



## IN THIS ISSUE

- Maintenance Shifts.... p. 1
- Reporting Fatigue....p. 2
- Fatigue ROI.... p. 3
- Outdated Mental Model....p. 5
- Safety Culture....p. 6

# MX Fatigue

## focus

## Maintenance Shifts: Can We Mitigate the Impact of Fatigue?

By The Honorable John Goglia

*About the Author: The Honorable John Goglia is an aviation expert and former member of the U.S. National Transportation Safety Board (NTSB). With more than 30 years experience in the aviation industry, he was the first NTSB Board Member to hold an FAA aircraft mechanic's certificate. Currently, John Goglia is senior vice president for aviation operations and safety programs for consulting firm JDA Aviation Technology Solutions.*

Since I began working on airplanes in the early '60s, aviation maintenance has been performed on basically three shifts centered around start times of 7 am, 3 pm, and 11 pm. Research as early as the 1980s has shown that maintenance performed between 3 am and 5 am has the greatest likelihood of being performed improperly because of fatigue issues. The concern, of course, is that critical work performed improperly could have dire consequences for the safety of flights in that aircraft. When I was an NTSB Board Member, we investigated a number of accidents where fatigue during these hours was an issue in suspected improper maintenance. One accident that stands out in my mind is the Air Mid West accident in Charlotte, North Carolina. The airplane crashed on take off killing 21 people. The NTSB determined that the aircraft took off tail heavy and the pilot was unable to keep the nose down because elevator travel was limited or restricted due to

improperly rigged flight control cables.

Board investigation revealed that work had been recently performed on the aircraft's elevator system. Interviews with the mechanics indicated a number of shortcomings with maintenance procedures, including lack of proper training, insufficient resources and the possibility that fatigue affected the quality of work performed. In fact, the work was performed on the midnight shift in the early morning hours. Compounding the fatigue issues, there was the lengthy commute the workers made getting to the repair facility.

So how do we mitigate the impact of fatigue – especially at the end of the midnight shift? One answer would be to look at whether shifting the start and end times of the shifts would help – but that's a long-term solution that probably requires long-term study. It's not reasonable to think that the basic three-shift day will change any time soon, but we can take steps to make sure that critical tasks are performed by well-rested mechanics.

To that end, I believe that we need to:

1. Recognize that fatigue is a threat to aviation maintenance and that the early morning hours are particularly vulnerable.
2. Spread awareness among maintenance employees of the indicators of fatigue and the limited ability to combat it with caffeine and other stimulants.
3. Train maintenance supervisors to be alert to signs of fatigue and the importance of not assigning critical work to fatigued employees. This is particularly key with the increased use of overtime to compensate for staffing shortages.
4. De-stigmatize mechanics self-reporting of fatigue similar to a pilot's ability to call in too fatigued to fly.

Fatigue management is everyone's responsibility. The FAA has a regulatory responsibility, airlines and repair stations have a management responsibility and each maintenance employee has a personal responsibility. No passengers should have to worry that maintenance performed on their aircraft was performed by someone too fatigued to do a proper job.

**"Fatigue management is everyone's responsibility."**



## What Does the Aviation Safety Reporting System Tell Us about AMT Fatigue?

By Dr. William L. (Bill) Rankin

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My first experience with the outcome of AMT fatigue happened around 1996. I was doing MEDA training for a Boeing customer when I learned about their peculiar line maintenance policy: "If you start work on an aircraft, you stay on that task until it is completed." I guess that they didn't want to worry about task handover, which we all know is a common contributing factor to error. A couple of months after I left, I learned that two AMTs had carried out a task on a 767 that took 28 hours to complete. While taxiing the 767 over to the heavy maintenance hangar, they both fell asleep and ran the left wing of the 767 into the hangar wall causing several million dollars worth of damage. The policy was changed within a week. I hope that we don't have to learn that type of lesson before making other work-related changes because of AMT fatigue.

What other lessons have we already learned from AMT fatigue? The Aviation Safety Reporting System (ASRS) contains AMT reports. NASA's Richard Borque ran a query on ASRS to find AMT fatigue-related reports. The query generated 105 reports from 1 January 1990 to about 1 June 2009. I read them all—talk about fatigue!! The first thing that I figured out is that they weren't all about fatigue. I dropped 28 of the reports from the analysis, which left 77

**"I hope that we don't have to learn that type of lesson before making other work-related changes because of AMT fatigue."**

legitimate, fatigue-related ASRS reports.

What did I learn from them?

First, I coded the reports regarding what kind of error the fatigue caused — errors of commission (i.e., did something, but did it incorrectly) or errors of omission (i.e., forgot to do something that should have been done). Professor James Reason of Manchester University believes that a majority of AMT errors are errors of omission. However, in this study I found that the errors of omission and errors of commission were about equal — 39 of the events were due to errors of omission and 38 of the events were due to errors of commission. So, it is possible that fatigue has more of an impact in causing errors of commission than in causing errors of omission. However this finding could also be due to a reporting bias—AMTs may find it easier to admit to an error of commission rather than

admitting that they just plain forgot to do something.

What were some of the errors of omission?

- Taxiing aircraft and forgot to stop at an active runway
- Failed to remove tape covering a pilot tube
- Failed to re-install flap screws
- Failed to enter information into computer after task completion
- Failed to install top-of-wing access panel (a common error in the ASRS database)
- Failed to disarm door before opening
- Failed to torque and safety a nut

Any of these sound familiar to you?

What were some of the errors of commission?

- Damaged RAT blade on functional test
- Installed flap control knob incorrectly
- Replaced incorrect O<sub>2</sub> bottle
- Locked out wrong valve
- Incorrect log book entry
- Installed fan blades in wrong order
- Incorrectly evaluated NLG door delamination.

Do any of these sound familiar to you?



**"Do any of these sound familiar to you?"**



“Mixing fatigue with time pressure is an error waiting to happen.”



(ASRS cont.)

Of course, the AMT submitting the ASRS report was free to write about any contributing factors that he/she cared to talk about. So, I looked through the reports for additional contributing factors that when combined with fatigue could lead to potential safety issues. Around 42 of the 77 reports mentioned fatigue as the only contributing factor. However,

- 10 also mentioned time pressure
- 7 also mentioned poor lighting
- 5 also mentioned stress
- 5 also mentioned multitasking (task overload, heavy workload)
- 5 also mentioned workplace distractions/interruptions,
- 2 mentions each for complacency, lack of experience, understaffing, hot and humid, and illness, and
- 1 mention each for lack of communication, pre-occupation, and high noise levels.

(Note: This does not add up to 77 total reports because some reports had up to 5 contributing factors mentioned.)

So, it appears that combining fatigue and time pressure is a bad mix for maintenance. The “poor lighting” surprised me a bit until I realized that many of these reports dealt with the midnight shift (where fatigue is most likely), and that lighting could easily be an issue for line maintenance in this situation.

So, what have we learned from this? First, fatigue is an issue with regard to AMT errors. Second, fatigue may have a bigger impact on errors of commission than on errors of omission. Finally, mixing fatigue with time pressure is an error waiting to happen.

## Challenges of Measuring Return-on-Investment of Fatigue Interventions

By Dr. Bill Johnson

*About the Author: Dr. Bill Johnson is the Chief Scientific and Technical Advisor for Human Factors in Aircraft Maintenance Systems for the Federal Aviation Administration. Dr. Johnson has over 30 years applied research and development experience with a focus on human performance in maintenance and repair of complex systems. His research efforts concentrate on every day solutions that affect human behavior and performance.*



A nuclear powerplant training manager once told me that he justifies buying a \$15M simulator by comparing the investment to the cost of a nuclear disaster. Unfortunately, it is not so straight forward to make a case for the Return-on-Investment (ROI) of maintenance fatigue interventions. It is difficult to *prove* that fatigue awareness training will prevent an airplane accident. However, it is still valuable to make the case for investing in fatigue awareness and other interventions.

The path to addressing and measuring the impact of fatigue in maintenance includes:

- Recognizing and quantifying fatigue challenges
- Facing those challenges with proven interventions
- Assessing the cost of interventions, and
- Measuring the impact

All of these steps require commitment from individuals, the company, and the government.

**“It is difficult to prove that fatigue is the primary cause of an event.”**

*(ROI Fatigue Interventions cont.)*

The *FAA Operator's Manuals* for maintenance and for airport operations ([www.hfskyway.faa.gov](http://www.hfskyway.faa.gov))

include chapters on fatigue and on ROI. The manuals make a case for measuring numerous small interventions and then assessing the financial impact. The scientific finesse is not only in getting the cost and return numbers close, but also in assigning the probability that the intervention will have a direct impact on safety and therefore on cost.

Interventions are usually focused on specific problems. For example, if there are numerous slip and fall incidents in the hangar or ramp area, the interventions are to make the hangar floor surface rougher and to redirect water on the ramp. ROI is easy. It is the cost of the intervention compared to the amount saved from reduced incidents. These factors are relatively easy to measure.

It is difficult to prove that fatigue is the primary cause of an event. The March 2009 Colgan Air accident had a number of suggested contributing factors, including weather, night time, lack of training, wages, lack of sterile cockpit, aircrew professionalism, and fatigue. While any of these factors can be causal, it is likely that a rested crew may have made different decisions and the landing could have been a non-event. Both the FAA and NTSB recognized the relevance of fatigue with a resultant streamlined path toward new rules for pilot rest. In this case

the challenge was recognized and interventions (i.e. duty time rules) were implemented though there has been no published ROI thus far.

NASA's Aviation Safety Reporting System has over 75 mechanic reports in which fatigue was an issue (see accompanying ASRS article by W. Rankin). These reports provide some insights for fatigue interventions. Most of the interventions are likely to focus on personal fitness for duty issues and on the importance of reasonable duty time with scientifically proven scheduling practices. Industry is recognizing the challenge and moving to address the issue.

### **Fatigue ROI Example**

Assigning cost to an event is always tricky. Never-the-less, an example is offered herein. It would be reasonable to project that a mid-size company, with 1000 mechanics/technicians, can incur as much as an estimated \$25 million in expenses related to error in maintenance and ramp operations. This does not have to be included in “the cost of doing business,” especially in tough economic times. Preventable errors include such things as component rework, damaged airframe systems, maintenance delays or cancelled flights, flight diversions, and more. It is hard to be sure about such a cost number because it does not usually put a value on opportunity costs, customer goodwill costs, and other less tangible losses. The causes of error could include any of the famous Dirty Dozen, like lack of knowledge, failure to communicate, lack of teamwork, and fatigue.

For this example the company decides to establish a Maintenance Fatigue Awareness Program. The program includes promotional materials like posters, hats, calendars, and four hours of training. The cost of this intervention includes wages and overhead for 4,000 hours of training, 4,000 hours of replacement workers during training,

curricula development, instructors, promotional materials, and other logistics. The conservative estimated cost of this intervention is \$1.1M over a six month period. Next comes the “fuzzy math” of estimating the impact of this intervention. Assume that 1,000 mechanics apply the training, improve their sleep habits and increase their sleep duration. They pay attention to the fact that alertness is a “fitness for duty” issue. At the same time the company uses scientifically-proven scheduling methods. Overtime work is continued at a reasonable rate. The company also creates a fair policy about “calling in tired.” Therefore, the workers and the company approach fatigue awareness with the same vigor as Mothers Against Drunk Driving treat alcohol impaired driving. The result could be an estimated 10% performance improvement resulting in a 10% decrease in expenses related to error. That could be an estimated \$2.5M savings in the first full year. The ROI is a function of the return (\$2.5M) minus the cost of the intervention (\$1.1M) divided by the cost of the intervention. The result, for this example is 127%. Plug in your own numbers to estimate the ROI for your organization.





## Outdated Mental Model

By Roger Hughes

About the Author: Mr. Roger Hughes is a Human Factors Educator and the writer, editor, and distributor of the Aviation Human Factors Industry News. He is Founder of Decoding Human Factors, Inc. and a former jetBlue Airways Human Factors Manager.

### “Stop, Think, Observe and Plan.”

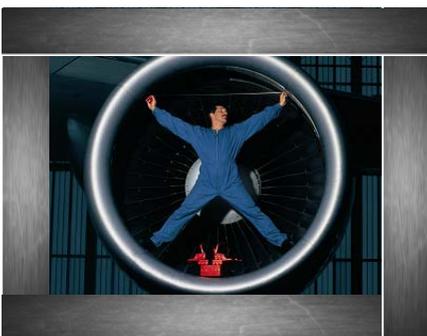
(ROI Fatigue Interventions cont.)

#### The Intangibles

Accountants would likely argue that concepts like ROI and intangibles do not belong in the same sentence. However, it is appropriate in the context of fatigue.

#### “Rested people are simply nicer!”

Recently a Southwest cabin crew member told me that SWA cabin crews are the friendliest/nicest in the industry. The crew member attributed the friendliness to the proactive SWA policy of scheduling the longest layover rest periods in the industry. The rest time is tangible. You can count it. Having friendly, qualified workers, who are alert and ready to perform their safety duties may be intangible, but it counts in my book. Rest assured (pun intended) that the results of proper cabin crew rest apply to every job in the industry, including maintenance!



The cover of a recent *National Geographic* magazine, *Adventure*, caught my eye with a story on why smart people make big mistakes (and how you can avoid them) written by Laurence Gonzales.

An AMT who is also a pilot conducted his preflight briefing for a cross-country trip in his private plane. The weather briefing on his route had no mention of bad weather. He had created a mental model of how the trip was going to unfold. As he was approaching his destination the skies ahead had many dark patches that didn't fit his mental model so he ignored them. As he was monitoring ATC he heard another pilot report she was flying up ahead in severe rain and thunderstorms. Suddenly he comprehended that he was flying into significant danger. Fortunately, he just had a few miles to go and landed. By the time he touched down and taxied to the terminal the far end of the airfield was consumed in rain and lightning. His outdated mental model almost did him in.

Another example occurred when during a professional rock-climbing titles participant Lynn Hill was preparing to climb what she called an easy route. She threaded her rope through her harness, but then instead of tying her knot, she stopped to put on her shoes. While tying them she talked to another climber then returned to climb the rock face. She recalls, “the thought occurred to me that

there was something I needed to do before climbing.” She dismissed this thought. She climbed the wall and when she leaned back to rappel to the ground she fell 72 feet, her life narrowly saved by tree branches. She had created a very efficient model for tying her rope to her harness. So the act of tying her shoes may have been similar enough to tying her rope that it allowed her to reach the unconscious conclusion that her rope was tied, even while leaving a slight residue of doubt. She should have listened to her inner voice.

At some level we see ourselves in this story with a knot half-tied somewhere in our lives, just waiting for us to put our weight on it. One of the frequently ignored factors in many accidents is the way we form models of the world and the way we use them. Once models are established, they require no thought. Mental models can sometimes betray us. We are lulled into complacency by our natural tendency to create models. We don't really perceive the world most of the time. We take in perceptions though our senses and then pull up what seems like the most relevant model. This explains how many accidents happen in what appears to be a safe work environment.

Mental models are created and reinforced every time we do repetitive tasks. Our minds'

eye is looking at our mental model instead of what is actually being seen. This may explain why emergency exit slides are blown when the door is still in the armed position or fuselage cracks go undetected. When Gregory Berns, Ph.D., a professor of psychiatry and behavioral science at Emory University was in survival school, he was taught an acronym STOP for Stop, Think, Observe, and Plan. That's what smart people do to break the complacency cycle. If you don't do that, your behavior will be whatever you've practiced. Slow down and think of the acronym STOP. It will allow you to override your mental image and have second thoughts because sometimes first thoughts are no thoughts at all.

## Safety Culture in Maintenance Operations

By Dr. Terry L. Von Thaden

*About the Author: Professor of Human Factors in the Aviation Human Factors Division at the University of Illinois, Institute of Aviation in Urbana-Champaign. Dr. Von Thaden's research involves the study of information complexity, and measures of the culture of safety in high risk, safety critical sociotechnical systems including security, medical, and transportation systems.*

Whether we act as individuals or as part of an established organizational structure we must conscientiously balance safety and productivity to achieve not only the best *way of doing things* but also the *thing* itself. Through establishing a positive safety culture in an organization, we can incorporate the *process (way of doing)* of safety into the *product (thing)* as well. In many industries, safety means the prevention of employee injuries. In others, such as aviation, employee safety is important, but the primary focus is on public and operational safety. It is important to identify the organization's safety culture as it represents a critical factor that influences human performance.

Safety culture is defined as the enduring value and prioritization of worker and public safety by each member of each group and in every level of an organization. It refers to the extent to which individuals and groups will:

- commit to personal responsibility for safety;
- act to preserve, enhance and communicate safety concerns;
- strive to actively learn, adapt and modify (both individual and organizational) behavior based on lessons learned from mistakes; and
- strive to be honored in association with these values.

The intent behind a culture of safety combines key issues such as personal commitment, responsibility, communication, and learning in ways that are strongly influenced by processes set down by leadership, but also influence the behavior of everyone in the organization toward the ultimate product of a proactive safety generating organization. Organizations possess a safety culture of some sort, but each culture is expressed with varying degrees of quality and follow-through.

An organization must evaluate its strengths and weaknesses to promote the creation of consistent and positive safety behavior among all employed there. But what does this mean for maintenance operations? In a recent study, we evaluated organizational factors relating to fatigue in commercial aviation. The 2,131 employees who responded to our survey represent flight crews and maintenance from 5 airlines. Across the airlines, self-reported fatigue items were relatively high for *calling in fatigued* and *reporting for duty fatigued*; with the exception of one negative item: *scheduling to work as much as legally possible; with little regard for sleep schedule or fatigue*. The average scores did not vary significantly between flight operations and maintenance. We found that policy and supervisory commitment to safety were the most effective predictors of self-reported fatigue, indicating organizational culture plays a role in the fatigue employees actually feel. Fatigue was also significantly related to self-reported safety behaviors, indicating that employees who feel fatigued are also likely to engage in other unsafe or risky acts.

To promote a strong culture of safety, an organization must proactively train the positive characteristics and inform the community of the priority of safety in operations, then, most importantly, it must uphold these values when put to the test. For these reasons, safety culture and risk in an organization must be specifically identified and clearly measured for any training or procedural changes to be introduced and accepted into the organization. This will lead to changes in the way the work is managed and performed over time. If a strong positive culture of safety is the goal, the human element must be the top consideration when scheduling maintenance activity. While this may appear at odds with lean production policies, that is, the efficient and quick performance of work, it is not. When the individual's health and safety is not properly cared for, their work suffers from mistakes and do-overs. This adds vulnerabilities in the maintenance process and affects the quality of the overall maintenance product. The end product must always continue to preserve safety and health when it comes to aviation maintenance. This focus, in turn saves time and money on the bottom line.