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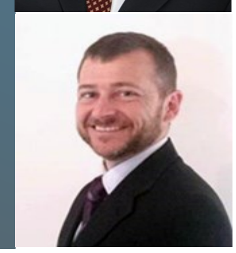
QUARTERLY

Two Countries Apply Trusted Human Factors Model to Manage Safety

Gareth McGraw and Bill Johnson



About the Authors: *Dr. William Johnson 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.*

Gareth McGraw is a Human Factors Advisor with Australia's Civil Aviation Safety Authority. He is an Aviation Maintenance Technician with 27 years' experience in both civil and military aviation, including two and a half years as a qualified Air Safety Investigator.

INSIDE THIS ISSUE:

Two Countries Apply Trusted Human Factors Model to Manage Safety

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Summary

Today's maintenance personnel have a reasonable understanding of the human factors challenges in their lives and work environments. They hardly need a basic course. Instead, they require ways to identify and report human factors and other hazards before they become serious threats to workers and to flight safety. Bill Johnson (FAA) and Gareth McGraw (Civil Aviation Safety Authority of Australia, (CASA)) review the focus on People, Environment, Action, and Resources (PEAR). Because of its simplicity, this time tested method of understanding maintenance human factors continues to evolve and be applied worldwide.

PEAR History

In the mid-nineties, there was considerable attention applied to developing methods to introduce human factors to maintenance personnel. The most popular model was SHEL/SHELL, which was the HF learning tool for most pilot crew resource management courses. Other excellent tools were introduced, mostly with a focus on human error. That includes James Reason's Swiss Cheese Model and Gordon Dupont's Dirty Dozen. While reduction and mitigation of human error was an important focus of HF familiarization, Drs. Mike Maddox and Bill Johnson wanted something that extended beyond error. Their specification was for a tool, or memory jogger, that could encompass all aspects of maintenance work. Their solution, while often called a model, was really a pneumonic that captured a way to consider maintenance human factors. Maddox and Johnson decided that human factors programs must consider people, the environment in which they work (physical and social), the actions that must be performed, and the resources necessary to complete the job in a safe and efficient manner. Those four elements created PEAR.

TWO COUNTRIES APPLY TRUSTED HUMAN FACTORS MODEL TO SAFETY (CONT…)

PEAR Described

The **PEAR** concept is simple (see Figure 1). There are only four words to remember. That is a pleasant relief to mechanics/engineers who are learning about and applying maintenance human factors. They remember the four letter words, like PEAR. Of course, there are many relevant concepts associated with each letter. Figure 2 shows an early example of items that are associated with People.

Figure 1. PEAR –An Easy Concept to Learn and Recall

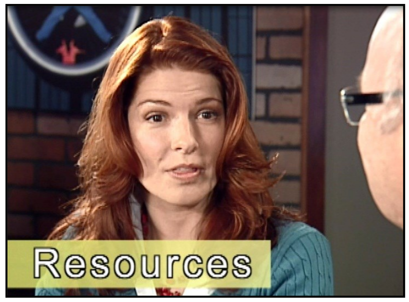


Figure 4. Dr. Bill and Dagmar Discussing PEAR

Another version of People is offered by the Civil Aviation Safety Authority of Australia (CASA). The nice thing about PEAR is that it has expanded, adapted, and usually improved by many who have applied it. Swiss Cheese, Dirty Dozen, and other training approaches had the usual set of materials and media. PEAR is best described in the FAA's Maintenance Human Factors Presentation System that is on the FAA website, referenced at the end pf this article. Most that have used the videos that feature Dr. Bill and the "Psychologist" Dagmar, see Figure 4.

Systems like PEAR are only as good as their usability and versatility in the maintenance environment. The remainder of this article shows excellent examples from Australia.

The Evolution and Application of PEAR in Australia

"Come and go" aviation safety initiatives can be likened to nature's selection process. The most adaptive species prosper as they are the ones that find solutions to their environment's constantly changing hazards and challenges. Those that can't adapt quickly become extinct. With regard to aviation safety, any idea that doesn't prove to be easily understandable and useful in providing practical safety solutions will also likely quickly become extinct!

PEAR is evolving to be one of safety's 'adaptive species.' It is an intuitive model that is easy to understand at all levels of the organization. The **PEAR** approach provides the ability to be applied across a wide array of contexts, processes, and environments. **PEAR** can structure and collect reactive, pro-active, and predictive data/information to meet the needs of today's safety management systems. One example of adaptation is how the "A" in PEAR has been used to look for human factors threats in job and task analysis.

CASA has adopted PEAR as an essential part of its ongoing program, Safety *Behaviours: Human Factors for Engineers*, for training maintenance human factors (SEE AMT Sept '13). In an effort to ensure that training information is used, CASA developed PEAR-centric aids for work planning, event investigation, and other hazard reporting.

The various planning and reporting aids show the strength and versatility of **PEAR.** It does not force engineers into an additional time consuming process. Instead, it is part of the way they normally identify and adapt to known and emerging hazards. It is easy for the workforce to see hazards in the people, environment, actions, and resources categories. Let's look at two CASA examples that apply **PEAR**.

Example 1: A Work Planning Approach with PEAR and the "Rule of Three"

Many investigators, including the author, have observed that many events are the result of poor planning. One solution is to structure [planning] behaviour to identify those human factors categories identified in PEAR. Engineers can then apply a simple risk assessment tool called the "Rule of Three (ROT)." The idea is that there are three 'categories' of circumstances or conditions that can be present in any job or task. The conditions can be assessed by the engineers/mechanics. The Rule of Three is shown in Figure 5.

The ROT assessment helps the worker to identify a single hazard or a combination of hazards that call for proceeding as usual, proceeding with interventions, or stoping a task altogether. This system is similar to Threat and Error Management. The combination of straightforward concepts, like PEAR and ROT, make safety management a field application. Figure 6 shows a PEAR-based pre-task planning flowchart to which engineers can apply the Rule of Three.

The CASA Safety *Behaviours: Human Factors for Engineers* Safety *Behaviours: Human Factors for Engineers* training will have its greatest impact if the training

(continued on page 4)

Figure 2. People Expanded

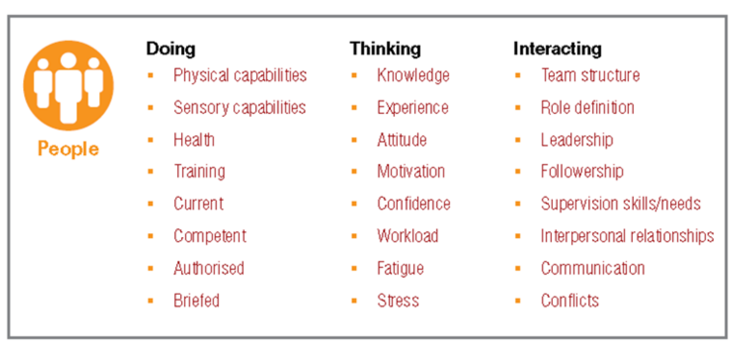


Figure 3. A CASA Adaption of the P in Pear

Two Countries Apply Trusted Human Factors Model To Safety (Cont…)

Figure 5: The Rule of Three

GREEN: Condition is OKAY and well within limits or assumptions

AMBER: While within limits the condition or circumstance is close to the edge of being acceptable

RED: Condition or circumstance is definitely out of limits

For that appropriate action, the ROT follows this process

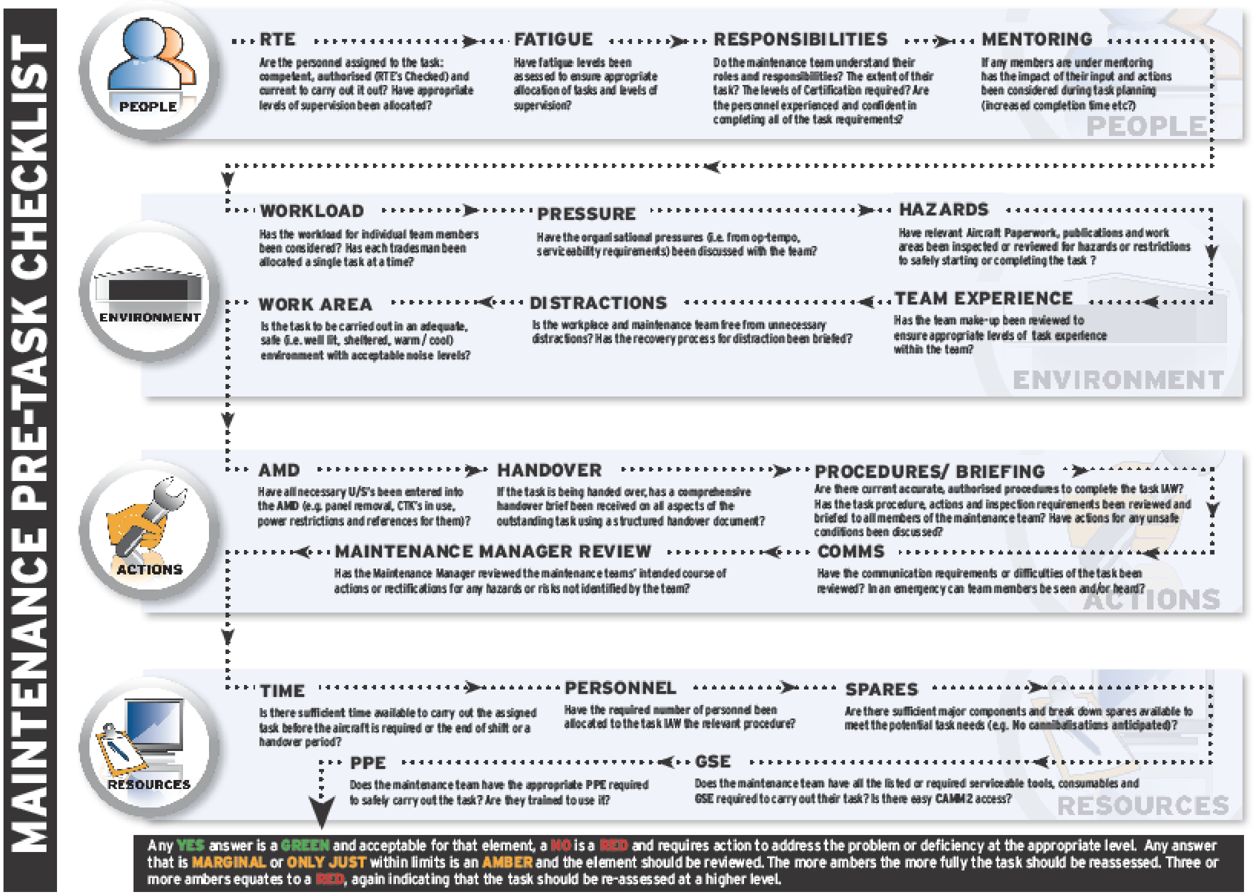
All GREEN = OKAY to proceed using normal controls

RED = STOP, action must be taken to mitigate a red back into a green (or possibly AMBER)

One or two AMBERS = Proceed with increased caution as some controls may well be weakened

Three AMBERS = RED and STOP! Controls may be significantly weakened; action must be taken to reduce one or more AMBER into the GREEN

Figure 6: The PEAR-Based Event Investigation and Hazard Reporting Tool



TWO COUNTRIES APPLY TRUSTED HUMAN FACTORS MODEL TO SAFETY (CONT…)

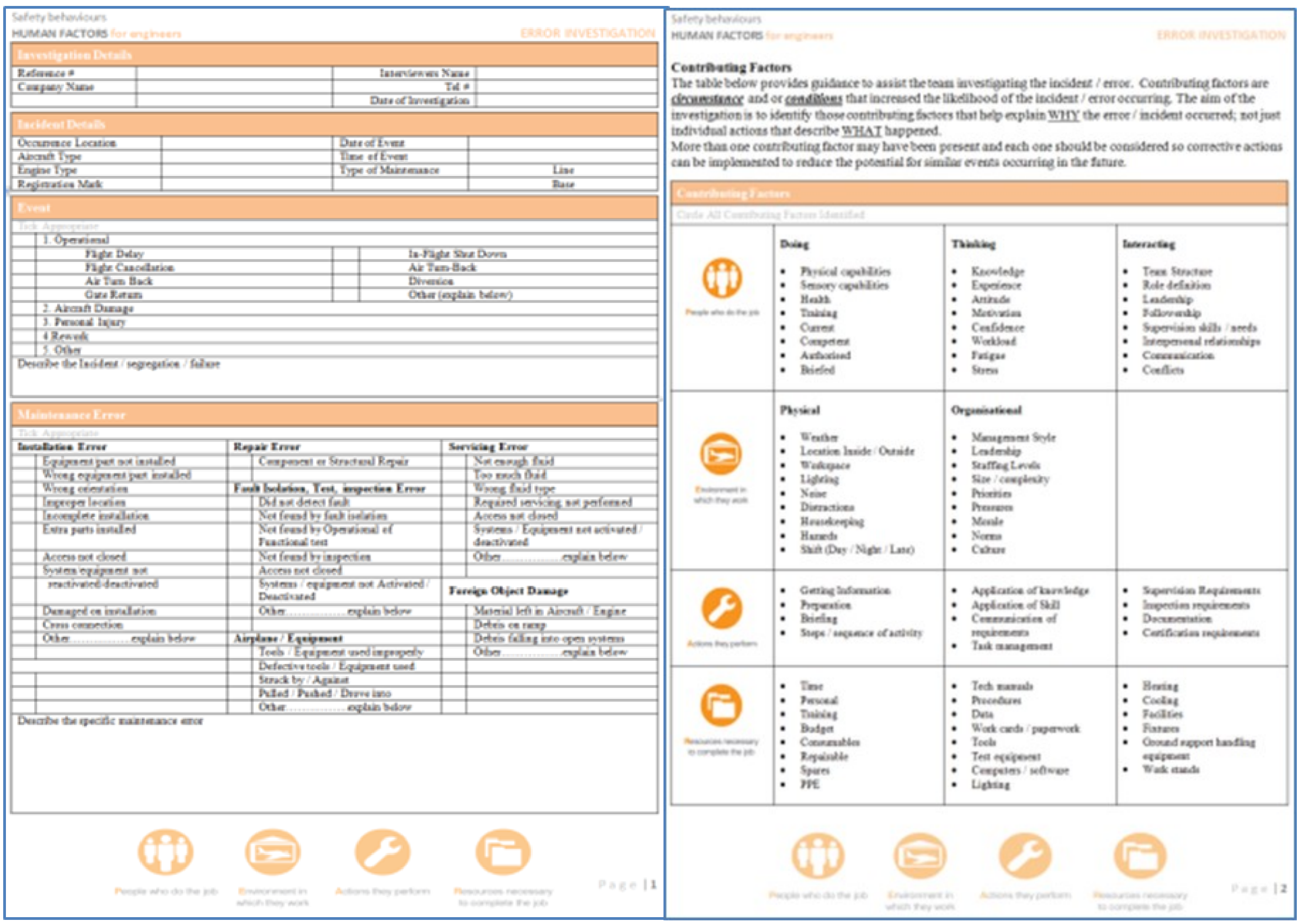
language is reinforced with job aids/tools. One enterprising CASA Airworthiness Inspector provided this type of tool when he adapted a well-known investigation template to use **PEAR** as its framework for identifying contributing factors to a maintenance event or incident. Figure 7 shows two example investigation forms.

Now, engineers are using **PEAR** to shape their approach to pro-active HF hazard identification. Organizations are applying the **PEAR** categories as a common language to aid engineers in isolating previously unidentified HF contributing factors after an incident or event has occurred. This information can then be used in adapting existing maintenance practices, processes, behaviors, or controls to make them work better. It is flight line and shop level safety management.

In conclusion, the simple elegance of PEAR is that ***it*** doesn't rigidly drive specific actions. It allows individuals and organizations to more effectively identify and design their own improvements and adaptations to the changing environmental and organizational hazards often found in aviation maintenance. CASA intends to insure that PEAR will evolve and survive as one of safety's natural selections.

Comments – Send comments to Dr. Bill Johnson at Bill-dr.johnson@faa.gov

Figure 7. PEAR Error **Investigation** ***Tools***



Safety behaviours
HUMAN FACTORS for engineers — ERROR INVESTIGATION

Investigation Details			
Reference #		Interviewers Name	
Company Name		Tel #	
		Date of Investigation	

Incident Details			
Occurrence Location		Date of Event	
Aircraft Type		Time of Event	
Engine Type		Type of Maintenance	Line
Registration Mark			Base

Event	
Tick Appropriate	
1. Operational	
Flight Delay	In-Flight Shut Down
Flight Cancellation	Air Turn-Back
Air Turn Back	Diversion
Gate Return	Other (explain below)
2. Aircraft Damage	
3. Personal Injury	
4 Rework	
5. Other	
Describe the Incident / segregation / failure	

Maintenance Error		
Tick Appropriate		
Installation Error	**Repair Error**	**Servicing Error**
Equipment part not installed	Component or Structural Repair	Not enough fluid
Wrong equipment part installed		Too much fluid
Wrong orientation	**Fault Isolation, Test, inspection Error**	Wrong fluid type
Improper location	Did not detect fault	Required servicing not performed
Incomplete installation	Not found by fault isolation	Access not closed
Extra parts installed	Not found by Operational of Functional test	Systems / Equipment not activated / deactivated
Access not closed	Not found by inspection	Other……………explain below
System/equipment not reactivated/deactivated	Access not closed	
	Systems / equipment not Activated / Deactivated	**Foreign Object Damage**
Damaged on installation	Other……………explain below	Material left in Aircraft / Engine
Cross connection		Debris on ramp
Other……………explain below	**Airplane / Equipment**	Debris falling into open systems
	Tools / Equipment used improperly	Other……………explain below
	Defective tools / Equipment used	
	Struck by / Against	
	Pulled / Pushed / Drove into	
	Other……………explain below	
Describe the specific maintenance error		

People who do the job — Environment in which they work — Actions they perform — Resources necessary to complete the job

Page | 1

Safety behaviours
HUMAN FACTORS for engineers — ERROR INVESTIGATION

Contributing Factors
The table below provides guidance to assist the team investigating the incident / error. Contributing factors are circumstance and or conditions that increased the likelihood of the incident / error occurring. The aim of the investigation is to identify those contributing factors that help explain WHY the error / incident occurred; not just individual actions that describe WHAT happened.
More than one contributing factor may have been present and each one should be considered so corrective actions can be implemented to reduce the potential for similar events occurring in the future.

Contributing Factors			
Circle All Contributing Factors Identified			
People who do the job	**Doing** • Physical capabilities • Sensory capabilities • Health • Training • Current • Competent • Authorised • Briefed	**Thinking** • Knowledge • Experience • Attitude • Motivation • Confidence • Workload • Fatigue • Stress	**Interacting** • Team Structure • Role definition • Leadership • Followership • Supervision skills / needs • Interpersonal relationships • Communication • Conflicts
Environment in which they work	**Physical** • Weather • Location Inside / Outside • Workspace • Lighting • Noise • Distractions • Housekeeping • Hazards • Shift (Day / Night / Late)	**Organisational** • Management Style • Leadership • Staffing Levels • Size / complexity • Priorities • Pressures • Morale • Norms • Culture	
Actions they perform	• Getting Information • Preparation • Briefing • Steps / sequence of activity	• Application of knowledge • Application of Skill • Communication of requirements • Task management	• Supervision Requirements • Inspection requirements • Documentation • Certification requirements
Resources necessary to complete the job	• Time • Personal • Training • Budget • Consumables • Repairable • Spares • PPE	• Tech manuals • Procedures • Data • Work cards / paperwork • Tools • Test equipment • Computers / software • Lighting	• Heating • Cooling • Facilities • Fixtures • Ground support handling equipment • Work stands

People who do the job — Environment in which they work — Actions they perform — Resources necessary to complete the job

Page | 2

AGING, HEARING, AND MANAGING RISK

DR. JAMES W. ALLEN, M.D.

About the author: Dr. Allen is a retired navy physician specializing in the prevention of health effects due to workplace exposures. He works on a consulting basis primarily to human relations and safety departments for government and corporations. Results of his clinical and environmental findings save companies lost work time, make them safer, comply with health laws, and improve workers' health. He can be reached through his web site www.WorkingHealthyAlways.com or email at jallen@workinghealthyalways.com.

AN OBESE WORKFORCE: IS AVIATION SAFETY COMPROMISED?

Not only is the American workforce getting older, it's also getting bigger …. *Literally*. In 1996 no state had more than 20% of their population in the obese category. By 2007 49 states had at least 20% of their population in this category. Body Mass Index (BMI) is the measure of obesity. Normal weight represents a BMI of 25 of less. A BMI of 25 to 30 is classified as overweight while individuals with BMI greater than 30 are classified as obese. Among the general US population from 2003 to 2004, 2 in 3 adults aged 20 years and over were in the overweight or obese categories (1). Among US workers for 2010, 27.7% were in the obese range (2). Plus sized clothing, special diets, menu calorie labeling, and fitness center promotions illustrate that obesity is well beyond a simple public health concern.

Does this obesity epidemic present a risk to air safety? While research has not directly answered this question, public health professions have issued warnings to employers to consider workplace intervention for obesity (2). Two employers are addressing this epidemic. In 2006 the Department of Defense (DoD) published a report citing youth obesity as a threat to national security. The Federal Highway Safety Administration (FHSA) requires truck drivers with BMI greater than 33 to receive additional testing before receiving their Commercial Drivers License. Obesity influences trucking and national defense.

Until air safety becomes a topic of obesity research, a maintenance facility may want to follow the lead of DoD and FHSA. Consider obesity in an AMT as a Latent Medical or Environmental Condition (LMEC) that is a link in a chain leading to maintenance error (figure 1).

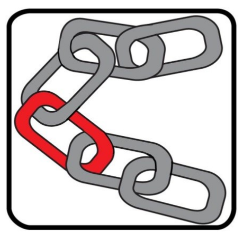


Figure 1: Obesity may represent a LMEC, the red link, in an accident chain (used with permission of author)

An analysis of medical and indirect costs highlights the risk from obesity that makes it a LMEC. Obesity increases the risk of well-known conditions such as type 2 diabetes mellitus, coronary heart disease, stroke, hypertension and sleep apnea. In 2008, Medicare, Medicaid, and private insurers paid an estimated $147 Billion to treat these conditions (3). In addition to these medical costs, indirect costs include reduced productivity of workers and absences from work. Obesity related work place absences cost US employers an estimated $8.65 billion annually and imposed a financial burden on states from 6.5% to 12.6% of total costs of absenteeism in the workplace (3).

Studies of obese workers in China, Sweden and Canada found a similar loss in productivity resulting in another warning to employers about the effects of obesity at work (4).

While absence from work is one measure of productivity, research indicates that obese workers are less productive when on the job. Presenteeism is a term used by researchers to represents the loss of productive time at work. Presenteeism is self-reported with costs related to the hourly wages of the workers. Specific behaviors associated with presenteeism include losing concentration, repeating a job, working more slowly than usual, feeling fatigued at work and doing nothing at work.

These behaviors, like those described in the Dirty Dozen, lead to human factors errors. Presenteeism may be the single largest driver of costs of poor health due to obesity (5). Figure 2 shows total per capita costs as bars each subdivided into the costs of medical expenditures, absenteeism and presenteeism. The height of the cost of presenteeism within each bar exceeds the costs of absenteeism and medical expenditures for each overweight and obese category.

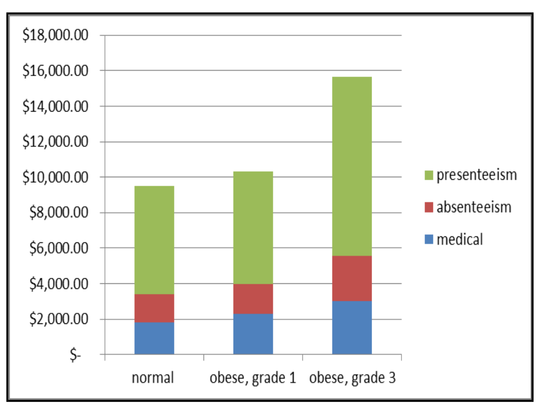


Figure 2: Per capita medical, absentee, and presenteeism costs comparing normal weight workers with mild obese (grade 1) and severe obese (grade 3) workers. (source: reference 5, used with permission of Journal of Occupational and Environmental Medicine)

AGING, HEARING, AND MANAGING RISK (CONT…)

Researchers have not yet examined obesity among AMTs but comparison with fatigue research reinforces the findings from the costs analyses. Both fatigue and obesity affect a sizable population, produce behaviors that increase the risk of maintenance errors, and lower productivity (Table 1). Employer based health promotion programs can mitigate effects from obesity similar to a fatigue risk management program. These similarities suggest the degrading effect of obesity on maintenance activities just as is documented with fatigue.

Table 1: Obesity and Fatigue, a comparison of their cost, risk, and control (references reflect source of data)

	Fatigue (ref 6)	Obesity (ref 1 to 5)
Population size	Adults, lack 1 to 1.5 hrs sleep	27.7% of workforce
Risk assessment	16 hr wakefulness consistent with blood alcohol of 0.05%	1.1 to 1.7 times more likely to experience absenteeism
Direct medical costs	Not provided	$ 147 B
Cost to business	$136 B per year	$11.7 B to $30 B per year
Largest Costs driver	Reduced productivity	Reduced productivity
Mitigate effects	Fatigue Risk Managements Program	Workplace health promotion program

Warnings from public health officials, analysis of cost from presenteeism, and similarities between obese and fatigued workers significantly support the recognition that the obese AMT poses a risk to air safety. Obesity contributes to the error prone behavior at work described in the dirty dozen. Implementing a risk management program that recognizes obese worker allows a Safety Management System to proactively manage a workplace hazard. Obesity is a LMEC. Managing this LMEC can break the chain before it leads to a maintenance incident (Figure 3).

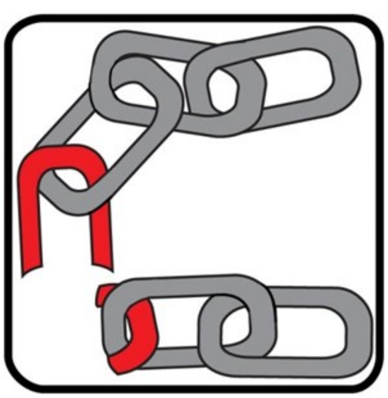


Figure 3: Broken red link prevents an LMEC from contributing to an adverse outcome. (used with permission of author)

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Readers' sidebar::

Does Obesity among the AMT effect on Air Safety?

With obesity research focused on maintenance HF errors unlikely, a readers' survey presents an alternative. Please reply to the email below with your answers – Yes or NO answers are fine

Question 1: Are you aware of obese AMT in your work area?
Question 2: Do you notice any difference in the work output for obese vs normal weight individuals?
Question 3: Would you accept a health promotion program sponsored by your employer that targets exercise to combat obesity?

Send responses to : jallen@workinghealthyalways.com
subject line: newsletter questions

Safety Data from Multiple Sources

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Safety Data from Multiple Sources

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In January 2015, the Federal Aviation Administration (FAA) announced a final rule that requires all air carriers under 14 CFR Part 121 (US commercial airlines) to have a Safety Management System (SMS) in place by January 8, 2018. SMS is a systematic, process-oriented approach to increasing safety. An SMS offers a structure to collect and examine safety data from different aspects of airline operations for the management of safety risk and assuring the effectiveness of safety risk controls.

The traditional approach to improving safety was to study the causes of past accidents and serious incidents (commonly referred to as a "reactive approach"). Investigation of accidents, incidents, and events help to identify why those occur by sorting out all the contributing factors, which led to the accidents/incidents/events. Contributing factors include root cause(s) and causal factors. A **Root Cause,** once removed from the problem fault sequence, prevents the final undesirable event from reoccurring. On the other hand, a **Causal Factor** affects an event's outcome, but is not a root cause. A thorough investigation can be very informative, consequent effective mitigations can prevent same or similar events from occurring again. The FAA Administrator Michael Huerta pointed out that "…we all know that our ultimate goal is to prevent accidents from happening at all." In high reliability systems like commercial aviation, accidents are rare. It remains important that we learn from the current mistakes albeit only a few. But, counting on lessons learned from very infrequent accidents/incidents/events is not sufficient for managing safety. SMS thinking recommends two additional approaches in identifying safety hazards:

Proactive approach—active identification of safety hazards through the analysis of the organization's activities, using tools such as mandatory and voluntary reporting systems, safety audits, and safety surveys.

Predictive approach—capturing system performance as it happens in real-time during normal operations such as observations of aircraft maintenance technician performance during a heavy check.

During real-world, real-time work, operational performance drifts away from the baseline safety system design. When the drift is significant and continuous, it contributes to a "slippery slope" of possible safety lapse. The drift can and must be navigated and controlled. Through different hazard identification approaches (e.g., reactive, proactive, predictive) in the SMS, an organization can help to correct the drift and bring the operational performance back to the baseline. In other words, those hazard identification processes/approaches are like navigational aids to help the organization navigate the drift. In reality, drift into failures is slow and incremental, often undetected for a long period of time. Faults and failures that are so apparent in hindsight may not be attention catching in the foresight. Mandatory/voluntary reporting can help to reveal a drift, however, sometimes it fails to do so. Sidney Dekker suggests that "the normal, everyday workarounds, frustrations, and improvisations needed to get the job done" (Dekker, 2014, p. 159) are not considered reporting worthy by those inside the organization. The gradual drift can be further disguised by low accident rate and low injury rate, which often is mistaken as the sole safety indicator. In his book "Safety Differently: Human Factors for a New Era" (Second Edition), Dekker states: "In very safe systems, incidents do not precede accidents. Normal work does."

That "normal work," to which Dekker refers, can be observed with Maintenance and/or Ramp Line Operations Safety Assessment (M/R-LOSA). For some time the FAA, Airlines for America (A4A), and some US airlines, with Boeing, have created and promoted M/R-LOSA to examine normal operations. In fact, Boeing offers M/R-LOSA support and training to the international industry, especially Boeing customers. The LOSA process employs system thinking, which focuses on the relationships and integration of the humans and other components within the overall maintenance/engineering system. For example, through strictly non-punitive peer-to-peer observations, M-LOSA takes snapshots of normal airline maintenance operations and helps the organization to understand daily decisions of normal, ordinary people under the influence of normal, everyday pressures. Compared to traditional audits conducted by external agencies or internal safety and quality assurance staff, M-LOSA paints the organization a much more realistic picture of what is going on. In addition to identifying safety threats and errors, through sampling, M-LOSA data can help to estimate the occurrence probability of those threats and errors, which exceeds the capability of most mandatory/voluntary reporting. The predictive capability of M-LOSA, can help to discover emerging risks that could result as a consequence of future changes inside or outside the organization and its operational environment. Mitigating action can be initiated before the risk actually appears. M-LOSA also identifies exemplary behaviors that can be reinforced in training.

Hazard identification, especially proactive and predictive data must be frontline employee centered. Workers have the most knowledge of hazards (see Figure 1). Frontline employees must play an active role in voluntary reporting and monitoring of normal operations. The organization is responsible for creating a good, just safety culture that fosters trust and encourages reporting and participation in normal operations monitoring.

The distinction between proactive approach and predictive approach is not always clear-cut. Proactive approaches often rely on large quantity of data and multiple sources of data (e.g., flight operations quality assurance and other automatic digital recording of flight data). Such systems rely on a team of analysts, making it sometimes time-consuming and difficult to obtain and apply. Predictive approaches, like LOSA, can be designed for rapid analysis with an immediate focus on the strengths and weaknesses of normal operations. The mere nature of peer-to-peer observation promotes a shared safety culture that simply cannot be attained with post-event reporting systems.

Data from different sources can be integrated in order to improve system safety. One US operator had observed an increased number of aircraft damage by approaching belt loaders in one of its major hubs. The damage was caused by belt loader drivers not complying with the operating procedures. The operator conducted many ramp LOSA observations to diagnose the causes of non-compliance. For example, they noticed lack of supervisory monitoring and mentoring, and lack of resources for some of the ramp activities, etc. The findings are not a real surprise but reinforce the necessity of addressing the individual fixes to reduce hazards. Investigation findings of the ground damage, complemented by the hundreds observations, convinced the organization and management to step back from blaming the frontline employees for not following procedures since the causes of non-compliance are beyond the employees' control.

References:

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Figure 1. The Iceberg of Ignorance

A Fond Farewell

Thank You and Goodbye

My time with the FAA has come to a close, but there are some people I want to thank in this, my farewell letter as co-editor of the Aviation Maintenance Human Factors Newsletter.

So: thank you Dr. Bill Johnson, author extraordinaire, for your support and for encouraging me to occasionally write for the newsletter; Dr. Katrina Avers for your management, support, and review; Gena Drechsler and Crystal Rowley for accepting the new positions as co-editors. Thanks, in particular, to the inimitable Roger Hughes of the Aviation Human Factors Industry News, who played a critical part in increasing our circulation.

A heartfelt thanks to the authors who submitted timely articles and you readers, particularly those who have been with us from the beginning. I'm off to Warner Robins, Georgia where I'll get to spoil my grandchildren on a daily basis. I'm leaving the FAA with one request…Lord guard and guide all those who fly.

Joy Banks

WWW.HUMANFACTORSINFO.COM

The FAA maintenance human factors site was launched in the late nineties. Its popularity grew tremendously over the years. Google hits reached in the hundreds of thousands yearly by 2010. Being over a decade since launched, the website was overdue for a "Heavy Check" to improve its search engine and public accessibility. Fortunately, the "Heavy Check" was not an "out with the old and in with the new." It continues to serve as an important dynamic repository of reports, conference proceedings, and other important MX HF materials. The new HF in Aviation MX website can be found at the original address hfskyway.faa.gov or under a number of alias addresses like humanfactorsinfo.com, and mxfatigue.com. Take a look today and please pass this information to your colleagues.

If you have a story to tell that will help enhance aviation safety, please email katrina.avers@faa.gov or bill-dr.johnson@faa.gov. The editorial staff will help writers with layout and graphics.

If you would like to be added to our quarterly distribution list, please email gena.drechsler@faa.gov.