maintenance Training, **June 19, 2018**. www.atec-amt.org*

See something missing?

Are you a regular reader of our Mx HF Newsletter? Do you see something we're missing? As always, please let us know! If you have ideas for future articles or would like to contribute, please contact our newsletter staff at:

janine.ctr.king@faa.gov