Australian Government
Civil Aviation Safety Authority

safety behaviours

HUMAN FACTORS

RESOURCE GUIDE FOR ENGINEERS

Contacts

For further support on how to get the most from this training resource, please contact your local Aviation Safety Advisor via **131 757** or **safetyadvisor@casa.gov.au**

For more detailed advice on human factors or to provide any general feedback regarding this training resource, please contact our human factors specialists via

131 757 | **humanfactors@casa.gov.au** | **www.casa.gov.au/hf**

ISBN 978-1-921475-34-4

For further information or additional copies, visit CASA's website www.casa.gov.au

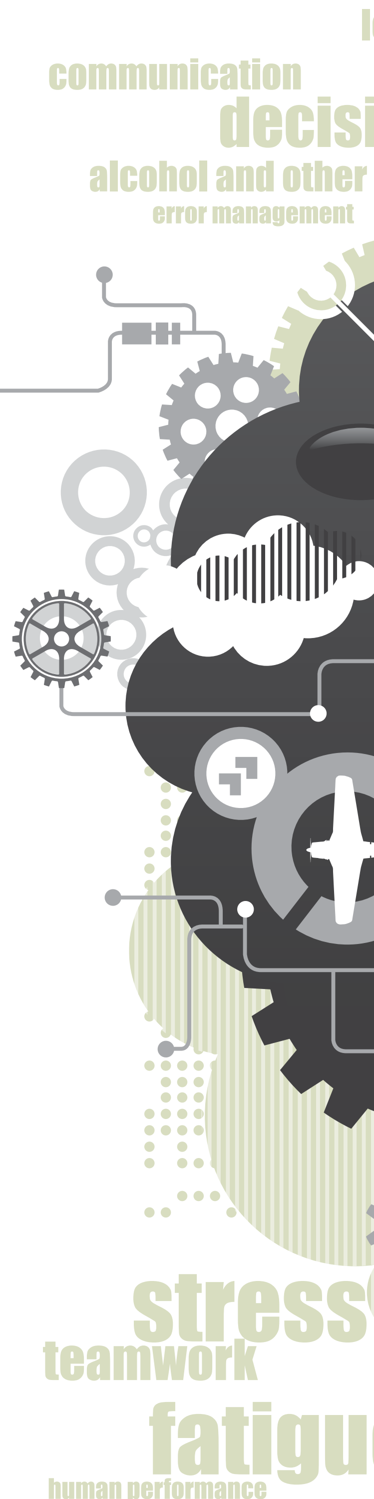
Notice: The information contained in this document was correct at the time of publishing and is subject to change without notice. It has been prepared by CASA Aviation Safety Promotion for educational purposes only. This guide outlines basic procedures — it should never be used as a replacement for official manuals or procedures. Reference should be made to the appropriate procedures at all times prior to the use of this information.

The Civil Aviation Safety Authority is responsible for the safety regulation of Australia's civil aviation operators, and for the regulation of Australian-registered aircraft outside Australian territory.

1111.1641

safety behaviours
HUMAN FACTORS

RESOURCE GUIDE FOR ENGINEERS



Welcome to the ***Safety Behaviours: Human Factors for Engineers*** resource guide, developed by CASA to provide comprehensive human factors information to further support your learning in this field. For some, this may be your first exposure to human factors theory; for others, it may serve as a good refresher.

Safety Behaviours: Human Factors for Engineers has been developed to provide a stronger focus on the needs of the Australian maintenance industry, and although it is designed with aircraft maintenance engineers and small to medium-sized aviation maintenance organisations (AMOs) in mind, larger organisations may also find it a useful supplement to existing human factors programs. The HF topics included are all relevant to the daily challenges of being a professional engineer.

Why has Safety Behaviours: Human Factors for Engineers been developed?

While it is well known that the majority of aviation accidents involve human factors somewhere in the causal chain, it is less well known that between 12 and 20 per cent of aviation accidents may involve maintenance human factors. Managing human factors effectively therefore, is an important issue for all maintenance engineers, regardless of what section of the industry they work in.

The Governor-General recently enacted Part 145 of the *Civil Aviation Safety Regulations 1998* (CASR) which includes human factors requirements for maintenance. This requirement is consistent with other aviation safety agencies internationally, such as the European Aviation Safety Agency (EASA) and the International Civil Aviation Organization (ICAO). CASR Part 145 requires maintenance organisations to apply human factors principles to safety and quality, institute a reporting system with an open and fair reporting culture policy, and ensure that personnel receive training in human factors principles. Training in human factors is required for all employees involved in maintenance, including contract staff.

This practical human factors resource may assist engineers and AMOs to meet the above requirements. Importantly, we hope it will serve as part of your ongoing professional development, so that you keep up-to-date with the latest human factors knowledge.

How to use this resource guide

Safety Behaviours: Human Factors for Engineers is part of a resource package that also includes:

- Background reading: safety magazine articles, accident reports and other resources
- A facilitator’s guide and participant/student workbook
- A CD containing electronic copies of the resource guide and all the above mentioned reference material
- A DVD featuring *Crossed Wires*, a drama to promote discussion about some of the key human factors issues outlined in the resource guide, as well as interviews with human factors experts.

These resources are designed for both self-and class-based instruction. Facilitators can incorporate them into their existing training agenda, or organise special self-contained sessions.For more information about ***Safety Behaviours: Human Factors for Engineers***, please email **safetyproducts@casa.gov.au**


leadership
ommunication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Contents


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 1

INTRODUCTION

The term human factors refers to the wide range of issues that affect how people perform tasks in their work and non-work environments. The study of human factors involves applying scientific knowledge about the human body and mind, to better understand human capabilities and limitations so that there is the best possible fit between people and the systems in which they operate. Human factors are the social and personal skills (for example, communication and decision making) which complement technical skills, and are important for safe and efficient aviation maintenance.

If eternal vigilance is the price of liberty, then chronic unease is the price of safety.

Professor James Reason

What are human factors?

Over the last 100 years or so, we have learned that relatively few accidents result purely from technical failures. In around 75–80 per cent of cases, deficiencies in human performance contributed directly to the outcome. For many years, aviation human factors focused on issues of concern to pilots, including visual illusions, in-flight decision making, and cockpit communication. Generations of pilots have studied accidents in which flight crew ran out of fuel, continued into bad weather, or were distracted by minor technical faults. In recent years, attention has turned to human factors in maintenance. Aircraft engineers deal with a unique set of human factors challenges that can lead to maintenance errors. Studying these human factors issues and understanding their effects will better prepare you to deal with human factors in your daily work.

The impact of human factors can be seen in many parts of a typical aircraft maintenance operation. Tasks may occur on work stands high above the ground, outside in all weather, in a noisy environment, or under time pressure. Task procedures might be poorly written or hard to obtain. Components are often difficult to access, the required tools or spares may be unavailable, and at times lighting is poor, or the work involves parts not directly visible to the engineer. There may be multiple interruptions during tasks. Just to make things more interesting, tasks often require more than one shift to complete, and may need to be handed from one engineer to another.

As an aircraft maintenance engineer, you will be all too familiar with these issues. The question is not ‘Do human factors issues affect maintenance?’ but ‘Where do we start?’

When we say that an accident involved human factors, we rarely mean that there was a problem with the specific people involved. In most cases of maintenance error, the people involved had the necessary knowledge and technical skills to perform their job, but were let down by non-technical factors, typically human factors. In many cases, highly experienced engineers—senior people in their organisations—made the mistakes.

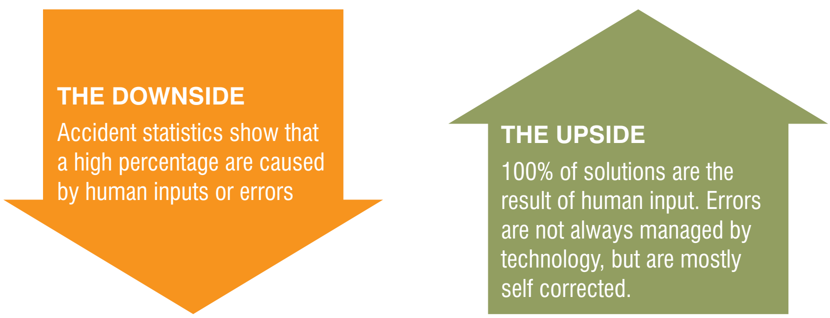
While the focus of our attention is usually on what human factors issues contributed to an accident, we should not forget that there are two sides to human performance: the downside is this capacity to make errors, but the equally important upside is that human beings are generally adaptable and flexible.

The positive side to human performance and error, for example, is that we are good at identifying and self-correcting our errors before they become consequential. Highly experienced people also tend to be flexible and adaptable when solving complex problems and can often resolve situations with limited information.

Ultimately, 100 per cent of completed maintenance tasks owe their success to the capabilities of maintenance personnel. By paying attention to the human factors of maintenance tasks, we can maximise the positive aspects of human performance, and be on guard against the limitations that are part of being human.

Two sides to human performance

The human element in any system is a supremely adaptable and effective problem solver that is often able to resolve situations with limited information



Maintenance accidents and maintenance errors

There are varying estimates of the proportion of aircraft accidents related to maintenance errors. Three studies found between 12 and 20 per cent of accidents involve maintenance. According to some authorities, maintenance errors may be playing an increasing role in causing accidents.

Percentage of accidents	Source of data
12%	Worldwide study of 93 major accidents between 1959 and 1983,[i].
15%	IATA figures from 2008 [ii]
20%	Boeing statistics on 232 commercial jet aircraft accidents [iii]

i Sears, R.L. Cited in Marx, D. A. & Graeber, R. C. (1994), Human error in aircraft maintenance. In N. Johnston, N. McDonald and R. Fuller (Eds), Aviation psychology in practice, (pp.87-104). Avebury, Aldershot.

ii Data from M. Maurino, cited in Johnson, W.B. (2010) Maintenance Human Factors Leaders Workshop Proceedings. Federal Aviation Administration. Washington, DC.

iii Boeing (1993). Accident Prevention Strategies: Commercial Jet Aircraft Accidents Worldwide Operations 1982-1991.

Even when accidents are averted, maintenance errors can be costly. Airline data show that between 20 and 30 per cent of in-flight engine shutdowns occur after maintenance problems, and around 50 per cent of engine-related flight delays and cancellations are due to maintenance errors[1].

There is some evidence to suggest there has been an increase in maintenance-related aviation accidents. Boeing indicates maintenance errors as the primary cause in six per cent of all accidents over the last ten years, while this figure was 3.4 per cent over the last forty years[2]. Similarly, the number of maintenance errors reported to the UK Civil Aviation Authority (CAA) has increased significantly over the past couple of years[3].

We could debate the accuracy of these figures. For example, some may argue that the increase is due to a better awareness today of human factors and what causes accidents. In other words, engineers may now be reporting a human error today they might not have reported twenty years ago, because of our more mature safety systems approach.

Whatever the statistics, one thing is clear; we still need to continue to look at why these errors occur to further improve aviation safety and efficiency.

Ironically, there are no statistics for the positive contribution of human factors. We should remember that in countless cases, human action has prevented or corrected dangerous situations. For example, Boeing research indicates that most fatigue cracks in aircraft are discovered by maintenance engineers who were actually performing an unrelated task when they noticed the crack.

---

1 Marx, D. A. & Graeber, R. C. (1994), Human error in aircraft maintenance. In N. Johnston, N. McDonald and R. Fuller (Eds), Aviation psychology in practice, (pp.87-104). Avebury, Aldershot.

2 Rankin, W.L. (1999). The importance of Human Factors in Design for Maintainability – A manufacturer's view. In: *Proceedings of the conference Human Factors in Aircraft Maintenance: Integrating Safety Management Systems to minimise risk,* Amsterdam: 27-28 April.

3 Hall, D. (1999), 'The importance of Human Factors in Aircraft Maintenance', in *Proceedings of the conference Human Factors in Aircraft Maintenance: Integrating Safety Management Systems to minimise risk,* Amsterdam: 27-28 April.

What maintenance problems are involved in incidents and accidents?

Three studies give an idea of the kind of maintenance problems that feature in accidents and incidents. In 1992, the UK CAA listed the most common maintenance errors found in occurrence reports:

1. Incorrect installation of components
2. The fitting of wrong parts
3. Electrical wiring discrepancies (including cross connections)
4. Loose objects (e.g. tools) left in the aircraft
5. Inadequate lubrication
6. Cowlings, access panels and fairings not secured
7. Fuel/oil caps and refuel panels not secured
8. Landing gear ground lock pins not removed before departure.

In 2003, a Boeing study found that the three most common errors were 'equipment or part not installed', 'incomplete installation', and 'cross connections'[4].

In 2008, a National Aeronautical and Space Administration (NASA) study analysed 1062 maintenance incidents reported to NASA's Aviation Safety Reporting System. The most common errors were:

- Required service not performed: (e.g. worn tyres not replaced)
- Documentation problems: (e.g. incorrect sign-off)
- Wrong part fitted (e.g. -250 tyre fitted to -100 aircraft)
- Unapproved or improper repair (e.g. non compliance with maintenance manual)
- Part not installed. (e.g. spacers and washers left off)
- Incomplete installation (e.g. nuts left 'finger tight')[5].

A note about accident case studies

Throughout this chapter, and the others that follow, we include examples of accidents resulting from maintenance errors. In virtually every case, the maintenance engineers involved were well-trained, motivated and were acting with integrity. In many cases, we find that the causes of maintenance errors lie in non-technical factors such as communication breakdowns, a lack of teamwork, incorrect assumptions, or memory failures. Accident reports are useful in helping us understand how maintenance mistakes occur, and how we can prevent them in the future. Yet they do not convey the emotional trauma that many engineers experience when their actions have led to the deaths of passengers and crew. When reading these case studies, keep in mind how the engineers involved must feel when they think about what they would do differently if they had a second chance.

[4] Rankin, B. & Sogg, S. (2003). Update on the Maintenance Error Decision Aid (MEDA) Process. Paper presented at the MEDA/MEMS workshop and seminar. May 21-23, Aviation House, Gatwick, UK.

[5] Hobbs, A., & Kanki, B. (2008). Patterns of error in confidential maintenance incident reports. International Journal of Aviation Psychology, 18, (1) 5-16.

British Airways BAC-111 windscreen blow-out

In June 1990, a windscreen of a British Airways jet blew out as the aircraft was climbing to its cruising altitude, partially ejecting the pilot through the open window. The windscreen had been installed by a shift maintenance manager during the previous night shift, between about 0300 and 0500. Seven engineers were scheduled to be on duty that night, but only five were available. Because the workload remained the same, the shift maintenance manager was helping out with tasks, and performing some himself. It was a busy night and he did not take a meal break, instead eating his sandwiches while he entered tech log write-ups into the computer. Although the aircraft needing the new windscreen was not required for service the next day, on his own initiative, he decided to do the job himself to get the task done earlier. He checked the maintenance manual briefly to confirm that the job was 'straightforward'. Some of the bolts that held the old windshield in place were paint-filled, corroded, or had been damaged during removal, so he decided to replace them. He did not refer to the illustrated parts catalogue, and did not pay attention to the advice of a stores supervisor who told him the size of the correct bolts The supervisor selected the bolts from a poorly lit and uncontrolled parts carousel by attempting to match them physically against a bolt that had been in place previously, not realising that some of the old bolts fitted to the windscreen were the wrong type. In the event, 84 of the 90 bolts securing the windscreen were smaller in diameter than the specified diameter.

The mobile stand set up at the aircraft did not give easy access to the windscreen and he had to stretch to install the bolts, giving him a poor view of his work. Partly as a result of this, he did not notice the excessive amount of countersink left unfilled by the small bolt heads. He used a torque-limiting screwdriver to fasten the bolts, but the clicks he obtained were from the bolt thread slipping in the anchor nuts, not from the torque-limiting mechanism of the screwdriver. To make matters worse, there was no requirement in the maintenance manual for a pressure check or duplicate inspection[6].

The accident report noted that the supervisor was a mature, dedicated engineer who was well respected by flight crew and engineers alike. However, he had a history of taking short cuts, ignoring mandatory instructions and failing to conform to good trade practices. The company was faulted for not detecting that the supervisor (and possibly other staff) were not following good work practices.

The case study above illustrates some key lessons about maintenance incidents:

- Even senior, experienced staff can make mistakes
- Errors are sometimes made by the most motivated staff—engineers who sit with their feet up in the break room do not make errors
- Errors do not usually occur randomly—they often reflect pre-existing problems such as poor work practices, unsuitable equipment or workload
- Error management is not just about *preventing* errors, but also making sure that appropriate checks and/or inspections are in place to capture and correct them.

[6] Air Accident Investigation Branch. (1992). Report on the accident to BAC One-Eleven, G-BJRT over Didcot, Oxfordshire on 10 June 1990. (No. 1/92). London.

A model of human factors in maintenance

Human factors can be divided into four main topic areas using the memory prompt **PEAR**.

Application of the mnemonic '**PEAR**' makes recognition of human factors (HF) even easier. It prompts recall of the four important considerations for HF programs: **People** who do the job; **Environment** in which they work; **Actions** they perform; **Resources** necessary to complete the job. The lists within each element are not exhaustive, but help to guide people on the human factors influences that should be considered.

PEAR was developed by Dr Michael Maddox and Dr Bill Johnson[7], specifically with maintenance in mind, as an easy way for aviation maintenance personnel to identify human factors and relate to tasks and conditions within the maintenance environment.

PEAR has been used for over a decade by some JAR/EASA 145-approved organisations and is included by the US Federal Aviation Administration (FAA) in their Maintenance Human Factors training package.

People | Environment | Actions | Resources

P stands for **People** (the humans in the system), with all our capabilities and limitations. It includes senses such as vision and hearing; physical characteristics such as strength and reach; as well as capabilities such as memory, communication styles, decision making, supervision and teamwork skills (leadership/followership etc.).

People relates to the suitability (physical, cognitive and social) of the selected personnel for a particular task. Suitability not only covers technical training but also human factors considerations such as fatigue, stress and motivations. It guides the review of the competency, supervision abilities, briefing needs, leadership skills and requirements of individuals against the task demands.

People

Doing	Thinking	Interacting
Physical capabilities	Knowledge	Team structure
Sensory capabilities	Experience	Role definition
Health	Attitude	Leadership
Training	Motivation	Followership
Current	Confidence	Supervision skills/needs
Competent	Workload	Interpersonal relationships
Authorised	Fatigue	Communication
Briefed	Stress	Conflicts

7 Dr Bill Johnson, Dr Michael Maddox. '*A PEAR-Shaped Model For Better Human Factors*'. CAT Magazine. Issue 2/2007

E stands for the **Environment** in which the work is done, not just the physical environment, but also the organisation itself. The physical environment includes lighting, temperature, noise level and time of day. The organisational environment covers issues such as supervision (quality and ratios), pressures (time, commercial and production etc.), organisation and safety culture and existing organisational norms and how these will affect individual and team performance and the potential for error. The organisational environment also covers the leadership shown and the effectiveness of management in supporting positive safety behaviours.

Environment

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

A represents the **Actions** people perform.

Actions list the requirements of a job to help to identify any specific areas that might increase the risk of error, such as ambiguous information, or complex tasks that need specialist skills and knowledge.

Actions

- Getting information
- Preparation
- Briefing/de-briefing
- Steps/sequence of activity
- Application of knowledge
- Application of skill
- Communication requirements
- Task management
- Supervision requirements
- Inspection requirements
- Documentation
- Certification requirements

The list of actions is aligned with a job task analysis (JTA)[8] process which is the standard human factors approach to identifying the knowledge, skills and attitudes necessary to perform each task in a given job. The JTA also helps identify what instructions, preparation and task management are necessary.

[8] Dr. Bill Johnson, Dr. Michael Maddox. '*A Model to Explain Human Factors in Aviation Maintenance*': Aviation News. April 2007

This may include:

- Accessing / finding task-specific information required
- Preparation and briefing requirements
- Identifying procedures to be followed
- Are those procedures clear and easy to follow?
- Task complexity and application of skill and knowledge
- Communication requirements (headsets required?)
- The level of supervision and inspection required (is a dual inspection needed?)
- The certification and documentation, including the complexity or user-friendly nature of the aircraft maintenance documentation.

R is for the **Resources** necessary to perform the work.

Resources are the broadest component of **PEAR**. They can be defined as anything that the maintenance engineer needs to get the job done. Resources details both the tangible items required and available, such as personnel, spares, technical manuals, tooling, and personnel protective equipment (PPE), as well as less tangible (but equally important) elements such as time and training availability.

Resources

- Time
- Personnel
- Training
- Budget
- Consumables
- Repairables
- 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

- Time and personnel should be the first resources considered, as they are critical to the planning process of any job.

An important resources element is focusing on identifying the areas where resources are deficient including:

1. Design (work stands, tools etc.)
2. Application (e.g. available, accurate procedures)
3. Where additional resources (time, personnel, training, lighting, PPE and consumables) are required.

PEAR applied to maintenance

People: The human and the interactions between people

The part of PEAR dealing with interactions between humans is particularly important in maintenance. Later in this human factors resource guide we will cover issues such as teamwork, assertiveness, situational awareness and communication.

We include normal human capabilities and limitations in this part; the unaided human eye is still the main tool for inspections, yet the limitations of our vision system sometimes lead to defects being missed. We rely on short-term memory each time we have to pay attention to a problem for more than a few seconds, yet the limits of our memory help explain why distractions and interruptions can be so dangerous. Good decision-making is an important safety net in aviation, yet we are more likely to make poor decisions when under time pressure or stress. A 'can do' attitude is normally a positive characteristic, but in maintenance, if we attempt to operate outside our performance limitations it can lead to danger if not tempered by appropriate caution.

Environment: Physical and organisational

The maintenance environment presents numerous human factors challenges, including the need to work outside, high noise levels, temperature extremes, and at times poor lighting. All these conditions can increase the probability of error. For example, a three-engine aircraft lost oil from all engines after maintenance engineers on night shift fitted magnetic chip detectors without the necessary O-rings. The work was performed outside, using the headlights of a tug for illumination. Furthermore, the engineers had no direct view of the task, and fitted each chip detector by feel, reaching inside the oil service door on each engine.

In addition to the physical environment, there is the organisational environment surrounding maintenance. Maintenance tasks are often performed under time pressure. As already discussed, time pressure is a particular threat when engineers are not used to handling it, and allow it to have undue influence on their decision making. Other aspects of the organisational environment are management style, organisational culture and workplace 'norms' – the unwritten, informal work practices that members of the organisation follow.

The organisational environment

How does your organisation stack up?		
Positive organisational characteristics		
1. There are sufficient staff appropriately licensed to cover the workload	Yes	No
2. The organisation never encourages shortcuts or procedure violations	Yes	No
3. Management acts quickly to fix unsafe situations	Yes	No
4. Staff are encouraged to report errors and unsafe situations	Yes	No
5. The company has a 'just culture' policy. Incidents are investigated to identify *why* they occurred, not whom to blame	Yes	No
6. Staff receive human factors training	Yes	No
Negative organisational characteristics		
7. There is an extreme 'can-do' culture. Staff do whatever it takes to get a job done on time	Yes	No
8. Tasks are routinely performed according to 'norms' (informal work practices), rather than documented procedures.	Yes	No
9. Staff are often required to work excessive hours	Yes	No
10. Work is done differently when there is time pressure	Yes	No
11. Shortages of spares or equipment often lead to workarounds	Yes	No
12. There is rapid staff turnover, or many inexperienced personnel	Yes	No

Nose wheel jammed on Dash-8

While preparing a Dash-8 aircraft to return to service after major repairs, maintenance engineers noticed that the nose gear was missing a cover plate designed to protect micro switches from dust and stone damage. No spare was available, and it would take months to get a new one from the manufacturer. To help the company meet a deadline, maintenance personnel decided to manufacture a substitute cover plate, without waiting to get engineering approval. The plate was only a protective cover, not a structural component, and this probably led them to believe that manufacturing a similar replacement part would not affect safety.

The original plate was shaped to provide clearance between it and the micro switches and was secured using counter-sunk screws. Because of the limited manufacturing capability at this maintenance facility, the replacement cover was manufactured from a flat plate and spacers were used to provide similar clearance. The holes in the replacement plate were not drilled to accept counter-sunk screws and it was secured using washers and hexagonal-head bolts. The bolt heads protruded beyond the normal position of the counter-sunk screw heads. The difference was sufficient to cause the landing gear to jam in the up position during a test flight following the repairs. A retraction test that might have detected the problem was successfully completed before the replacement plate was fitted.

Positive-gravity manoeuvres and a touch-and-go landing failed to shake the nose gear free. The crew decided to land once all other traffic was clear and emergency services were in place. A landing was completed with the aircraft sliding to a stop on its main wheels and nose.

The accident investigator noted that a culture of 'getting the job done' existed in the company and there was a strong sense of loyalty and motivation among the maintenance staff. The report concluded, 'Staff excelled themselves in order to meet deadlines. Whilst this approach is laudable, research and investigation has shown that it can lead to incorrect practices if the appropriate balance is not found'.

As is illustrated in the example above, an awareness of how the physical and organisational environment influences maintenance tasks is an essential part of human factors. If you can identify error-producing conditions in your work environment, you will be better prepared to change those things you can change, and deal with those things that are beyond your control.[9]

[9] Bureau of Air Safety Investigation. Occurrence report 199602602.

Actions: Procedures, paperwork and poor design

The **actions** component of **PEAR** includes all of the hands-on requirements needed to complete a task; from gathering information on tasks, identifying approved data and procedures, the physical and mental demands of the tasks, to finalising and certifying a job complete.

The FAA has estimated that airline maintenance personnel spend between 25 and 40 per cent of their time dealing with paperwork. In airlines, maintenance engineers frequently deal with maintenance documentation that is difficult to interpret, or that describes procedures in ways that appear to be out of touch with current maintenance practices. In General aviation, on the other hand, the problem may be that approved documentation for older aircraft is simply not available, or is hard to obtain. Many maintenance engineers use 'black books', personal sources of unapproved technical data that may, or may not, be up-to-date.

A common problem faced by maintenance engineers is a conflict between following procedures and the pressure to get a job done. Human factors researchers in Europe have called this the 'double standard of task performance'.

> 'There is an official way of doing things, which is laid out in the documentation, which has legal status… Then, there is the way in which work is actually done, which is supported by unofficial documentation and which frequently diverges from the official way. The technician sees himself as being responsible for the safety of the aircraft, and to use his judgement to do what is necessary to ensure this (not always exactly as in the manual – sometimes more)'.[10]

An awareness of human factors associated with the actions required to complete a job by people at all levels of the organisation can help to identify areas where the formal procedures can be improved. An accurate knowledge of the task demands will help to identify informal work practices developed to meet these demands that need to be brought into alignment with the formal procedures. For this reason, human factors awareness is needed not just by aircraft engineers but also by managers and the writers of technical documents.

In August 2005, a Boeing 737 crashed near Athens after the aircraft failed to pressurise and the crew lost consciousness. In its formal findings, the investigation board noted that the instructions in the maintenance manual were vague[11].

---

10 McDonald, N. *Human-Centred Management Guide for Aircraft Maintenance Aircraft Dispatch and Maintenance Safety*. Aerospace Psychology Research Group. Trinity College, Dublin.

11 Hellenic Republic Ministry of Transport & Communications. Air Accident Investigation and Aviation Safety Board (AAIASB). Aircraft Accident Report. Helios Airways Flight HCY522, Boeing 737-31S at Grammatiko, Hellas on 14 August 2005. Accident Report 11/2006.

Failure to pressurise after outflow valve left in open position

Early on the morning of 14 August 2005, a Boeing 737-300 aircraft departed Cyprus for Prague via Athens. About 5 minutes after take-off, at an altitude of 12040 ft. and at a cabin pressure that corresponded to an altitude of 10000 ft., an aural warning horn sounded. On this aircraft, the same aural tone is used to indicate two conditions, Take-off Configuration Warning and Cabin Altitude Warning. A minute and a half later, with the aircraft still climbing, the captain contacted the company Operations Centre on the company radio frequency and reported that that the crew had a take-off configuration warning. The operations centre put a ground engineer on the line to communicate with the captain. The engineer later reported a confusing conversation in which the captain mentioned a problem with the ventilation cooling fan lights. Since the message from the captain did not make any sense to the engineer, he asked the captain to “confirm that the pressurization panel was selected to AUTO.” The captain responded “where are my equipment cooling circuit breakers?” The engineer replied “behind the captain’s seat”.

During the conversation with the company operations centre, the passenger oxygen masks deployed as they were designed to do when the cabin altitude exceeded 14 000 ft. The communication between the ground engineer and the captain ended as the aircraft climbed through 28900 ft. Shortly after, the flight crew are believed to have lost useful consciousness as a result of hypoxia. The aircraft levelled off at FL340 and continued on its programmed route, eventually entering a programmed holding pattern near Athens. There was no response to radio calls to the aircraft.

F-16 fighters were scrambled to intercept the 737. One of the F-16 pilots observed the aircraft at close range and reported that the captain’s seat was vacant, the first officer’s seat was occupied by someone who was slumped over the controls, the passenger oxygen masks were dangling, and motionless passengers were seen seated wearing oxygen masks in the cabin. A person who appeared to be a flight attendant was then seen to enter the cockpit and sit in the captain’s seat. At around 9 am, the engines flamed out due to fuel exhaustion and the aircraft crashed into hilly terrain northwest of Athens airport. All the 115 passengers and 6 crew died.

During the previous flight, cabin crew had noticed frozen door seals and noises around the right aft service door, and the flight crew wrote up an entry in the aircraft tech log ‘aft service door requires full inspection’. Between 1:30 am and 3:15 am engineers performed a visual inspection of the aft service door and carried out a cabin pressurisation leak check. During the leak check, the engineer who would later speak with the captain during the flight went to the cockpit to pressurise the aircraft, while another engineer stayed in the rear of the aircraft near the R2 door. No defects were found and the log entry was signed off.

The maintenance manual procedure for the cabin pressurisation check required the pressurisation mode selector in the cockpit to be set to the MAN (Manual) position. The investigation board found that after the pressurisation test, the pressurisation mode selector was not selected back to AUTO. As a result, the aircraft's out flow valve (OFV) remained fixed in the open position, the position it was last left in. The investigation board stated 'Although not a formal omission, it would have been prudent to position the pressurisation mode selector back to AUTO'. The board noted that the last action item in the pressurisation check procedure stated 'Put the Airplane Back to its Initial Condition'.

The board considered that these instructions were vague because they did not state specifically that the pressurisation mode selector must be returned to the AUTO position, although the procedure explicitly required setting that selector to the MAN (manual) position for the test.

During their pre-flight preparations, the flight crew was required to confirm that all selectors, including the pressurisation mode selector, were in their proper positions for flight. The flight crew apparently did not recognize that the pressurisation mode selector was set to MAN instead of AUTO, as required. As a result, the out flow valve (OFV) remained fixed in the open position, and the cabin did not pressurise.

The official accident report provides a much more detailed treatment of the accident and the wider organisational issues that were associated with it, but the vagueness of the maintenance manual instructions was a significant contributing factor.

The pressurisation panel. The pressurisation mode selector can be seen at bottom right

The tail assembly of the aircraft

Many aircraft systems are not designed for ease of maintenance and this can lead to increased physical and mental demands on the maintenance engineer in order to complete a job. Here are just a few:

- Access and visibility problems where the work has to be done by feel or with the use of mirrors
- Plumbing or electrical connections that permit cross-connection, or connection to the wrong system
- Similar components that are physically interchangeable but have different functions
- Components that can be installed in the reverse sense.

If we use **PEAR** to look at the **Actions** required to complete a job, we can identify design traps such as those listed above that can lead to maintenance errors during the complex application of skill in those task steps.

James Reason[12] lists measures that should be included in any framework to manage error. These include:

- Measures to reduce the error vulnerability of particular tasks or task elements
- Measures to discover, assess and then eliminate error-producing factors within the workplace.

Although maintenance engineers cannot change the design of aircraft; extra defences can be put in place during jobs where analysis using HF knowledge identifies an increased risk of error. These defences can be related to Reason's measures to achieve error management aims. They could include:

- Warnings in manuals where components can be incorrectly installed
- Extra inspections on safety-critical or complex tasks, and tasks within areas of limited access or visibility
- More supervision if inexperienced maintenance engineers complete tasks that are identified as complex or error prone.

Without these defences, errors can occur that have a catastrophic consequence, such as the accident outlined below when an incorrect part fitted to an ATR 72 ultimately led to fuel exhaustion and the resultant ocean ditching of the aircraft.

[12] J. Reason, (1997). Managing the Risks of Organisational Accidents, Chap 7 'A Practical Guide to Error Management'. Aldershot: Ashgate.

Wrong fuel indicator fitted to aircraft

An aircraft engineer was replacing a faulty fuel quantity indicator (FQI) on an ATR 72 twin turboprop aircraft. He referred to the illustrated parts catalogue (IPC) and found three part numbers suitable for the ATR 72. However, when he looked up these parts in the company spare parts management system, they showed as NIL STOCK. He was not aware that although the part numbers in the IPC contained a dash after the first three digits, the dash was not recognised in the company parts system. The engineer tried searching with just the first three digits of the part number, and eventually found a part that was listed by the parts management system as suitable for both ATR 42 and ATR 72. The engineer was not aware that this information was incorrect, and the FQI was only suitable for an ATR 42. He found the FQI in stores, and left it to be installed by an engineer on the incoming shift. The second engineer installed the FQI, in accordance with the manufacturer's procedures. He did not check the part number with the IPC. Had he done so he would have seen that the part was only for an ATR 42.The installation procedure did not require a manual check on the accuracy of the FQI readings, only a check that the indicator lights were working.

The next day, the aircraft was refuelled in preparation for a return flight from Tunisia to Italy. The newly installed FQI was indicating 1800kg over actual fuel on board, and neither the flight crew or ground personnel noticed that a much smaller quantity of fuel was pumped than expected. Fifty minutes into the flight, at around 23,000ft, both engines flamed out due to fuel exhaustion. When it ditched into the Mediterranean, the aircraft broke into three pieces and sixteen people died.

ATR 72 fuel quantity indicator

What actions could be done in line with Reason's measures to manage error (and reduce error vulnerability) to prevent recurrence of a similar accident?

- A different keyway design on each type of fuel quantity indicator's electrical connection to prevent fitment to the wrong aircraft type? (Though this might be difficult as it would require action by both the aircraft and FQI manufacturers)
- A warning in the manual on the risk of fitting an incorrect part and a reminder of the requirement to check any items to be fitted with the IPC?
- A requirement to test the FQI at empty and full ranges after installation?
- A greater awareness in ground staff of how to identify when fuel upload seems inadequate?

Task error vulnerabilities and possible solutions associated with the actions required to complete a job will be more readily and proactively identified if maintenance engineers use human factors knowledge and tools such as **PEAR**.

A lack of, or deficient, **Resources**.

Many maintenance incidents begin with a lack of necessary resources, such as time, spares, or specialised tools. Shortages like this will sometimes lead to work arounds or disruptions, as was the case with the Dash-8 jammed nose wheel example given above. General aviation maintenance engineers in particular, frequently have to deal with a lack of resources and equipment. Knowing how to deal with a lack of resources requires judgement that may take years to build up. One LAME described the following situation, that occurred early in his career.

'It was a Friday afternoon and I was about to knock off for the weekend. I decided to do one last-minute job and tighten the nose-wheel steering cables on a twin-engine aircraft. Not having an appropriate flagged rig pin I used a bolt through the aircraft floor to hold the rudder pedals in neutral. It got dark and everyone was anxious to go home, and I was holding them up. At the end of the job I signed off the maintenance release but forgot to remove the bolt. On Monday the aircraft was flown for a whole day checking out a pilot with landings every 20 minutes. If they had feathered an engine or there had been an engine failure they would have been in real trouble, as the limited rudder movement was from this bolt flexing in the floor structure'. (De-identified incident report)

The resources in this case were not just physical ones, like a rigging pin; they also included having the time to carry out the job without pressure and stress affecting performance. Good performance in any given task requires knowing if you have both the physical resources and less tangible resources, such as time, to do it without resorting to work arounds. This knowledge will allow you to manage your potential for error and keep your risks as low as possible.

The benefits of human factors training

Beginning in the 1970s, many airlines introduced human factors training for pilots. This training, originally called cockpit resource management, has also been referred to as non-technical skills, crew resource management, threat and error management, or just plain human factors. Over the years, the content of aviation human factors training has evolved and expanded from an early focus on communication and decision making to an approach based on error management. This is the idea that aviation personnel should not only be trained in techniques to prevent error but, more importantly, should also be prepared to manage and recover from inevitable errors.

Accident rates have steadily declined since the 1970s, and while much of the improvement is probably due to improved aircraft and equipment, there is no doubt that the emphasis on human factors has also played a part. The former CEO of British Airways, Sir Rod Eddington, was once asked to list the most significant developments in twentieth-century aviation. In addition to the jet engine and radar, he considered that improved awareness of human interactions and communication had made a significant contribution to aviation safety.

The benefits of human factors training in aviation have resulted in the concepts being adopted in many other fields. Surgeons, maritime crews, astronauts and firefighters now commonly receive training in human factors, based on concepts originally developed for aviation.

In the 1990s, human factors programs started to become standard for maintenance personnel at many organisations around the world. While training in human factors is often the most visible part of these programs, a human factors program will also typically include incident reporting systems, fatigue management interventions, a policy to encourage the open sharing of incident information, and actions to identify and correct ergonomic problems in the workplace.

Maintenance human factors programs have many benefits. Not only do they improve the quality of maintenance, they also have the potential to help reduce workplace injuries and accidents and reduce the need for costly re-work. Research has indicated that, overall, maintenance human factors training can save money. One study at a U.S. airline reported a US$60,000 saving per year. Following a two-day human factors training course, there was a 68 per cent reduction in ground damage incidents, a 12 per cent decrease in job injuries, and a 10 per cent reduction in staff overtime[13]. Also, the introduction of a maintenance resource management program at another U.S. airline reduced lost-time injuries by 80 per cent over two years, with a total claimed cost saving of US$1,300,000 over that period[14].

CASA has now mandated this training for maintenance personnel in Australia.

DIRTY DOZEN

1. Lack of communication
2. Complacency
3. Lack of knowledge
4. Distraction
5. Lack of teamwork
6. Fatigue
7. Lack of parts
8. Pressure
9. Lack of assertiveness
10. Stress
11. Lack of awareness
12. Norms

[13] Stelly, J. & Poehlmann, K.L. (2000). Investing in human factors training: Assessing the bottom line. Presented at the 14th Annual Human Factors in Aviation Maintenance Symposium, Vancouver B.C. 17-18 April.

[14] Taylor, J.C. (2000). 'A new model of return on investment for MRM programs'. Presented at the 14th Annual Human Factors in Aviation Maintenance Symposium. Vancouver, B.C. 17-18 April.

International and Australian aviation maintenance human factors program requirements

CASA requirements

The recently introduced Civil Aviation Safety Regulation (CASR) 145 is based on the European Aviation Safety Agency's (EASA's) part 145, and includes human factors requirements for maintenance. The regulation requires organisations to apply human factors principles to safety and quality, institute a reporting system with a just culture policy, and ensure that personnel receive training in human factors principles. Training in human factors is required for all employees involved in maintenance, including contract staff.

CASR 145 lists the following initial human factors training topics, similar to those in EASA 145. Continuing training should concentrate on those areas in the company where problems and errors are occurring; where hazards stemming from HF influences have been identified; and where human factors guidance material details training is most necessary.

Training requirements referred to in 'acceptable means of complianace' and 'guidance material' for CASR 145

Human factors training topics

1. General/introduction to human factors
   - Need to address human factors
   - Statistics
   - Incidents
2. Safety culture/organisational factors
3. Human error
   - Error models and theories
   - Types of errors in maintenance tasks
   - Violations
   - Implications of errors
   - Avoiding and managing errors
   - Human reliability
4. Human performance and limitations
   - Vision
   - Hearing
   - Information processing
   - Attention and perception
   - Situational awareness
   - Memory
   - Claustrophobia and physical access
   - Motivation
   - Fitness/health
   - Stress
   - Workload management
   - Fatigue
   - Alcohol, medication, drugs
   - Physical work
   - Repetitive tasks/complacency
5. Environment
   - Peer pressure
   - Stressors
   - Time pressure and deadlines
   - Workload
   - Shift work
   - Noise and fumes
   - Illumination
   - Climate and temperature
   - Motion and vibration
   - Complex systems
   - Hazards in the workplace
   - Lack of manpower
   - Distractions and interruptions

6. Procedures, information, tools and practices
   - Visual inspection
   - Work logging and recording
   - Procedure – practice/mismatch/norms
   - Technical documentation – access and quality
7. Communication
   - Shift/task handover
   - Dissemination of information
   - Cultural differences
8. Teamwork
   - Responsibility
   - Management, supervision and leadership
   - Decision making
9. Professionalism and integrity
   - Keeping up to date, currency
   - Error-provoking behaviour
   - Assertiveness
10. Organisation's HF program
   - Reporting errors
   - Disciplinary policy
   - Error investigation
   - Action to address problems
11. Feedback

ICAO requirements

The International Civil Aviation Organization specifies that maintenance organisations should have safety management systems, and human factors training for maintenance personnel. ICAO has published two detailed educational documents on maintenance human factors[15].

Human Factors in Aircraft Maintenance and Inspection

Human Factors Guidelines for Aircraft Maintenance

Federal Aviation Administration requirements

For over 20 years, the FAA has sponsored research and educational material on human factors in maintenance. At present, the FAA *encourages* human factors training, but does not require it.

Some recent documents released by the FAA, and available via the FAA website (www.faa.gov) include:

- *Operators Manual: Human Factors in Aviation Maintenance*[16]. What you need to do to establish a maintenance human factors program, including event investigation, document improvement, human factors training, shift/task turnover, fatigue management and sustaining programs over the long term.
- *Maintenance Human Factors Presentation System*. A tool explaining what human factors is, why it is important for maintenance, and how to apply HF effectively in the maintenance environment.
- *Advisory Circular AC 120-72*. Guidance on how to develop a human factors course for maintenance.
- *Advisory Circular AC 120-66B*. Encourages airlines to set up voluntary incident reporting systems involving airline management, unions and the FAA. Reporters are guaranteed immunity from FAA enforcement action if the reported incident meets certain requirements, such as not involving 'intentional disregard for safety'.

---

[15] ICAO (1995). 'Human Factors in Aircraft Maintenance and Inspection'. *Human Factors Digest* No.12; ICAO (2003) *Human Factors Guidelines for Aircraft Maintenance* (contains a training syllabus for human factors in maintenance in appendix B of Chapter 5).

[16] FAA (2005). *Operator's Manual. Human Factors in Aviation Maintenance*. Available www.hf.faa.gov/opsmanual

EASA requirements

The European Aviation Safety Agency (EASA) has led the way in regulations on maintenance human factors. EASA 145 was the precursor of CASR 145, and contains extensive human factors in maintenance requirements for maintenance organisations.

EASA 66 lists human factors knowledge among the basic initial requirements to qualify as certifying maintenance staff on commercial air transport aircraft. The recommended syllabus includes teamwork, working with time pressure and deadlines, communication, and the management of human error. Although these syllabus items are listed in the appendix to the regulation as an 'acceptable means of compliance', EASA has not listed alternative means of compliance, so this syllabus has the force of a regulatory requirement.

Civil Aviation Authority (UK) requirements

The UK CAA has published two comprehensive documents on maintenance HF to help maintenance personnel and organisations meet the HF requirements of EASA parts 66 and 145.

- *An Introduction to Aircraft Maintenance Engineering Human Factors for JAR 66* (EASA 66), and
- *Aviation Maintenance Human Factors* (EASA / JAR145 Approved Organisations)[17].

The CAA has also released an airworthiness notice (AN 71) encouraging operators to introduce maintenance error management programs incorporating non-punitive reporting systems.

[17] CAP 715 *An Introduction to Aircraft Maintenance Engineering Human Factors for JAR 66* (EASA 66); CAP 716 *Aviation Maintenance Human Factors* (EASA / JAR145 Approved Organisations).

Key points

- The majority of aviation accidents involve human factors somewhere in the causal chain. Between 12–20 per cent of accidents may involve maintenance factors.
- In most cases of maintenance error, the maintenance engineers involved were well trained and were acting with integrity. In many cases, the people involved were motivated by a genuine desire to do a good job and help their employers.
- Human factors in maintenance can be summarised by the PEAR model:

  P Stands for the **people** who do the work, in this case maintenance engineers. It includes not only our capabilities and limitations, but also our interactions with other people.

  E Stands for the **environment** in which the work is done—physical and organisational.

  A Represents the **actions** necessary to complete the job efficiently and safely.

  R Stands for the **resources** needed for the job—physical, such as tools and technical manuals, as well as the number and qualifications of people necessary.

- Human factors training is now required for maintenance engineers and other personnel who are involved in maintenance. There is good evidence that human factors training can help to reduce accidents, as well as reducing costs and increasing efficiency.

Further information

ICAO (1995). 'Human Factors in Aircraft Maintenance and Inspection'. *Human Factors Digest* No.12; ICAO (2003) *Human Factors Guidelines for Aircraft Maintenance* (contains a training syllabus for human factors in maintenance in appendix B of Chapter 5).

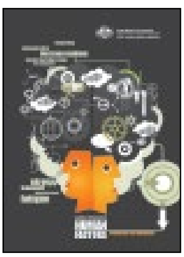
CAP 715 *An Introduction to Aircraft Maintenance Engineering Human Factors for JAR 66* (EASA 66)

UK CAA CAP 716 *Aviation Maintenance Human Factors* (EASA/JAR145 Approved Organisations) Guidance Material on the UK CAA Interpretation of Part 145 Human Factors and Error Management Requirements

McDonald N. and others, *Human-centred Management Guide for Aircraft Maintenance Aircraft Dispatch and Maintenance Safety*

FAA (2005) *Operator's Manual. Human Factors in Aviation Maintenance.*
Available www.hf.faa.gov/opsmanual

FAA Human Factors in Maintenance website: https://hfskyway.faa.gov



When you are ready, please turn to page 5 of the *Workbook for Engineers*, read the overview and complete chapter 1.


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 2

ERROR MANAGEMENT

Error is an unavoidable part of being human. It has been estimated that we make over 50 errors each day. For example, approximately five per cent of phone calls dialled are wrong numbers, and the average error rate with simple arithmetic is around three per cent. Most everyday errors have minor consequences. It does not matter a great deal if we forget to pick up groceries, burn toast, or have trouble installing software on our home computer. Most everyday errors are also reversible. If we make a wrong turn while driving we can turn back in the direction we intended, and we can usually find lost car keys after a few minutes of searching. However, maintenance errors can have more serious consequences, and are not always caught and corrected as easily.

The point of learning about human error is not to find out where people went wrong; it is to find out why their assessments and actions made sense to them at the time.

Sidney Dekker, Professor of Human Factors and Aviation Safety

Human error types, causes and consequences

Studies of error in safety-critical industries can estimate the overall probability of errors, but we cannot predict when and where each individual error will occur. The table below shows estimated error probabilities for maintenance tasks. These estimates relate to 1960s technicians working on electronics and missile systems, but they are still relevant for aircraft maintenance today. For example, the probability that nuts and bolts will not be installed is estimated to be two per thousand, but the chance that they will not be tightened is double this. Interestingly for error mitigation, when someone is checking the work of another person, there is a 10 per cent chance that they will miss a problem.

Estimated error probabilities on maintenance tasks

Task	Errors/1000 tasks
Install nuts and bolts	2
Connect electrical cable	3
Install O-ring	3
Tighten nuts and bolts	4
Read pressure gauge	11
Install lock wire	32
Check for error in another person's work	100

Given the high probability of human error, it is remarkable that relatively few serious maintenance errors occur each year. Credit is due to the systems in place, and the professionalism of maintenance personnel. Nevertheless, industries that rely on accurate and consistent human performance must be designed to deal with the inevitability of human error.

The threat human error poses can be viewed in the same light as other threats the aviation industry must manage. Take lightning, for example. We know that lightning will strike airport structures from time to time. We understand the long-term risk factors (height of the structure, surrounding topography) and the immediate risk factors (presence of a thunderstorm). We can also take appropriate precautions to prevent lightning strikes, and limit their effect when they occur (grounding, surge protection).

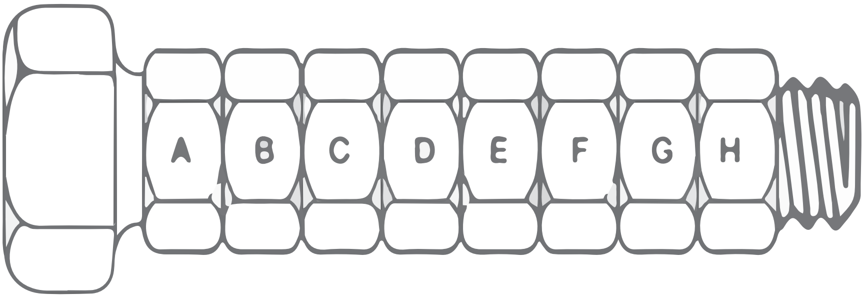
Human error can be seen as a natural threat that must be managed in much the same way. An understanding of the risk factors for human error can help us to reduce its frequency. We can also anticipate it, and take precautions to limit its effects. The one difference is that unlike hazards in nature, human error is a constantly evolving threat, as it stems from human beings' infinite adaptability and capabilities. The maintenance errors that occur this year, with current procedures and equipment, may be different to those that will occur next year: the solutions that work today may need to be revised and updated to continue work in 12 months time.

Maintenance and human error

Engineering maintenance has unique characteristics, which make error management particularly difficult:

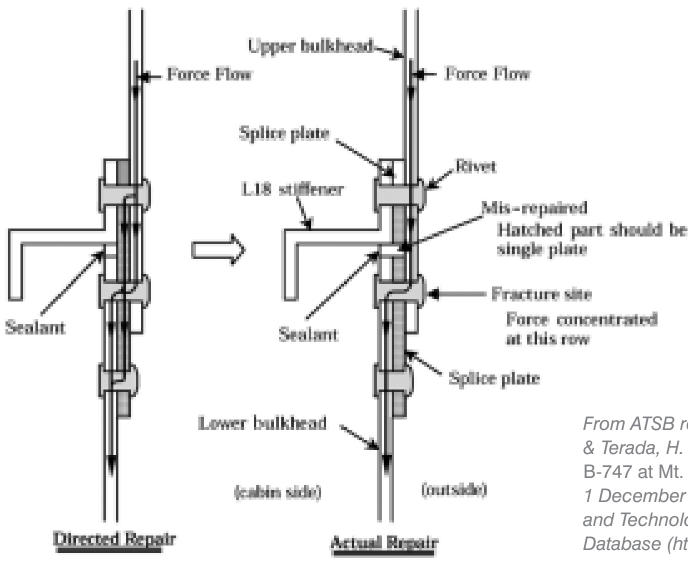
- Maintenance activities present many opportunities for error. A simple example illustrates this point (see diagram below). A bolt fitted with eight nuts can only be disassembled one way, but there are over 40,000 ways in which it can be reassembled incorrectly. Consider how many more error opportunities the average general aviation aircraft presents!

Reason's nuts and bolt example



- Errors may be buried deep inside aircraft systems. Once maintenance is complete and the aircraft is returned to service, the chances of detecting the error before the next scheduled maintenance may be slight.
- Errors can lie dormant for months, or even years, before causing a problem. A loosely-secured nut may take months to vibrate free, and a fatigue crack caused by improper maintenance may grow slowly over years. The world's worst aviation accident involving a single aircraft occurred to a Boeing 747 that had undergone major repairs to its rear pressure bulkhead seven years before the eventual accident. The repair had involved replacing the lower half of the bulkhead, and it should have been spliced to the upper half using a single doubler plate extending under three lines of rivets. For reasons unknown, part of the splice was made using two doubler plates, as shown in the figure below. As a result, the join relied on a single row of rivets. A fatigue facture developed that eventually caused a catastrophic failure of the rear pressure bulkhead. The resulting damage made the aircraft uncontrollable.

Rear pressure bulkhead repair



From ATSB report, Citation is Kobayash, H. & Terada, H. (2006). Crash of Japan Airlines B-747 at Mt. Osutaka*. Retrieved 1 December 2008, from Japan Science and Technology Agency Failure Knowledge Database (http://shippai.jst.go.jp/en/).*

- Many maintenance errors are found and corrected without being reported or documented. As a result, the full extent of maintenance error is unknown, and the lessons that could have been learned from each error are not always shared within the industry.

Errors are both consequences and causes

Identifying a human error is a starting point, not a conclusion. If our aim is to learn from the error and to lessen the chances of it happening again, we need to consider the organisational context that surrounded the person's action: including equipment, procedures, people, the environment and management. There are two aspects to managing error:

- Reducing the probability that people will make errors
- Making sure that the system is prepared to deal with errors when they occur.

The use of the term 'human error' does not mean we have a problem with people. Human error generally points us to systems problems. Although error can lead to unwanted events, it also can provide valuable opportunities to identify and implement system improvements.

Errors and violations in aviation maintenance

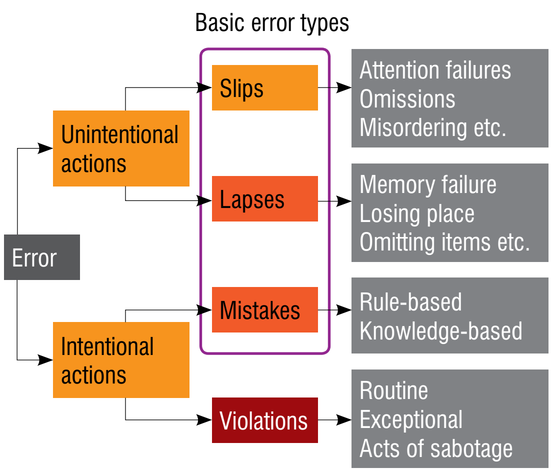
Types of errors

A widely-used categorisation system for human error is the Reason model shown in the figure below. Once you have identified the type of error involved in an incident, you can then develop possible solutions.

Human errors can be divided into two basic categories, unintended actions and intended actions. 'Unintended action' means that we find ourselves doing a task in a way we never meant to (a slip), or we leave out a step we intended to carry out (a lapse). These errors typically occur when our attention is distracted.

Intended actions can be divided into 'mistakes' and 'violations'. When we say that the action was intended, in most cases we do not mean that the person intended harm.

Reason model of error



Adapted from Human Error, J. Reason, Cambridge University Press, Cambridge (1992).

Slips

Many people are familiar with the feeling that they have been doing a familiar task on autopilot. Slips occur when we perform a routine action that was out of place in the situation, usually because we are distracted and habit takes over. For example, in the first week of January, it is not uncommon to write the previous year. Many slips in maintenance are slips of the pen, where a signature is put in the wrong place or a checklist item is missed. Slips also occur when using tools and when activating cockpit controls.

> While performing maintenance on the co-pilot's circuit breaker panel, the ELT was accidentally activated via the cockpit arm/on switch. The switch is poorly located and inadequately guarded.

Anonymous report

Lapses

A lapse occurs when we forget to complete an action we had been intending to perform. Examples are forgetting to remove tools or rigging devices at the end of a job, forgetting to close hatches, or leaving nuts finger tight when the intention had been to torque them up. One of the most widely reported lapses in maintenance is failing to replace oil caps. Many lapses occur when the engineer has been interrupted part way through a task, often when called away to a more urgent job. They may then fail to return to the task, leave out a step, or lose their place in the task. In the following case a person forgot to finish a task after an interruption.

> While servicing the no. 2 engine, I was called away by an air carrier contract fueller on the aircraft to address a problem with opening the fuel panel door. When this problem was solved, I apparently went back to the no. 2 engine and took my oil cart and stand away. I have no recollection of reinstalling the oil tank cap, or closing the cowling door. Later we received feedback that the engine had experienced a loss of four litres of oil after landing.

Anonymous report

Mistakes

Mistakes are a type of error where the problem has occurred during thinking rather than doing. The person carries out their actions as planned, except that what they planned to do was not right for the situation. Reason describes two types of mistakes, rule-based and knowledge-based.

Rule-based mistakes occur in familiar situations where an engineer has a pre-existing 'rule' or guideline they use to guide their actions. This need not necessarily be a formal rule; it could be a procedure or work habit that they usually follow in that situation. The mistake happens when the rule no longer fits the situation, or the engineer mis-identifies the situation. For example, an engineer who pushed in a pulled cockpit circuit breaker, without first stopping to check the cockpit control settings, failed to apply a good rule or work habit to a familiar situation. In another case, an electrician wrongly assumed that a colleague had disconnected the power supply, because this was their routine work practice.

> A mechanic did not check the position of the flap lever before he pushed in a cockpit circuit breaker that provided electrical power to a hydraulic pump. When the pump started, the flaps began to retract automatically. This could have caused damage to the aircraft, or injured other workers.

Anonymous report

Knowledge-based mistakes reflect a lack of necessary knowledge, or a lack of awareness of where to find the necessary information. This is most likely to occur when a person is performing an unfamiliar task, or is dealing with a non-routine situation. Typically, a person who has made a knowledge-based error will say they did not know about a procedure, or were confused by the task.

> An apprentice was spraying solvent to clean an engine with the AC power on. Solvent ignited over engine and into oil-soaked drip tray. The apprentice had never been told of the dangers of solvent cleaning.

Anonymous report

You might think that apprentices or inexperienced engineers would be most likely to make knowledge-based mistakes but, in fact, experienced personnel are more likely to be dealing with complicated or uncommon problems, and so may have more opportunities to make these kinds of errors.

Violations

Violations are intentional deviations from procedures or good practice. In most cases, the violation occurs because the engineer is trying to get the job done, not because they want to break rules. One LAME expressed it this way: ‘Management tell us to follow the procedures to the letter, but then they tell us not to be obstructive and to use common sense’. Reason’s error model shows three types of violations: ‘routine’, ‘exceptional’ and ‘sabotage’. Sabotage will not be dealt with here, because it is an extremely rare event in aircraft maintenance.

Routine violations are the everyday deviations from procedures made to keep things moving and get the job done efficiently. While not justifying such actions, they are the easiest to understand. Routine violations are frequently so widespread in a company that they become the normal way that everybody works. Researchers in Europe found that 34 per cent of maintenance engineers acknowledged that they had not strictly followed procedures in their most recent maintenance task. Common reasons for these violations are unworkable procedures, and lack of resources, such as specialised tools or spares. In some cases, there is an easier way to perform the task, and the engineer gravitates to that method. Examples are not using a torque wrench, instead judging torque by feel; or referring to a personal source of maintenance data instead of going to the maintenance manual.

Exceptional violations are often well-intentioned attempts to get the job done, despite problems such as missing documents or a shortage of parts. The engineer knows that they are deviating from procedures, but may be able to justify their actions, and usually considers that the risk is minimal. At times, for example, engineers may be tempted to skip a required engine run to allow an aircraft to depart on time. In many cases, exceptional violations, in isolation, are not dangerous, yet they reduce the margin of safety. If another problem occurs, there may be nothing standing in the way of an accident. In the following example, an engineer decided not to manually check the fuel in a tank. In this case, there was no safety consequence; however, if circumstances had been different, the results could have been catastrophic.

> The centre tank fuel quantity indicator was inoperative. According to the MEL, before each flight day, the centre tank needs to be sumped. Since the aircraft was needed at the gate, I signed the log as ‘sumped tank’, knowing that there was still about 60–120 litres of fuel in the tank. I did not want maintenance to take a delay. I was pressured to get the aircraft on the gate. I felt it was my sole responsibility to get it there with enough time to make its departure. What I should have done was to take the delay and sump the tank.

Anonymous report

Error-producing conditions in aviation maintenance

Some errors, such as slips, seem to be an unavoidable part of life. If you perform a simple action often enough (e.g. removing and replacing a fuel cap 1000 times), by the law of averages, an error is almost bound to happen. Other errors are more closely related to causal factors in the workplace: issues with the people, environment, actions and resources—in other words, the elements of the PEAR model. In several studies of maintenance error, the same error-producing conditions appear repeatedly:

- Time pressure
- Problems with equipment, tools and spares
- Training and experience
- Coordination within maintenance
- Fatigue
- Procedures and documentation
- Supervision.

Some error-producing conditions are more powerful than others. The table below shows estimates of how different conditions increase the risk of error[18]. Poor instructions or procedures are said to triple the rate of error. Lack of experience with the task is estimated to result in a 17-fold increase in the risk of error.

Examples of error-producing conditions

Condition	Risk factor
Lack of familiarity with the task	x17
Time shortage	x11
Information overload	x6
Poor feedback from system	x4
Inexperience	x3
Poor instructions or procedures	x3

The conditions that increase the risk of violations can be different to those that produce errors. Violations are often associated with time pressure, poor procedures, poor supervision, and shortages of equipment or spares. The table overleaf shows some of the reasons people gave for not following procedures.

[18] Williams, J. (1988) 'A data-based method for assessing and reducing human error to improve operational performance'. In: W. Hagen (Ed), *1988 IEEE Fourth Conference on Human Factors and Power Plants*. New York: Institute of Electrical and Electronic Engineers.

Why people don't follow procedures

Procedures are not followed because ...	% agreeing
People prefer to rely on their own skills and expertise	72
People assume they know what is in the procedure	70
If they were followed to the letter, the job could not be done in time	62
People are not aware that a procedure exists for the job they are doing	57
It is difficult to locate the right procedure	50
They do not describe the best way to carry out the work	48
They are too restrictive	48
It is difficult to find the information you need within the procedure	48
Human Reliability Associates Ltd (from CAA CAP 716)	

Error management strategies for individuals

Unfortunately, there is no guaranteed set of steps you can take to avoid making errors. The material in this resource guide will inform you about human factors in maintenance, and help you deal with the human factor challenges you face as a maintenance engineer. Subsequent parts of this resource will cover issues such as the limitations of memory, dealing with fatigue and stress, and improving communication. All maintenance tasks involve a potential for error, but by the end of this guide you should be able to recognise when you are in a situation with a higher than normal risk of human error. In general, you are in an elevated area of risk for human error when one or more of these conditions apply:

1. You are performing a task you have never done before
2. Procedures are ambiguous or confusing
3. Interruptions occur part way through the task
4. Special tools, equipment or spares are unavailable
5. There is more time pressure involved than you are used to dealing with
6. You are fatigued
7. You are working with unfamiliar people
8. You feel uneasy or uncomfortable about the task

One airline developed the following list of key behaviours together with its maintenance personnel. Each of the seven statements was developed in response to incidents, and helped to create a new set of standard practices at the organisation.

Seven key behaviours in maintenance

1. When performing principal systems or structures maintenance, we must review the current maintenance instructions before beginning a task
2. We must document all additional disassemblies not specified in the task instructions
3. We must document job status at end of shift, or when moving to a new task
4. We must attach a red tag to all disassemblies that might be inconspicuous to anyone closing the work area
5. We must confirm the integrity of each adjacent connection after installing any line replacement unit (LRU)
6. We must complete all required checks and tests
7. We must, when closing a panel, conduct a brief visual scan for safety-related errors

Error capture

The first objective of error management should be to reduce errors by identifying and correcting error-producing conditions. This will involve looking carefully at each of the elements of the PEAR model in the workplace to find areas where improvements can be made. After efforts have been made to reduce errors, there are two remaining error-management strategies: error capture, and error tolerance.

While you cannot prevent all errors, it is possible to detect many errors before they cause harm. Post-maintenance functional or operational checks, and dual inspections are examples of procedures designed to capture errors before they have a chance to cause harm. However, these procedures rely on human performance, and likewise, can fail because of human error. Checks and inspections are sometimes omitted because of factors such as time pressure or overconfidence. The error probabilities included at the beginning of this section included an estimate that around 10 per cent of dual inspections are ineffective.

The following incident report illustrates a case in which a check designed to capture error was ineffective because of poor decision making:

> At the end of a shift, we realised that an engine hadn't been run to check for oil leaks when the aircraft was to be placed on line. Under pressure to avoid a delay due to this oversight, the run was carried out too quickly, and the engine was not un-cowled properly to check for oil leaks. Consequently, after departure that particular engine ran out of oil as the result of a damaged seal. Several factors were involved here—primarily fatigue and inexperience.
>
> *Anonymous report*

Less formal approaches can also be effective in capturing errors. For example, a read-back of spoken instructions can be effective in capturing communication errors.

Error tolerance in aviation maintenance

Even if an error has occurred, and has not been detected, it may still be possible to manage the risk associated with it. Error tolerance is an approach designed to eliminate single points of failure so that errors not captured in the system do not lead to an accident. One approach is to minimise the simultaneous disturbance of multiple redundant systems. In the airline industry, the special maintenance precautions applied with extended-range twin-engine operations (ETOPS) are an example of such an approach. When an aircraft is being maintained under ETOPS procedures, the performance of identical maintenance actions on multiple elements of critical systems is avoided wherever possible. For example, the staggered maintenance required under ETOPS procedures reduces the risk that the same error will be made on both engines of a twin-engine aircraft.

The following example illustrates a case where a functional check was not part of a maintenance procedure. If it had been, an error might have been captured and the accident could have been prevented.

Air Midwest, Beech 1900D

On 8 January 2003, Air Midwest flight 5481 crashed shortly after take-off from Charlotte, North Carolina, killing the two crewmembers and all 19 passengers on board.

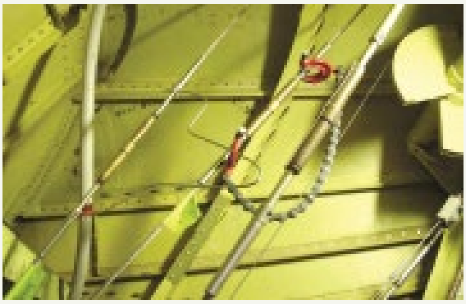
The NTSB established that after take-off, the pilots had been unable to control the pitch of the aircraft. There were two reasons for this. First, the aircraft was overloaded, and its aft centre of gravity exceeded limits. Second, the elevator control system did not have the full range of nose-down travel. This was due to incorrect rigging that had occurred during a maintenance visit just over 24 hours before the accident. The accident flight was the aircraft's tenth after the maintenance work, yet the previous nine flights all involved lower passenger loads and a centre of gravity that was further forward.

source: NTSB

On the night of 6–7 January, the aircraft had undergone a scheduled maintenance check, which included checking the tension of the elevator control cables. The engineer was performing this task for the first time, and was receiving on-the-job training from a quality assurance inspector. Finding that the cable tension was less than required, the engineer performed selected steps from the elevator control system rigging procedure to tighten the cable tension using cable turnbuckles.

However, in tightening the cables, he inadvertently restricted the amount of nose-down elevator travel to about half of what should have been available. The maintenance manual for the Beech 1900D did not have an isolated task procedure for adjusting cable tension. Instead, the manufacturer specified that the entire rigging procedure should be followed. However, the engineer and the inspector misunderstood the technical procedure and thought that it was only necessary to perform the steps specifically relating to adjusting cable tension. One of the steps skipped from the rigging procedure would have required a crosscheck of elevator positions with a read-out from the aircraft's flight data recorder at the end of the maintenance procedure. This step might have alerted the engineer that the full range of elevator travel was not available.

After the engineer had finished adjusting the control cable, he checked the movement of the controls from the cockpit. The inspector signed off the duplicate inspection, and also performed a physical check of the elevators that included grasping the elevator and moving it through its available travel. He concluded that the travel was within limits.



Beech 1900 elevator cable turnbuckle assemblies source: NTSB

At the time of the accident, there was no requirement for a post-maintenance functional check at the end of the control cable rigging procedure. Such a check would have involved an engineer in the cockpit moving the control wheel through its full forward and aft range of movement, while an engineer positioned at the tail of the aircraft measured the deflection of the elevator using a travel board.

Five weeks after the accident, the aircraft manufacturer added such a post-maintenance functional check to its elevator control rigging procedure. The accident highlighted the difficulties of capturing maintenance errors once they have been made. The NTSB noted that the U.S. Federal Aviation Administration did not have a general requirement for complete functional checks to be performed after maintenance on critical flight systems or components.[19]

19 National Transportation Safety Board. (2004). 'Loss of Pitch Control During Take-off. Air Midwest Flight 5481'. Raytheon (Beechcraft) 1900D, Charlotte, North Carolina, January 8, 2003. NTSB/AAR-04/01.

Key points

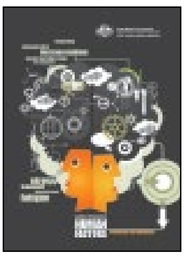
- No matter how hard we try, we can never completely eliminate human error.
- Maintenance error is a hazard that must be managed in the same way that we manage other hazards.
- We can manage human error in two ways:
  - by reducing it as much as possible
  - by making sure that systems are in place to capture errors, or tolerate those errors that are not captured.
- Telling people not to make errors, or trying to change human nature, is not an effective error management strategy.
- Error management requires a systems approach. This includes all the elements of the PEAR model: people, environment, actions and resources.

Further information

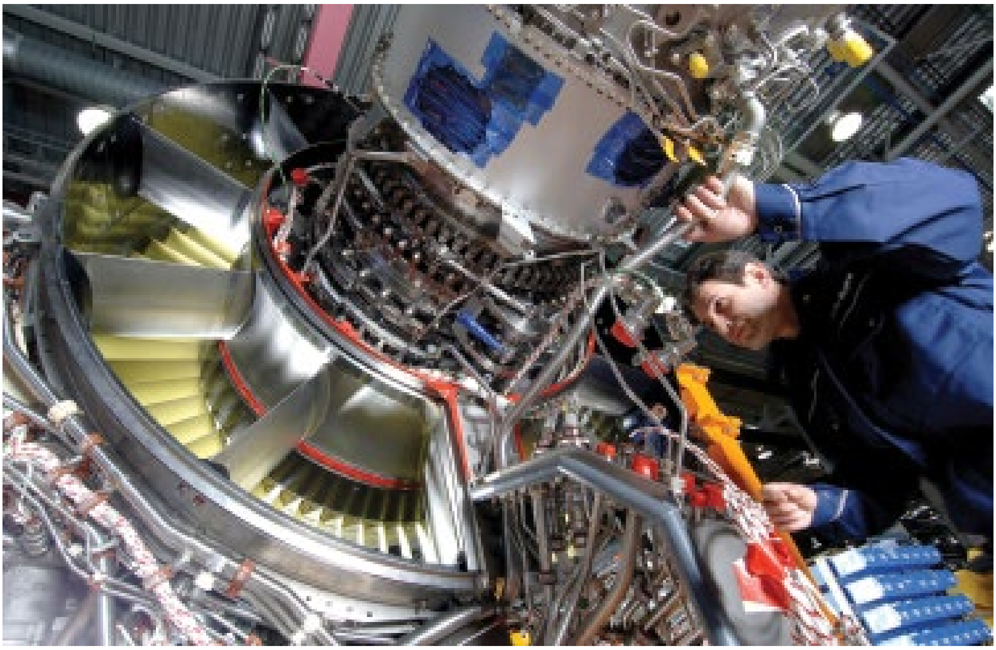
The FAA has a large amount of information on maintenance error and human factors on its maintenance human factors website: https://hfskyway.faa.gov

The UK CAA has published two comprehensive guides to maintenance human factors, CAP 715 *An Introduction to Aircraft Maintenance Engineering Human Factors for JAR 66 (EASA 66)*; and CAP 716 *Aviation Maintenance Human Factors (EASA / JAR145 Approved Organisation*s). Available at www.caa.co.uk

Several books have been published on maintenance human factors, including Reason, J & Hobbs, A. (2003) *Managing maintenance error: A practical guide*. Ashgate: Aldershot.



When you are ready, please turn to page 13 of the *Workbook for Engineers* and complete the exercises.




leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 3

HUMAN PERFORMANCE AND ITS LIMITATIONS

To understand human performance fully—the way we attend to things, perceive, think, remember, decide and act—we first need to understand how human beings process information, how we use our brains. Maintenance engineers make many decisions every day, and perform vital safety-critical tasks. Information processing is fundamental to doing these effectively.

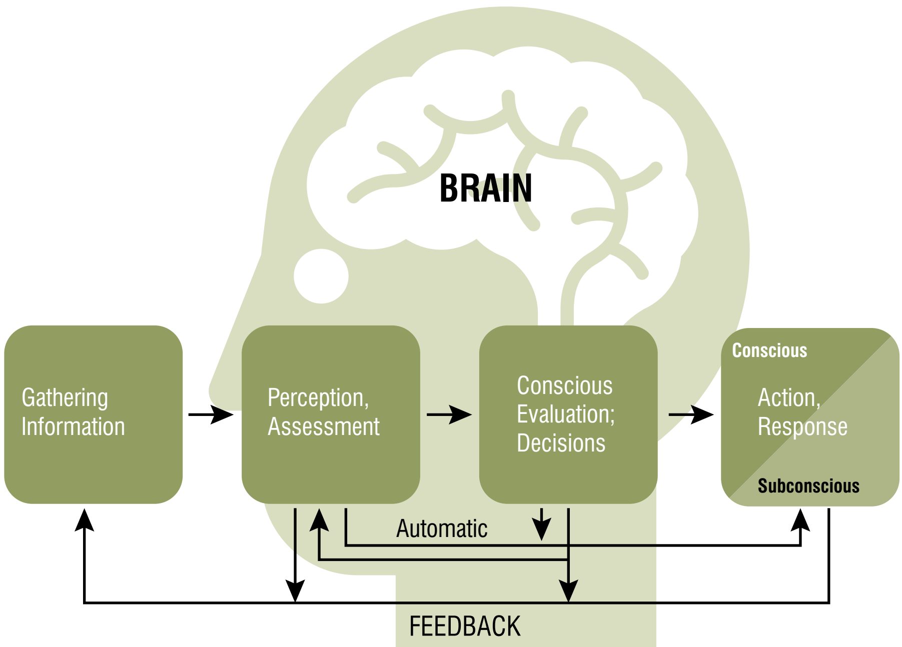
The greatest risk to man is not that he aims too high and misses, but that he aims too low and hits.

Michelangelo, Italian Renaissance painter, architect, poet, sculptor and engineer

How humans process information

Maintenance engineers make many decisions every day. To do this we use our brains, so to know how the brain works, we need to have a look at the ways in which we process information.

Information Processing Model



The five stages of information processing

Human beings basically process information in five stages:

Stage 1: Gathering information

First we must gather information. We do this by using our senses (sight, hearing, touch or smell [plus others such as balance etc]) to collect information using our receptors, which transform this information (about temperature, for example) into sensations (feels hot). Stimuli can either originate from an external source such as sound—or from an internal one—such as thirst or hunger.

Stage 2: Perception or assessment

Once we have gathered this information, we must make sense of it. This involves perception and assessment, arguably the most important stage in the whole process. Our brain gives the information an initial once-over to see whether it is meaningful; for example, have we seen this before?

At this point we must satisfy our human need to understand our environment. To do so we rapidly create an internal model (like a pattern) with which we are comfortable. The resulting model or pattern is influenced in two ways: by the raw sensory information we perceive; and either by previous experience, or our current expectations.

Here we are most vulnerable to being fooled either by the information itself, or by our own expectations—our eagerness to make the input fit what we have seen before. So, depending on our interpretation, our brain takes preliminary steps to work out how the information is to be dealt with. If our brain has seen it all before and it is commonplace; for example, walking up a flight of stairs, or changing gears while driving the car; the information is directed via the automatic (or motor) program path. If the information is new or complex, our brain assigns it to the full conscious evaluation/decision route.

Stage 3: Evaluation and decision making

If the information is complex or new, our brains will deal with it by giving it full and conscious attention. We may make the decision immediately, or store the information for a later decision. This will require the use of memory. Our initial evaluation may show that the input is familiar, so we can deal with it using a well-known procedure or method that has worked before; for example, putting a nut on a bolt. Doing so will still require a small amount of our conscious attention, but for the most part our response is directed automatically.

On the other hand, our initial evaluation might be that this new information is complex or unfamiliar. When this occurs, we have to think more deeply (apply significant cognitive resources) to resolve the situation. Quite often this will require such a level of concentration and brainpower that our ability to attend to other matters will be reduced, or even disappear; for example, trying to understand a previously unknown electrical wiring fault, or dealing with an unfamiliar engine running emergency.

Stage 4: Action/response

Our action or response occurs either consciously, with full awareness, or subconsciously using our automatic programs. If it is performed consciously, we act and/or speak with full attention. If it is performed subconsciously, we act as if we are on 'automatic pilot'.

Visualise an automatic task you can perform while doing other things; for example, driving a car while maintaining a conversation. But if the driving task becomes more difficult, such as attempting to parallel park in a particularly tight spot, our brain will revert to the 100 per cent full-attention requirement, and we stop our conversation. So while we can do more than one thing at a time, our brain is limited by being able to process only one thing at a time!

Stage 5: Feedback

The final stage is feedback, which allows us to confirm that what we are getting is what we are expecting. Feedback is not just a one-time deal. It occurs continuously throughout the various stages of information processing to ensure the information we are receiving continues to fit our expectations. The feedback stage provides the opportunity for:

- Clarifying details of the information
- If need be, seeking out additional information
- Refining the information
- Making small or large corrections with our actions and/or responses
- Identifying emerging hazards.

The whole process is repeated as often as necessary, so that either the status quo is retained, or necessary changes are implemented. When performing any skilled task such as soldering in a replacement electrical contact etc. we continuously monitor both the environment and the consequences of our action to form a closed loop feedback system. This provides us with valuable opportunities to assess both emerging errors and hazards. Identifying errors in a timely manner means that corrections can be made, and ensures the action continues as intended.

However, in the maintenance workplace, incorrect actions may not give instant feedback—under-torqued bolts, or omitted locking devices (split pins etc.), may not provide feedback for months after the error.

Engineers should have a basic awareness and understanding of how individuals process information. This helps us to better understand and accept error in ourselves and in others. This understanding of information processing is particularly useful when analysing errors, as it helps us to determine whether they are the consequence of one, or a combination of, the following:

- Deficiencies in receiving stimuli/information through our senses (not enough information)
- Deficiencies in perception/assessment of the information (not deciphering the information accurately)
- Deficiencies in the evaluation and decision-making processes
- Inappropriate action/response, despite satisfactory processing to that point
- Failure to monitor or respond to the feedback properly
- Effect of external factors detrimental to the process overall, such as excessive workload or fatigue.

High workload, and periods with a high volume of information to be processed in a short timeframe, can cause information overload. This may lead to degraded performance and an increased likelihood of error.

The senses

The most used and important senses for an aircraft maintenance engineer are arguably vision, hearing and touch. The crucial role of these senses can be seen in the following case study, where the maintenance process failed to detect fatigue damage, eventually leading to an explosive decompression in flight.

Poor maintenance inspection leads to fatality

On April 28, 1988, at 1346, a B-737-200 N73711 Aloha Airlines Flight 243, experienced an explosive decompression and structural failure at 24,000ft, while en route from Hilo to Honolulu, Hawaii.

Approximately 18 feet of the cabin skin and structure aft of the cabin entrance door and above the passenger floor line separated from the airplane during flight. On board were 89 passengers and six crewmembers. One flight attendant was swept overboard during the decompression and is presumed to have been fatally injured; seven passengers and one flight attendant received serious injuries. The flight crew performed an emergency descent and landing at Kahului Airport on the island of Maui.

The National Transportation Safety Board determined that the probable cause of this accident was the failure of the Aloha Airlines maintenance program to detect the presence of significant disbonding and fatigue damage that ultimately led to failure of the lap joint at S-10L and the separation of the fuselage upper lobe.

Contributing to the accident were the failure of Aloha Airlines management to supervise properly its maintenance force; the failure of the FAA to require Airworthiness Directive 87-21-08 inspection of all the lap joints proposed by Boeing Alert Service Bulletin SB 737-53A1039; and the lack of a complete terminating action (neither generated by Boeing nor required by the FAA) after the discovery of early production difficulties in the B-737 cold bond lap joint, which resulted in low bond durability, corrosion and premature fatigue cracking.

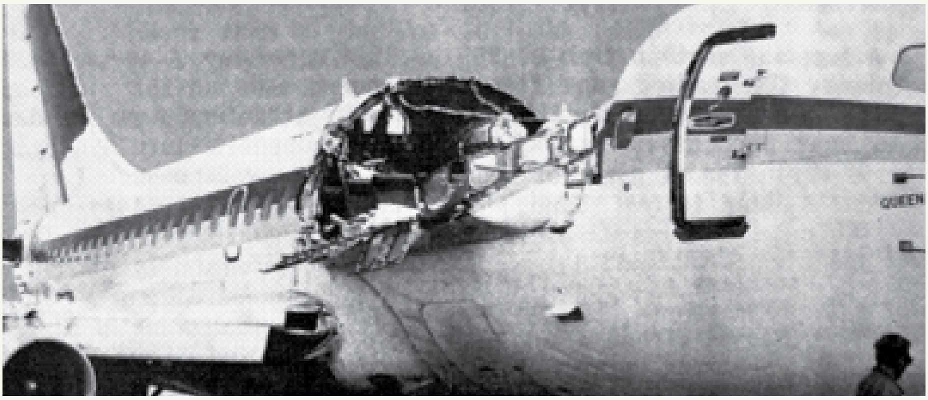
Aircraft now receive additional maintenance checks as they age. However, several other aircraft operating in similar environments did not exhibit the same phenomenon.

The NTSB investigation revealed that the most extensive and longer D-check had been performed in several early morning instalments instead of a full, uninterrupted maintenance procedure.

According to the official NTSB report of the investigation, Gayle Yamamoto, a passenger, noticed a crack in the fuselage upon boarding the aircraft before the ill-fated flight, but did not notify anyone. The crack was located aft of the front port side passenger door. The crack was probably due to metal fatigue related to the 89,090 compression and decompression cycles experienced in Aloha's short-hop flights.

How was it that the crack could be noticed by a passenger boarding the aircraft but had been missed by the engineer conducting the D-check?

The NTSB made a number of recommendations concerning the human factors aspects of maintenance and inspection for the continuing airworthiness of transport category aircraft, to include repair procedures and the training, certification and qualification of mechanics and inspectors.



source: NTSB Report Number: AAR-89-03

Vision

Vision is vital for engineers—think of the number of items subject to visual inspection. Vision can be improved by ensuring you have appropriate lighting to illuminate the work area, and ensuring that protective eyeware is clear and suitable for use. An individual's lack of colour discrimination, or defective colour vision, may make it difficult to distinguish between red and green, even with appropriate illumination. This can lead to error in tasks where colour discrimination is necessary, such as dealing with electrical wiring etc.

Hearing

Continuous exposure to high levels of noise can be very fatiguing. It affects cognitive tasks such as memory recall ('I can't think straight for all the noise!'). Whenever possible, you should try to remove or eliminate the source of noise, rather than attempting to reduce it by such things as wearing ear protection. Think about closing the hangar doors to remove external sources of noise, for example, but if you cannot prevent the noise, ensure that appropriate personal protective equipment (PPE) is used. In noisy environments, use appropriate communication headsets where possible, bearing in mind that ear plugs and headsets may restrict you from hearing warnings from other team members, or being aware of approaching hazards. If you are wearing headsets or ear defenders, exercise caution and keep a very good lookout.

Touch

Touch is a vital sensory input for the engineer, as components are often fitted and removed within very confined spaces, with limited visual cues. This means the engineer often has to rely on feel when fitting and/or removing components. Working in a confined space also increases the risk of error, because of reduced dexterity, lack of visibility, and limited space for tools and lighting. These tasks may also require the use of extensive PPE such as heavy gloves, which will reduce your sensitivity to touch.

Memory and its limitations

Memory is the ability to store and retrieve information, and is part of our normal learning process. It allows us to develop consistent responses to previously memorised data. We compare sensory data so that we can decide what to do, based on our previous experiences. Because of this, our memory stores are vital to the decision-making process. It is generally agreed we have three types of memory:

1. Sensory memory

Our sensory memory only retains information for a second or two; for example, an image or photograph may be retained briefly before it is overwritten by something new.

2. Short-term memory

Our short-term memory allows us to store information long enough to use it, hence why we often call it our 'working memory'. Short-term memory holds information for about 15–30 seconds. Think about when you are asked to remember a phone number without writing it down. Short-term memory has a recall limit of 7+/- 2 items.

Information in short-term memory can be lost very quickly through interference, distraction, or simply by being replaced with new information. Engineers often rely heavily on short-term memory, such as remembering a specific hydraulic pressure, or the tightening torque required for a specific retaining nut. This means that as an engineer you should always refer to a checklist or manual to make sure you do not over rely on perishable memory.

3. Long-term memory

Our long-term memory enables us to store a vast amount of information. It stores general information, factual knowledge, and memories of specific events. Long-term memory is classified as one of two types:

Semantic memory

Semantic memory is our store of factual knowledge about the world, such as learnt concepts and relationships (2+2=4). It does not relate to time and place, but rather refers to the rules by which we understand the things around us. This type of memory involves knowledge associated with data, skills, knowledge and things we are able to do for a purpose. It is our memory for meaning. It is generally believed that once information has entered semantic memory, it is never lost. Occasionally, it may be difficult to locate ('I can't remember') but it is always there.

Episodic memory

Episodic memory refers to our store of events, places and times, and may include people, objects and places. It is almost automatic, allowing us to place our experiences in context. If you asked people to tell you where they were, or what they were doing on 11 September 2000 when the New York World Trade Centre's twin towers were attacked, they could probably recall this from their episodic memory stores.

How can we improve our short-term memory?

Mental repetition One way to increase your ability to recall information from short-term memory is to revise it regularly to keep it top-of-mind.

Chunking This involves putting gaps between, or grouping, three to four letters or digits e.g. 345 237 9463. Chunks are much easier to remember than a long, unbroken string—3452379463.

Linking Link the data from short-term memory to something you know from your long-term memory; for example, you need to recall the following data from a piece of test equipment – 21..04..186..911. Your wedding anniversary is the 20th of the 4th, so the first four digits are recalled as the day after your wedding anniversary (21-4); the second three digits are the same as the engine in your first car (Holden 186) and the last three digits are the same as the date of the twin towers attack in New York (911).

Record the data The best way to be able to ensure accurate recall from short-term memory is to write information down for future reference.

How can we improve our long-term memory?

Think of the last time you could not remember something (e.g. a person's name), but a few hours, or even days, later you suddenly remembered it.

- **Pre-activate the knowledge**—think about the procedure before carrying it out. Go through it in your mind and mentally rehearse the steps you are going to perform.
- **Use visual imagery to learn new information**—information can be remembered by associating it with a familiar place or person. For example, to remember how to conduct CPR, think of it being acted out by somebody you are close to in a pleasant place, such as on a white sandy beach. This might sound a little out there, but visual imagery is a powerful memory aid. In general, the weirder or more bizarre the association, the more likely you are to remember it.
- **Use physical context**—you remember information better if you learn it in the actual place in which you will apply the skills. This is why learning emergency evacuation drills is better in the hangar than in the classroom, and why practising techniques using a maintenance simulator is more effective for knowledge transfer.
- **Ask questions**—do not just study material by re-reading it, but by asking yourself questions, so the information is more deeply encoded. For example, under what circumstances would I use this information? If I don't remember the information what could happen?

Information-processing characteristics

Our information-processing system is essentially a single pipeline where information goes in at one end (sensory input); is processed sequentially; and eventually comes out at the other end (as an action). The information is processed centrally and in the sequence it is received. This means that high-priority or important information may not necessarily be processed first.

All processing of information uses part of our limited capacity, so we can easily top out with information overload. In other words, we can take in only so much at any given time. New information can easily replace old information, particularly if the information is held in our short-term memory. Preoccupation, fatigue and stress can reduce information-processing capacity and therefore performance.

We tend to be most reliable under moderate levels of workload that do not change suddenly and unpredictably. When workload is excessive, the likelihood of human error is increased. High workload and times when a high volume of information must be processed in a short time can cause performance to decrease dramatically.

Managing human performance limitations

Senses

The senses can be affected by PPE (for example gloves), or by extremes of stimulus such as low light or excessive noise. Before you begin any maintenance task, you should consider how PPE might affect whether you complete the task successfully. Is the available PPE fit for purpose? Is the available lighting adequate for the task? If hearing protection is required, how will you communicate effectively with other members of the team?

Vision

Aircraft aviation technicians require a reasonable standard of eyesight and should wear glasses or contact lenses as prescribed. To ensure good eye health, have frequent eyesight checks. Colour discrimination is also important, especially if the tasks are to be performed in low or poorly lit areas. Above all, ensure there is adequate lighting—portable lighting or powerful torches may be required.

Hearing

Colds, flu and ear infections can affect our hearing capability. Generally, we have poor control over vestibular input (we can close our eyes, but cannot close our ears effectively). Use communication equipment such as headsets in noisy environments. Moving the aircraft to a more appropriate work area to avoid tarmac noise and for a more appropriate working area may be an option. Continued exposure to very loud noise leads to fatigue and therefore a higher potential for error.

Perception

Our attention mechanism is limited—once its capacity is exceeded, performance will degrade. It is important therefore, that physical and mental workload are maintained within reasonable levels. It can also be difficult to maintain attention for long periods on complex tasks. Think about scheduling appropriate breaks during the task, and ensuring workload is maintained at an appropriate level.

It is very easy for our perception to be fooled, for example through visual illusions. Our assumptions can also lead us to an incorrect perception. One example of this is carrying out an inspection. The engineer is normally checking to ensure that everything is correct. Because of this we can sometimes 'see what we expect to see'. In reality, we should expect to find something wrong, rather than simply checking that everything is as we expect it to be.

Poor assumptions played a part in the incorrect installation of a trim control cable on a Beech 1900, as outlined in the case study below:

Incorrect installation of trim control cable causes fatal crash

Colgan Air Flight 9446 was a repositioning flight operated by Colgan Air for U.S. Airways Express. On August 26, 2003, a Beech 1900D on the route hit the water 100 metres off shore from Yarmouth, Massachusetts, in the United States, shortly after taking off from Barnstable Municipal Airport in Yarmouth. The plane was bound for Albany, New York.

The NTSB summarised the accident as follows:

The accident flight was the first after maintenance personnel replaced the forward elevator trim cable.

When the flight crew received the aircraft, the captain did not address the recent cable change noted on his maintenance release. The captain also did not perform a first-flight-of-the-day checklist, which included an elevator trim check.

Shortly after take-off, the flight crew reported a runway trim, and manually selected nose-up trim. However, the elevator trim then travelled to the full nose-down position. The control column forces subsequently increased to 250 pounds, and the flight crew were unable to maintain control of the aircraft.

During the cable replacement, the maintenance personnel skipped a step in the manufacturer's airliner maintenance manual (AMM), and did not use a lead wire to assist with cable orientation. The AMM also incorrectly depicted the elevator trim drum, and the depiction of the orientation of the cable around the drum was ambiguous.

The maintenance personnel stated that they had completed an operational check of the aircraft after maintenance. The Safety Board performed a mis-rigging demonstration, which reversed the elevator trim system, on an exemplar airplane. An operational check on that aircraft revealed that when the electric trim motor was activated in one direction, the elevator trim tabs moved in the correct direction, but the trim wheel moved opposite to the corresponding correct direction. When the manual trim wheel was moved in one direction, the elevator trim tabs moved opposite to the corresponding correct direction.

The National Transportation Safety Board determined the probable cause(s) of this accident were:

The improper replacement of the forward elevator trim cable, and subsequent inadequate functional check of the maintenance performed, which resulted in a reversal of the elevator trim system and a loss of control in flight.

Factors included the flight crew's failure to follow the checklist procedures, and the aircraft manufacturer's erroneous depiction of the elevator trim drum in the maintenance manual.

- Ensure adequate rest—take breaks.
- Advise your supervisor and maintenance crew if stressed, fatigued or preoccupied.
- Confirm understanding when communicating critical information to or from others.
- Avoid distractions yourself and avoid distracting others.

Evaluation and decision making

Effective decision making for engineers starts with good situational awareness and a realistic assessment of the data and/or feedback. The next step is evaluating your available options and selecting and implementing the best/safest/most efficient option. This is not simply a one-off or stand-alone process, but rather a continuous cycle involving the updating of situational awareness, the evaluation of the appropriateness (or otherwise) of the decision, and coming up with, (and assessing) alternatives where necessary.

Memory

Because our memory is fallible, it is vital that we refer to the manuals/data etc. rather than relying on recall from memory. This applies even if the information to be remembered or recalled is relatively simple. If you are at all unsure of the memorised information, check it. Noting something down temporarily can avoid the risk of forgetting, (or confusing) information, but using personal notebooks to store this information long term is dangerous, as that data is not amended and can rapidly become outdated. Use appropriate checklists to help with tasks requiring a number of independent steps and mentally rehearse the task before you start—that will help you recall its individual task elements.

Actions and feedback

There is more chance of making errors if the task involves new steps. Error can also result from wrong perceptions of the available information or sensory input. To avoid this, carry out each task as if it were the first time, and before you start the task, mentally rehearse procedures and ask others how appropriate your plan is. If the task is difficult, or has an unusual and unexpected outcome, stop and review the situation and, where necessary, ask for help or clarification. Experience and regular supervision is also vital here in order to interpret feedback for engineers with limited experience, or those under training.

In the maintenance environment, incorrect actions or errors may not give instant feedback. Incorrectly torqued bolts or omitted locking devices may not provide feedback for months after the error. New tasks or incomplete feedback can lead to incorrect interpretation. To assess the feedback you have received accurately, you need an internal reference to a previously learnt standard.

For this reason, inexperienced personnel, or personnel under training, require high levels of guidance and supervision, as they may not have the required store of experience in their long-term memory to accurately assess the feedback received. Take the time to evaluate all feedback during a task, especially when the feedback is different to what is expected. Regrettably feedback on poorly conducted maintenance may take the form of a catastrophic failure. Sometimes the fault can lie dormant in the system for a considerable time. (For example, an incorrectly torqued nut may very slowly back off over time, eventually coming off completely.)

Situational awareness

What is situational awareness?

The simple view about situational awareness is that it basically involves paying attention to your surroundings. Commentators on the subject suggest that having good situational awareness allows us to respond faster to changing circumstances, by knowing what is going on around us and predicting how things will change.

From the aviation maintenance perspective, we can define situational awareness as: ‘the accurate perception of the factors and conditions affecting the safe operation of the maintenance activity, now and in the future’.[20]

20 ADF Maintenance Human Factors Foundation Course (AL1) 26 Nov 2009.

Consider the following example:

You have completed installing a component in an aircraft. The final steps include performing a function test in accordance with the manufacturer's manual. This is fairly straightforward. It requires applying hydraulic pressure, and testing the functionality of the component by moving the flight controls. However, other maintenance activity is going on in the area where the flight control will move. If you were to ask those working in that area to stop what they are doing, not only would you interrupt their work and potentially induce human error on their part, you would also cause delay to the overall maintenance check.

A quick assessment and brief discussion with those working in the area determines you can carry out the test safely *after* the other engineers' work is complete.

As a precaution, you also decide to write it up in the logbook to ensure the test is safely completed, and in case you are interrupted.

Developing situational awareness

To develop situational awareness throughout a task, maintenance personnel must:

- Start off with a full and accurate knowledge of the system's current state and the environmental status
- Consider what they intend to do, and in particular, how appropriate that is in the given circumstances
- Think about how what they intend to do will affect or change the environment and other personnel working around them.

what has happened;
what is happening;
and what might happen.

Maintaining situational awareness

Once you have an adequate level of situational awareness, the challenge is to maintain it. We maintain our situational awareness through constantly comparing the facts with our understanding. Effective communication allows for the continual update of understanding and the ability to check this understanding against up-to-date information. It is also the best tool to check individuals' understanding against that of others, an essential for identifying degraded situational awareness (between individuals and teams).

If it feels wrong it probably is!

If you feel that something is wrong …

- Stop and review your actions
- Think about how your actions may be affecting the current system status (for yourself and others around you)
- Consider the possible adverse consequences of continuing.

Loss of, or degraded, situational awareness has been a major factor in many maintenance incidents and accidents. How do you know when your situational awareness is degraded? Here are some common clues:

- Ambiguity or confusion
- Narrowing of task focus
- Reduced frequency of, or poor, communication
- Feeling rushed
- Unexpected results
- Increasing anxiety
- Use of undocumented procedures
- Violations.

Distractions, unexpected events, and schedule pressure are all factors that reduce situational awareness. Unfortunately, these are commonplace factors in maintenance. An inspector and mechanic reported on the chain of events that contributed to a main gear tyre hubcap departing a B737-700 aircraft, as shown in the following case study:

Interruption and distraction at root of incident

The inspector's report read as follows:

I was the inspector for the right wing and right main gear. A mechanic changed the no. 3 main tyre, but left the hubcap loose. There were many factors contributing to this, including: moving the aircraft in the middle of the job; the mechanic working on the tyre was called for a drug test during the job; and a general hurried atmosphere. The mechanic signed off the job card and so did I. I did a walk-around after the tyre change, but did not find that the hubcap was loose. The aircraft made two flights before the no. 3 hubcap came off.

The mechanic's report read as follows:

I changed three main gear tyres, nos. 1, 3, and 4 on a B737-700 aircraft. We started with no. 4, was finishing up on no. 4, then I started on no. 3. After putting on the tyre I put the hubcap on with the three bolts, but I didn't have any tools, so I got up to get some. I decided to move the tyre over by the table on which the other tyre was leaning. When I did, the table moved and both tyres fell over, so I got someone to help me pick them up. After moving them to a better location, it was time to swap the aircraft with a hangar line overnight aircraft. After swapping the aircraft, the hangar supervisor came and got me for a random drug screening. When I got back, the tyre was done. I do not recall ever going back to tighten or safety the hubcap. The next day they found a hubcap on or near the runway, and after determining it was from an aircraft, started looking for the aircraft that had lost it. They found the aircraft that was missing the no. 3 hubcap.

When inevitable work interruptions occur, a mechanic usually has the option of noting on the job card or write-up that the job is unfinished ('hub cap in place, not tightened'), or tagging the part to increase situational awareness.

Could an incident like this happen to you?

How do you handle interruptions and distractions in the work environment?

Adapted from *Aviation Human Factors Industry News,* Volume VII, Issue12, 1 April, 2011

Recovering from a loss of situational awareness

Recovery from a loss of, or degraded, situational awareness is vital to maintaining a safe operating environment. Recovering situational awareness is a deliberate process involving checking and seeking information from other team members, or someone independent of the task.

To recover from a degradation or breakdown in situational awareness, consider the following strategies:

Communicate	Communicate the elements of confusion or discrepancy with others in the team, or your immediate supervisor.
Request assistance	This can be essential when conformation bias has greatly decreased the ability to review the situation accurately.
Stop, and review your steps	Discussion should centre on the value of retracing steps to a known 'good' state of situational awareness. It can be difficult to update your understanding while trying to complete the task.
Debrief/discuss what happened	Lessons learnt provide valuable information to prevent others from repeating the mistakes.

Key points

- Human beings basically process information in five stages:
  - Stage 1: Gathering information
  - Stage 2: Perception or assessment stage
  - Stage 3: Evaluation and decision making
  - Stage 4: Action/response
  - Stage 5: Feedback
- However, in the maintenance workplace, incorrect actions may not give instant feedback. Under-torqued bolts or omitted locking devices (split pins etc.) may not provide feedback for months after the error.
- Having appropriate lighting, and ensuring that PPE such as protective eyeware are clear and suitable for use, can improve visibility.
- High workload, and situations when a high volume of information must be processed in a short time can cause information overload. This may decrease performance and increase the likelihood of error.
- Continued exposure to very loud noise leads to fatigue and therefore to a higher potential for error.
- Short-term memory is our 'working memory'. It is a finite resource and has an item recall limit (seven items, plus or minus two). Information is easily lost through interference from new information.
- Long-term memory stores information that has previously been learned or used as general, factual knowledge.
- We tend to be most reliable under moderate levels of workload that do not change suddenly and unpredictably. When workload is excessive, the likelihood of error increases.
- From the aviation maintenance perspective, situational awareness can be defined as 'the accurate perception of the factors and conditions affecting the safe operation of the maintenance activity, now and in the future'.
- We maintain our situational awareness through the constant comparison of facts against our understanding. Effective communication is vital to ensure an adequate update of information as new information is received.

Further information

Endsley, M.R., & Robertson, M.M. (2000): ‘Situation awareness in aircraft maintenance teams’, *International Journal of Industrial Ergonomics*

The Australian Transport Safety Bureau (ATSB), Aviation Research and Analysis Report – AR-2008-055, titled ‘An Overview of Human Factors in Aviation Maintenance’ by Alan Hobbs Ph.D, December 2008.

The United States Federal Aviation Administration has a large library of documents on aviation maintenance human factors (including - Operator’s Manual for Human Factors in Aviation Maintenance). These publications can be accessed through the FAA’s maintenance human factors website below.

ICAO has published two educational documents on maintenance human factors: *Human Factors in Aircraft Maintenance and Inspection* (ICAO Digest 12,1995) and *Human Factors Guidelines for Aircraft Maintenance* (ICAO Doc 9824, 2003).

The European Aviation Safety Agency (EASA) Part -145 includes human factors requirements for maintenance organisations. The guidance material and acceptable means of compliance documents also specify how the intent of the EASA regulations can be met.

The United Kingdom Civil Aviation Authority (CAA) has published a number of documents covering aviation maintenance human factors. These include CAP 716, Aviation Maintenance Human Factors, (EASA/JAR145 Approved Organisations), Guidance Material on the UK CAA Interpretation of Part 145 Human Factors and Error Management Requirements and CAP 718, Human Factors in Aircraft Maintenance and Inspection, (previously ICAO Digest No. 12).

Websites

Aviation Human Factors Industry News www.decodinghumanfactors.com/current-newsletter

The Human Factors on Aviation Maintenance and Inspection (HFAMI) web site www.iasa.com.au/folders/Safety_Issues/others/maintsnafu.html

Royal Aeronautical Society Human Factors Group www.raes-hfg

Neil Krey’s CRM Developers Forum www.crm-devel.org

Federal Aviation Administration (FAA) hfskyway.faa.gov

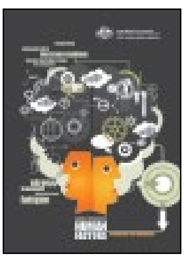
International Civil Aviation Organization (ICAO) www.icao.int

European Aviation Safety Agency (EASA)www.easa.eu.int

Transport Canada www.tc.gc.ca

United Kingdom Civil Aviation Authority (CAA) www.caa.co.uk

United States Air Transport Association (ATA) www.airlines.org



When you are ready, please turn to page 19 of the *Workbook for Engineers* and complete the exercises.

© Gregor Schlager / Lufthansa Technik AG / 2002

© Lufthansa Technik AG

© Lufthansa Technik AG


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 4

DECISION MAKING

Why is effective decision making so critical in aviation maintenance? It is important because the maintenance environment presents so many challenges for engineers. Engineers often have to work with different types of equipment, processes and personnel. They must deal with routine and non-routine tasks, and regularly work within controlled schedules and ever-present deadlines. Their work involves dealing with people within their own organisation, suppliers and contractors, and in some cases, directly with the customer. These conditions can sometimes lead to poor decisions, resulting in compromised safety.

In a moment of decision, the best thing you can do is the right thing to do. The worst thing you can do is nothing.

Theodore Roosevelt, American president

Introduction

Decision errors are not slips or lapses but can typically be classified as mistakes. In other words, the problem wasn't a failure to execute a correct course of action, but rather selecting a wrong or inappropriate course of action in the first instance. A plan proceeds as intended, but proves inadequate or inappropriate to the situation at hand.

Human Error (Hooey & Foyle, 2006)

Decision Error
42%

Action Error
35%

Information Error
23%

This chapter provides various tips and techniques to help you make better decisions when carrying out maintenance. Decision making is a process of making a judgement, or selecting an option to resolve a situation. There are skills you learn that are so well practised (e.g. operating a familiar piece of equipment, or driving your car) that they are highly resistant to wrong decisions, although this resistance can be broken down if you are fatigued or under high levels of stress. For example, fatigue may reduce our ability to anticipate risk when driving. However, there are many decisions that we have to make that are non-routine and unexpected.

Decision making can fall into two distinct types that occur depending on the circumstances. These can be described as intuitive (or naturalistic) decision making and analytical decision making.

Intuitive/naturalistic decision making is common with familiar tasks and often involves a certain level of automation – particularly when confronted with a well-known or well-rehearsed scenario. Intuitive/naturalistic decision making is commonly employed by experts. Decisions are based on recognition of similar past events, decisions and solutions with a 'IF this happens THEN I do that' relationship. For example: Maintenance engineers often use intuitive/naturalistic decision making when initially diagnosing a fault. At the basic level the maintenance engineer will consider- have I seen this fault before? – Do I have a solution in memory?

Analytical decision making occurs when we are confronted with an unknown or novel situation. We enter into a more time-consuming process, involving gathering data and more detailed evaluation of the various options. This process may involve a level of 'trial and error' and therefore careful consideration of possible consequences must be included.

Decision-making process

In decision making (and especially in analytical decision making) there are arguably several distinct steps. As with any process, recognising these steps and knowing what they achieve can help to evaluate your own decision making and identify ways to improve your performance.

Accurate situational awareness is the basis for effective decision making

Step 1: monitoring the system/situation to identify if/when it requires an input or correction

Accurate situational awareness allows you to know when the situation/system requires an input or correction. A combination of knowledge, experience and vigilance means you are aware of a problem requiring a decision – to act or to change your action. This may be to maintain safety or achieve your desired goal or end state.

Step 2: gathering all relevant data.

Gathering all information relevant to the problem or decision to be made gives a good understanding of influences affecting the system or environment, so that you can learn more about the situation and look for possible causes and solutions. This step may mean collecting files, calling stakeholders, or group brainstorming. For effective data gathering you must know what data is accurate and whether it is relevant. It is impractical to review all the available data in depth.

Note: Be careful of 'confirmation bias'. This is a normal human response. When deciding on a course of action we may look for information that supports how we see a situation, instead of analysing data that may show our perception does not apply to the current circumstances. Look for, and evaluate, **ALL** relevant data, **ESPECIALLY** if it may contradict the current perception of the environment/circumstances.

Ask: Where did the information come from? Does it represent various points of view? What biases could be expected from each source? How accurate is the information gathered? Is it fact or opinion?

Step 3: evaluating available options

Evaluating options should include team discussion, generating a solution/s and assessing risks (likely consequences of any action). Remember the possible influence of group think and review as many options as practicable.

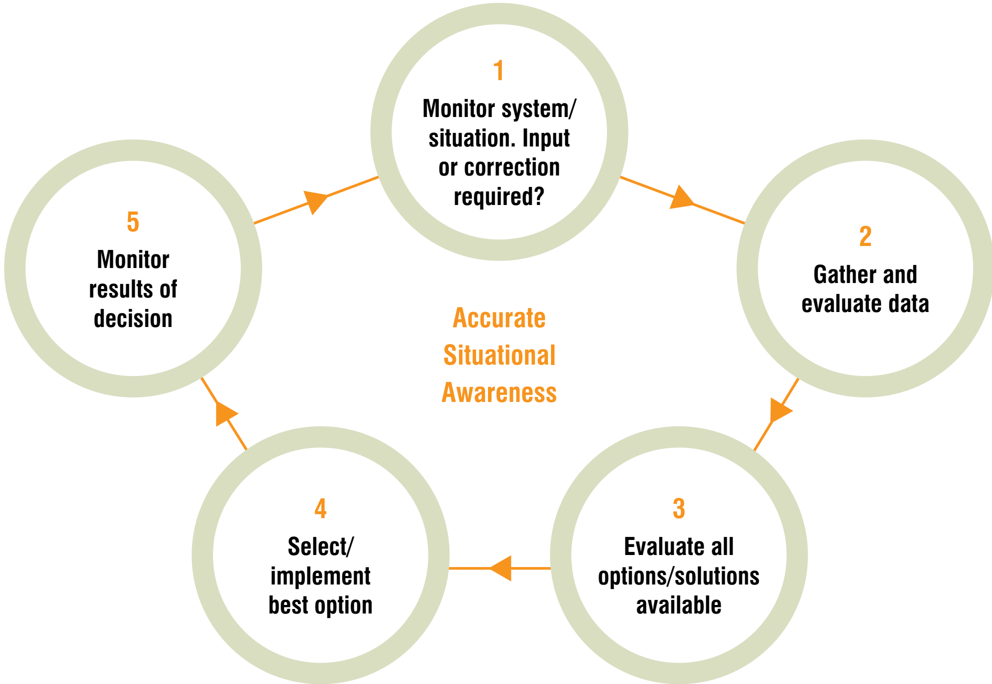
Step 4: selecting and implementing the best option

This involves defining the criteria: including the best/safest/most efficient option for the desired goal, taking into account the risk assessment and whether the decisions/actions are within regulations and/or people's authority levels.

Step 5 (and final step): monitoring the initial results of the decision

Once the result of your decision becomes evident you need to evaluate its appropriateness and adjust accordingly. This may involve a continuous process of observing, evaluating and adjusting, as in the diagram on the following page.

Note: The last step can also be viewed as the re-start of the decision-making cycle, but having it as a distinct phase can reinforce the need to actively monitor the results of decision.



A sample decision-making process.

Factors influencing decision making

Engineers are often confronted with unexpected situations when maintaining aircraft. Few industries have more constant pressure than aviation maintenance to get jobs done on time. Various influences can shape the effectiveness of our decision making, such as our knowledge and experience, communication effectiveness (to gather information), stress, time pressure and fatigue.

- Previous experience and knowledge will shape the extent to which individuals are able to know what information or feedback is relevant and how to make sense of it (see perception and assessment in chapter three).
- The quality of communication used in order to gather information and inform your decisions will also affect the quality of your decision-making.
- Fatigue will be discussed in a later topic but, stated briefly, fatigue can affect cognitive performance; reducing the ability to fully process all available information and increasing the possibility that essential information is missed.
- Stress and time pressure may encourage individuals or teams to 'grab' at the first solution that comes to mind, without looking at either potential consequences or other possibilities.

While we may have the right intentions, sometimes we make poor decisions that can lead to undesired results, such as a delay, damage or worse. Engineers need to be aware of the limitations and biases that may influence their decisions in the selection of particular options, especially during challenging circumstances, these can include:

- A tendency to give more weight to early evidence as opposed to information gathered later
- Not extracting as much information from a source as is possible
- Treating all information as if it were equally reliable, even though it may not be
- A limit to the number of hypotheses that can be considered at a time
- A tendency to focus attention on a few pieces of information only
- A tendency to seek information that confirms an already favoured choice of action, and ignoring information that may discount it, (confirmation bias)
- A belief that mildly positive outcomes are more likely than mildly negative ones
- A corresponding belief that highly negative outcomes are less likely than mildly negative ones.

How do individuals and teams make effective decisions?

- Good situational awareness is required to identify and clarify any problems or decisions to be made.
- As much information as possible relevant to the problem or decision to be made must be gathered, to ensure the best understanding of the system or environment's state.
- Personnel must be careful not simply to look for information that supports more favoured courses of action. Instead, also look for any information that does not support them.

One of the key challenges maintenance engineers face when making decisions, which may have wider impact on other maintenance activities or systems, is having the correct information when those decisions need to be made.

Knowing the limitations and biases that we are all subject to will help maintenance engineers to critically consider the accuracy of information, alternative courses of action, and their implications.

> 'A good decision outcome does not necessarily mean that a good decision process was used'[21]

Often, an engineer may be questioned by a supervisor, manager, or even a customer, as to what they think might be causing a defect. This brings judgements based on the engineer's own knowledge and previous experience into the decision-making process. If they allow their judgement to be influenced by external factors, such as pressure or input from their peers, or do not reference their judgement against procedures and approved data; the decision-making process can be susceptible to 'drift'. This drift occurs when individuals, with all the limitations and biases listed above, do not analyse the situation properly and base their decision-making process on previous events where a desired outcome was achieved, even though incorrect decisions might have been made.

The following case study illustrates the problem of drift.

[21] Decision making for single pilot helicopter operations- European Helicopter safety team-June 2012

Good intentions, wrong repair

Every engineer has seen it, and has had to decide what to do about it. They come in every size, from small and immaterial to large enough to put an aircraft out of service for several days. Of course, whether it is from FOD (foreign object damage) or bird strikes, we are referring to the common problem of 'dents'.

We have manufacturers' repair manuals to help us deal with the problem of dents— whether it is a 'must-fix' or whether we can just leave it alone. That, however, is where the problem lies; the dilemma of to fix or not to fix? After years of working on an aircraft type, an engineer can decide within a glance whether to deal with a dent or leave it alone. However, the decision is made that much harder when there is a quick turn-around of an aircraft full of passengers, and you have to make a decision about what to do. Your decision could mean grounding the aircraft, inconveniencing the customer, and possibly playing havoc with schedules.

Take, for example, a recent dent to a Boeing 737-300 #1 engine nose cowl. The aircraft arrived at the gate and during the walk-around the engineer noticed the dent to the nose cowl. Taking measurements, he recorded it, and then checked the log book to see if it had previously been written up and deferred. Finding nothing previously noted, the maintenance engineer investigates further; pulling out the structural repair manual, he checks and finds that the dent is outside of limits, and will need to be repaired before further flight. The maintenance engineer advises his supervisor.

Now the problem is in the hands of the supervisor. Unable to defer the dent any further, because the repair manual says it must be fixed, the supervisor heads to the aircraft to see for himself.

The maintenance engineer meets the supervisor at the aircraft and shows him the dent, giving the supervisor the manual, which allows him to see the allowable limits for himself. Because the dent is out of the limits shown in the manual, the supervisor has to do some quick thinking. He knows the aircraft is due to leave within the hour.

Looking up, he can see that passengers are already boarding the plane. The supervisor notices that the dent is deep, but not wide and that that is what is going to cause the limitation problem. The supervisor then suggests that if the dent was wider; it would be within limits to fly before a repair is needed. The supervisor makes his idea known to the engineer, and then makes the suggestion to the engineer to enlarge the dent.

This is a problem for the engineer, who is dedicated to fixing problems, not to damaging aircraft! What does he do? Stick to what he knows is right, or take part in creating further damage to the nose cowl? The engineer politely refuses to do what the supervisor requests.

The supervisor is starting to run out of time, so he hurriedly obtains a rubber mallet and a 2x4 piece of wood. Aligning the 2x4 over the dent, he pounds with the mallet on the piece of wood. After several hits, the dent is now wider than it is deep, and measuring it, he decides that the size is now legal to defer.

While this is going on, passengers have been watching this impromptu repair. Also watching are several engineers and other supervisors. Returning to the building, the supervisor signs off on the engineer's write-up stating that the dent is actually within allowable limits.

Now did the supervisor take into account possible hidden damage on the inside of the nose cowl? Did he take into account the fact he was deliberately causing further damage? Did he take into account the impact of his actions on the people watching, both on the ground and on the plane? Did he endanger the lives of the passengers? The plane departed and no further incidents were noted, but does this mean that the right decision was made?

What are the key lessons from this incident?

- Always remember that your actions may be on public display
- The limitations stated in approved manuals should always be applied as they are and not be interpreted differently by increasing the damage to the aircraft to change the limitation
- We are often measured by our ability to meet a deadline, but we must always consider safety first
- Our decisions should be made based on complete and accurate (approved) information, so that we can take into consideration the full effects of those decisions.

Reproduced with permission from Stuart Hughes

Few industries have more constant pressure to see a task completed than aviation maintenance

Managing uncertainty

Decision making relies on an accurate understanding of the relevant workplace environment and task conditions (situational awareness). However, as has already been said, aviation is a complex environment, with competing commercial, task and safety demands, strict regulations and organisations highly dependent on one another. Aircraft maintenance engineers often have to manage a high level of uncertainty in workload, timeframes for the required outcomes, and resource availability.

Dealing with this uncertainty in aviation maintenance requires careful attention when making any decisions that could affect the safe completion of maintenance or the operation of an aircraft. In order to deal with the complexity of the maintenance environment, maintenance personnel should focus on identifying:

- 'Are the present conditions drifting towards the boundaries of safe operation?'
- 'What conditions are within my ability (or authority) to influence?'
- 'Regardless of organisational stresses and conditions, what do I need to do to ensure the safety of aircraft that I, my colleagues, or my organisation work on?'

So, if there is insufficient information to make an informed decision on the serviceability of an aircraft or system, the only way to manage the uncertainty is to seek more information and not assume anything. Even if an aircraft system, component or tooling is 'just outside of tolerance' it must be rectified, replaced, adjusted or placed inoperative.

Uncertainty in maintenance should only involve areas such as variations in upcoming workload or how to manage resources, personnel and timeframes for safe completion of tasks; not the serviceability of aircraft or components, or an increased risk they could degrade or fail before the next service or inspection.

How can we consistently make better decisions under the normal pressures of work?

- Assess timeframe — what REALLY is the time available?
- BEWARE OF BIASES — if a task is time critical you cannot afford the time for a wrong decision!
- Fix a decision deadline — is a solution available SAFELY within the evaluated timeframe?
- Prioritise tasks — what MUST be done? — What could be done if the time is available etc?
- Manage workload — ensure that workload is realistic and evenly distributed
- Keep everyone in the loop — communication is essential; remember, goals must be defined, roles and responsibility clearly outlined and feedback sort.

Based on the preceeding steps, when you select what you believe to be the most appropriate course of action or decision, take a few moments to play your own 'devil's advocate' to look for reasons why it may be wrong. Ensure you continue to evaluate the outcome of the decision. Continued observation and adjusting of actions may be required to ensure its effectiveness.

The role of planning and preparation in improving decision making

Most aircraft maintenance activities involve either performing inspections or repairing and replacing unserviceable assemblies. During this maintenance not all scenarios can be expected and planned for, but often maintenance activities do involve some prior knowledge of what will be required, whether it is parts, materials, tools, equipment or facilities. Often combinations of many of these will be required during the course of maintenance activities.

Failure to plan is planning to fail

Winston Churchill

Planning of tasks, equipment and spares

Planning is critical to making good decisions. It ensures there are adequately qualified and alert personnel, tools, equipment, material, maintenance data and facilities at the right place, at the right time, for the scheduled and, (as far as is possible) unscheduled tasks. Indeed, CASR Part 145 states that an organisation may only maintain an aircraft (or aircraft components) when all necessary facilities, equipment, tooling, material, maintenance data and certifying staff are available.

Planning should therefore extend to having knowledge about what relevant resources are available, in case they are required. Decisions made in a maintenance environment may be influenced by access to replacement parts and support equipment, or at least being able to obtain them in a timely manner. Engineers sometimes find that a part may need further attention, but may decide to defer it, especially if they knew a replacement is not readily available.

Remember the resource component of PEAR? Making a thorough consideration of resources part of your planning and preparation can help to support good decision making by increasing timeframes for getting parts and equipment and reducing the pressure of trying to organise them in the middle of a task.

Sometimes engineers may find themselves in a situation where task completion is perceived as the prime objective, but a lack of required supporting data, facilities, tooling and equipment may mean it is not possible to complete the task by the book. In these situations, violations or workaround are more likely to occur, particularly when manufacturers' required spares are not available to perform the task. Routine violations may become the norm within an organisation, or even the habits of an individual, usually because people believe that the rules are too rigid, or unnecessary. These routine violations typically occur during the performance of simple maintenance tasks.

The following case study illustrates the danger of deciding to employ workarounds.

Lack of resources … not a problem

When the flight crew of a B747 passenger aircraft checked in for their evening's flight, they were informed that there was a known problem with the 4L main entry door, but the engineers responsible were confident that the aircraft would be declared serviceable at or near the scheduled departure time. This proved to be the case and the aircraft's flight engineer checked the door for satisfactory operation himself. Due to a recent history of problems with this door, the cabin crew stationed at the door were briefed to monitor it after take-off and keep the flight deck informed of any changes.

Shortly after take-off, during the initial climb to cruise altitude, the door handle moved from the 3 o'clock closed position to the 1 o'clock partially-open position. Then nominated cabin crew notified the flight deck, and as a precaution the crew decided to return to the departure airport.

During pressure testing on the ground, engineers found that the door handle moved towards the unlock position. After comparison with another door, they discovered that the upper torque tube had been replaced recently during troubleshooting for a previous defect. It was discovered that the upper torque tube had been drilled in such a way that there was an incorrect angular relationship between two sets of holes in it. When the replacement torque tube was compared with the failed one, it was found that the axis of the bell crank bolt holes had been drilled with approximately 18 degrees of circumferential displacement from their required correct position, resulting in the door being rigged incorrectly.

The first report of problems with the door had been made several days earlier, and resulted in the discovery of a broken torque tube and latch crank. A replacement tube and crank assembly were ordered. There was a shortage of certifying staff and an appropriate licensed aircraft maintenance engineer (LAME) had to be called in on overtime. When the LAME arrived at 2100, he was briefed by the shift lead. The new torque tube arrived at 0030, and was found to be 'undrilled'. The aircraft maintenance manual called for a drill jig, which allows for the holes to be drilled precisely. However, the drill jig was not available, and the machining workshops were closed for the night. The LAME and the shift lead decided to drill the tube in the local hanger workshop due to time constraints and the operational requirements for the aircraft. Rigging of the door began at approximately 0230 and continued for three hours. The team was fatigued by this time, and so the decision was made to hand the task over to the incoming day shift.

Reproduced with permission from Stuart Hughes

As the day shift LAME was not available, a verbal handover was made to one of the two available day shift AMEs assigned to complete the task. Later, another qualified LAME was tasked with coordinating the activity on the door in addition to his other work. The door was later inspected by the LAME, who considered that all the aircraft maintenance manual requirements had been met. The door was then reassembled, and the aircraft was released for service at 1700 the next day.

However, there were continued problems with the door, culminating in the incident. When the drilling error became apparent, another torque tube was obtained and drilled off in the machine workshops using a vertical milling machine. The door was subsequently reassembled and rigged with no problems. The aircraft was returned to service with no further door problems since being reported.

The major lesson to be drawn from the above incident is that a lack of time or resources can lead to poor decisions and workarounds.

Consider the following scenario:

During a routine inspection you discover a control linkage rod-end is worn and has significant free play. This type of linkage is prone to wear on this type of aircraft, hence the regularity of the specific inspection. A check of the limitations in the manufacturer's manual indicates it is at the limit of (but still within) allowable wear. Knowing the aircraft will be operated extensively after your check, and considering it is at the limit after a second check, you decide to replace the part.

After checking with the hangar storeman, you discover this part is not in stock, and a replacement is a week away. Considering that when checking the wear twice it was at the allowable maximum and a replacement is not available, you now change your mind.

Is this your preferred decision?

Referring back to dealing with uncertainty, what else could you do?

Going back to the questions you could ask yourself:

- 'Are the present conditions drifting towards the boundaries of safe operation?'

You could gather more data on proposed aircraft usage, wear rates and system tolerances to assure yourself that it will remain functional until a replacement is available.

- 'What conditions are within my ability (or authority) to influence?'

You cannot get a replacement part so you can either accept the present condition of the component or place it unserviceable. In deciding which option to take ask yourself:

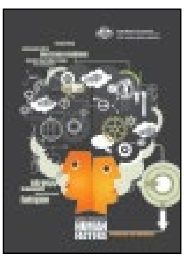
- 'Regardless of organisational stresses and conditions, what do I need to do to ensure the safety of aircraft that I, my colleagues, or my organisation work on?'

In answering this question; if you can state that the component is still within tolerance and will be operated under normal conditions, while it might have been beneficial to replace it at the present time, the aircraft will still be operating within safe boundaries until a replacement is available.

This would reduce your level of uncertainty and ensure that you had made a fully informed decision based on as much information as possible and considering all of the possible consequences.

Key points

- Decision making is a critical skill in aviation maintenance.
- The process of decision making includes: defining the problem, considering the options, selecting and implementing the options available; and reviewing the outcome.
- The need to make a decision to address a problem or unexpected situation can bring with it added situational issues, such as stress and time pressures.
- Decisions should be informed, that is they should be made based on all the required information available.



When you are ready, please turn to page 27 of the *Workbook for Engineers* and complete the exercises.


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 5

FATIGUE

Fatigue is a threat to aviation safety because it can have a negative effect on performance. Perhaps one of the most insidious aspects of fatigue is that when we are fatigued, we are often unable to recognise that we are fatigued, that our performance is deteriorating, and that we should act accordingly. For engineers, who are often shift workers, fatigue is an important issue. We use the word fatigue all the time, but what exactly does it mean? This chapter looks at the symptoms of fatigue, its effects and some strategies for managing it.

Fatigue cannot be prevented by personality, intelligence, education, training, skill motivation, size, strength or professionalism.

Ron Heselgrave

What is fatigue?

We use the word fatigue all the time, but what exactly does it mean? There are several different meanings of the word:

- Tiredness after hard physical work
- Emotional fatigue
- Short-term effects of intense concentration on a task
- An overwhelming need to sleep.

This chapter deals mainly with the last type of fatigue. As we will show, fatigue can have a major effect on your safety and the quality of your work when you are maintaining aircraft.

We can distinguish between two types of sleep-related fatigue:

- Acute—this is generally only short term and can be remedied with a good night's sleep
- Chronic—a longer-term problem, as there is usually a build-up of sleep deprivation.

Fatigue can act like a toxin accumulating in our body. We can generally deal with a small amount of it, and work it out of our system by catching up on a night's sleep, but chronic fatigue accumulates and can have increasingly dangerous effects.

Case study

The maintenance was AOG* and was carried out and completed in a straight 36-hour shift. The aircraft was expected to be on line first thing in the morning and no back-up aircraft was available. At about 5.30am, a ground run was carried out with no defects evident. The aircraft was then released for a maintenance flight, which was uneventful. On the post-flight release to service, a rag was found caught on the main driveshaft and had shredded itself by about 50 per cent, hitting the aircraft structure during the flight. I was very tired and failed to notice the rag before the ground run and the maintenance flight. No company policies were in place regarding working periods.

Incident report

* AOG = aircraft on ground: the aircraft could not be flown until maintenance complete

The effects of fatigue

One obvious hazard of fatigue is that the fatigued person loses the fight to stay awake while at work. Clearly this is most dangerous when the person is operating equipment or driving a vehicle. A sleep episode can take the form of a microsleep, which is a brief moment (generally between two and thirty seconds) when the person starts to enter the first stage of sleep, possibly with their eyes still open, sometimes for less than a few seconds before regaining consciousness. The person is typically unaware that they have experienced a microsleep, and may continue to perform simple repetitive tasks while asleep. When truck drivers volunteered to wear sleep-monitoring equipment while they worked, researchers were amazed to find that some drivers were showing signs of the first stage of sleep while driving on interstate highways[22].

Sleep deprivation can produce effects very similar to those produced by alcohol. An Australian study found that people who were given a simple vigilance task in the early hours of the morning, after being continuously awake for 17 hours, performed as badly as if they had a blood alcohol concentration of 0.05 per cent. Seven or more hours of wakefulness can produce impairment similar to that produced by a blood alcohol concentration of 0.10 per cent[23]. In other words, conducting a complex maintenance task when you are fatigued is like drinking on the job.

Think about it!

Consider these two imaginary scenarios:

Scenario 1

You are about to take your first parachute jump. You are handed your newly packed parachute by your instructor, Bob. He proudly tells you that he has just prepared your chute for you. You notice that Bob is leaning a little unsteadily on the rigging table. You also smell alcohol on his breath. When you ask Bob about this, he shrugs and tells you that he always likes to have a few shots of vodka to steady his hand before he starts rigging chutes.

Scenario 2

You are about to board a Cessna 172 for a brief flight. The aircraft has just come out of major maintenance. You speak with your colleague, Jim, who is also a LAME. He is normally a cheerful and talkative person, but on this day he has bags under his eyes and does not have much to say, except that he is looking forward to going home and having a good sleep. He tells you he has just worked 24 hours straight and is exhausted. He says his last job was a routine task, but for some reason he had trouble focusing on it. This last job involved replacing the aileron control cables on the aircraft you are about to board.

Is there a difference between these two scenarios?

22 Mitler, M., Miller, J, Lipsitz, J, Walsh, J and Wylie, C (1997). *The sleep of long-haul truck drivers*. The New England Journal of Medicine, 227, 11, 755-761.

23 Dawson, D & Reid, K. (1997). *Fatigue, alcohol and performance impairment*. Nature 388, 17 July, 235.

The above scenarios suggest that the performance of both Bob and Jim is impaired, the difference being what has caused that impairment—alcohol or fatigue. Just like someone who is intoxicated, if you are fatigued you will react more slowly, have trouble paying attention, be prone to memory lapses, and can show impaired judgment. You may also become withdrawn and uncommunicative. Boring tasks requiring close attention (such as some inspection jobs) are most affected by fatigue. Just as a drunk person may think they are sober, fatigued people often don't realise just how impaired they are.

Society does not tolerate drunk drivers or intoxicated workers. There is increasing awareness that the impairment resulting from severe fatigue is also no longer acceptable in safety-critical environments such as aircraft hangars. Therefore, there should be no difference in the way we view and take action on the behaviour of Bob and Jim described above—both are unsafe.

The effects of fatigue on performance are summarised in the table below:

Effects of fatigue

Performance category	**Effects**
Attention: reduced	Leave out steps in tasks
	Preoccupation with single tasks or steps
	Tunnel vision, less likely to notice the unexpected
	Less aware of poor performance
	Concentration requires more effort
Memory: diminished	Poor memory for tasks completed or underway
	Forget to perform task steps
	Revert to 'old habits'
	More likely to forget to return to interrupted tasks
Mood: withdrawn	Reduced communication
	More irritable, frustrated by minor difficulties
	Temptation to shortcut tasks
Reaction time: increased	Slower to notice problems
	Less smooth control of equipment or vehicles

Adapted from: *Graeber, R. C. (1988) 'Aircrew fatigue and circadian rhythmicity'. In E. L. Wiener and D. C. Nagel (Eds.).* Human Factors in Aviation*, pages 305-346. San Diego: Academic Press.*

Fatigue can affect all maintenance tasks, whether it is because of impaired judgement, difficulty in focusing attention, or other performance deficiencies. Two common types of fatigue-related errors in maintenance are:

- Memory failures

  Fatigued engineers are more likely to forget to perform routine actions, such as replacing oil caps and are more susceptible to distraction and resulting memory lapses.

- Failures to notice defects or problems

  Fatigued engineers have more difficulty detecting defects during inspections, and may be less likely to notice problems in their own work, or the work of others, as a result of inattention or poor concentration.

The reduced performance caused by fatigue imposes a burden on the aviation industry not only in terms of flight safety, but also in financial costs through delays, the need for re-work, and other inefficiencies. For example, an air turnback of an airline aircraft caused by a relatively simple error such as a gear lock pin left in place, as outlined on the next page, can cost tens of thousands of dollars.

Case study

As the wing upper forward mount bolts and nuts were being torqued, the torque wrench being used broke. Another torque wrench was obtained, but it was noticed that it was out of calibration. Myself and the technician who was performing the work discussed this and rationalised that 'it was only out of calibration by a month or two'. We decided to continue the procedure using the out-of-calibration torque wrench. When it was brought to my attention last night, I immediately arranged to have the aircraft grounded and a torque check done. I don't want to sound like I'm making excuses, but I believe this occurrence is a result of fatigue and stress. During the previous seven days, both myself and the other technician had worked many long hours. Over the previous 30 days I have had three days off … in hindsight, I should have recognised then that I was badly in need of some rest. Instead, I pressed on.

Aviation Safety Reporting System report

Are we the best judges of our level of fatigue?

People are notoriously bad judges of their own level of fatigue. Asking a fatigued person if they are OK to keep working is like asking someone who is drunk if they are OK to drive. Even if we are not good judges of how tired we are, we can still keep track of how long we have been awake, how much sleep we have had recently, and the quality of that sleep. Before starting work, you could ask yourself these questions:

- How much sleep have I been getting over the last few nights?
- How long have I been awake?
- Will I be working at a time when I would rather be sleeping?
- Have I had good-quality sleep?

Your answers to these questions can help you to assess how likely you are to be at risk because of fatigue.

The impact of fatigue in the workplace

Some people in the aviation industry see fatigue as a normal and unavoidable part of aviation maintenance. They consider that with enough effort, a tired worker can continue to perform their job effectively. Increased effort or concentration might help for a few minutes, but it cannot compensate for fatigue over an entire shift. Fatigue has a very real detrimental impact on safety in aviation and in many other industries. Here are some myths about sleep and fatigue:

Myth	Reality
'Five or six hours sleep a night is generally enough.'	Very few people can manage on this amount of sleep without being seriously affected.
'Daytime sleep is just as good as nighttime sleep.'	Shiftworkers who have to sleep during the day generally get lower-quality sleep, and less of it.
'We can judge how fatigued we are accurately.'	Studies have shown that fatigued people often don't realise that their abilities are impaired by fatigue.
'We need less sleep as we get older.'	We still need the same amount of sleep, but our sleep becomes more fragmented, and we tend to wake earlier.

Human error is recognised as a causal factor in the majority of industrial and transport accidents. Fatigue, in turn, is one of the major causes of human error. Here are some facts about the role of fatigue in industrial and transport accidents:

- Industrial and engineering disasters, including those involving nuclear power, tend to occur in disproportionate numbers in the early hours of the morning
- Shift workers have twice the number of highway accidents as workers on day schedules
- Fatigue is involved in 31 per cent of truck accidents resulting in the death of the driver
- Driving while sleepy is as dangerous as driving while intoxicated. In some parts of the world, a driver can be charged with motor vehicle homicide if they cause a fatality and have not slept in 24 hours. In Australia, road safety legislation now views motor vehicle accidents involving fatigue as 'voluntary impairment'—in other words you make a conscious choice to drive when tired
- Fatigue is the largest identifiable and preventable cause of incidents in Australian transport operations. Twenty to thirty per cent of road accidents involve driver fatigue. The figure is 5–15 per cent for fatal road accidents
- Australian road statistics show that sleep-deprived individuals are 4–7 times more likely to have an incident driving to and from work.

The causes of fatigue

Fatigue is caused by a combination of two processes—sleep debt and circadian rhythms.

Sleep debt

Adults generally sleep between seven and eight hours per night, although the need for sleep varies between people, with some individuals needing up to 10 hours of sleep to remain alert. A century ago, before the widespread use of electric lighting, people typically slept around nine hours per night. Today, family demands, work commitments and even television viewing habits combine to limit the opportunities for nighttime sleep. In our busy world, many people are suffering from sleep deprivation without being aware of it. Extreme sleep deprivation has severe health effects, but even mild sleep deprivation can affect health and our ability to perform tasks in our work and personal lives.

If we obtain less sleep than we need, we build up a sleep debt. Each successive night of inadequate sleep adds to the debt. Even reducing our sleep by just one hour each night over several nights (e.g. getting seven hours when we really need eight) can reduce our mental efficiency.

Shift workers, who sleep during daylight hours, also build up a sleep debt because daytime sleep tends to be briefer and of poorer quality than sleep obtained at night.[24]

---

[24] Czeisler, C. A., Weitzman, A., Moore-Ede, M.C., Zimmerman, J.C., and Knauer, R.S. (1980). Human sleep: its duration and organisation depend on its circadian phase. Science, Vol 210, Issue 4475, 1264-1267. Folkard, S. (1996). Body rhythms and shiftwork. In Warr, P. (Ed.), Psychology at work (pp. 39-72). Middlesex: Penguin.

Obviously, a sleep debt may build up when a person's work and family commitments do not allow them to sleep for as long as their body needs. But sleep debts can also occur when sleep is disrupted by alcohol and other drugs, and medical conditions. Medical conditions that can cause sleep disruption include the following:

- **Insomnia** An inability to get to sleep, or a difficulty staying asleep. In many cases, insomnia is a symptom of another problem, such as medical conditions, side effects of medicines, or sleep disorders. Insomnia can also be caused by worry or emotional upsets.
- **Restless legs syndrome (RLS)** A disorder that causes a strong urge to move your legs. This urge to move often occurs with strange and unpleasant feelings such as creeping, tingling or burning. Moving your legs relieves the urge and the unpleasant feelings.
- **Periodic limb movements (PLM)** Involuntary leg movements while asleep. The movements often disrupt sleep and may cause the person to wake up.
- **Sleep apnoea** A disorder in which breathing pauses or becomes shallow during sleep (see below).

If you think you may be experiencing any of these conditions, see your doctor immediately.

Sleep apnoea

Sleep apnoea is one of the more common medical conditions related to sleep disturbance. It is a condition in which breathing stops for ten seconds or longer during sleep. This reduces the level of oxygen to the brain, and results in disturbed sleep. The condition is often associated with snoring. During a typical episode of sleep apnoea snoring stops as the person ceases breathing. After a period of silence, they wake up, gasp or snort, and then return to snoring.

Sleep apnoea affects between two and five per cent of the population. However, the condition is more common in men who are overweight and/or have a large neck size.

Sleep apnoea typically results in excessive daytime sleepiness. It also causes forgetfulness, clumsiness on tasks requiring careful movements, and may lead to reduced sex drive and/or impotence.

The good news is that effective treatments are available for sleep apnoea. As well as weight loss, your doctor may recommend surgery, or the use of a device that will keep your airway open while you sleep.

When to see a doctor
Consult a medical professional if you experience, or if your partner observes, the following:

- Snoring loudly enough to disturb the sleep of others or yourself
- Shortness of breath that awakens you from sleep
- Intermittent pauses in your breathing during sleep
- Excessive daytime drowsiness, which may cause you to fall asleep while you're working, watching television, or even driving.

Mayo Clinic

Circadian rhythms

Our bodies have very steady 24-hour rhythms in their physiology, biochemistry and behaviour. Alertness, body temperature, sleep tendency and human error have also been shown to follow a 24-hour pattern. These rhythms are known as *circadian* rhythms, the word circadian being Latin for 'about a day'. Our body's internal clock is kept on correct time by exposure to light, particularly early morning light. Our circadian rhythms are so reliable that even if we are removed from the 24-hour rhythm of night and day (such as wintering in Antarctica) the rhythms continue to run. Without regular exposure to a daily cycle of light and dark, circadian rhythms eventually begin to 'free run' and will no longer align closely with the 24-hour day.

Circadian rhythms have an important role in regulating sleep patterns. Chemical changes occur in the body as it prepares for sleep, typically between 8pm and midnight. Body temperature reaches a low point at around 3am, and then begins rising steadily, apparently as our body gets ready for the day ahead, even before most people are naturally awake.

Do shift workers adapt to permanent night shifts?

Not usually! Research shows that fewer than 30 per cent of permanent night shift workers actually adjust their rhythms to a nighttime schedule. In most cases, they remain on a typical daytime pattern.[25] As a result, even workers on regular nightshifts will still experience a strong drive for sleep during the night, and will find it more difficult to obtain good quality rest during daylight hours.

Beware the WOCL!

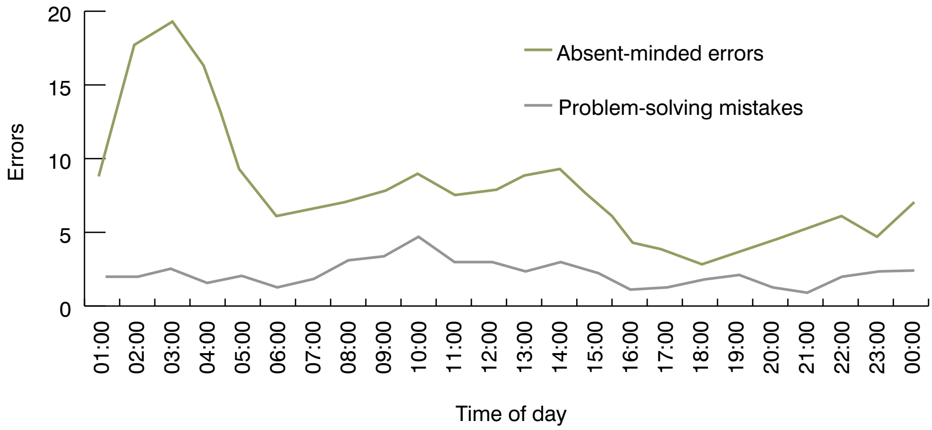
The period from around 2am–5am when we would normally be asleep, is often referred to as the window of circadian low (WOCL), and is a time when mental functioning is generally at its worst. The WOCL is a high-risk time for human error. Even people without a sleep debt find that their work performance is affected by fatigue during the WOCL, but a sleep debt will intensify the negative effects of the WOCL.

Studies of thousands of industrial errors have shown that although they can occur at any time of day or night, a large proportion of errors occur at around 3am. There is often a second, although smaller, risk period at around 3pm. That afternoon period is sometimes called the 'post-lunch dip', but it happens regardless of whether people eat lunch or not.

In a recent study, hundreds of errors reported anonymously by LAMEs and AMEs were examined to see how they varied throughout the 24-hour day. Nearly all the errors were minor and were quickly corrected. Most of these several hundred errors were absent-minded ones made during routine or monotonous tasks such as re-fitting caps and covers, removing tools, and positioning stands and equipment. Problem-solving mistakes such as mis-diagnosed faults were less common. To control for the possibility that the 24-hour pattern of errors might just reflect the number of people working at each hour of the day and night, the number of errors reported at each hour was adjusted to even out any effects of staffing level changes. The results showed that absent-minded errors showed a strong circadian rhythm, with a big peak between 2am and 3am. Problem-solving mistakes, on the other hand, happened at all times of the day and night. Although the cases came from airlines, the same pattern was observed in general aviation (GA), even though overnight work is generally less common in GA.

25 Spencer, M., Robertson, K., & Folkard., S. (2006). *The development of a fatigue risk index for shiftworkers*. Colegate, UK: HSE Books.

Airline maintenance errors throughout the 24-hour day



These results remind us to be alert to the dangers of fatigue. Everyone involved in maintenance, whether LAMEs or AMEs, needs to be aware that it is harder to focus your attention during the window of circadian low. This in turn may increase the odds of errors, particularly absent-minded slips and memory lapses, as indicated in the following case study:

Case study

Six … mechanics were … sent to ZZZ to accomplish the engine change [#2 engine on a B737-300]. These mechanics had worked 24-plus hours straight to complete the engine change. When the aircraft left XXX on a revenue flight to ABC, the flight crew was unable to retard #2 engine below 90 per cent N1 and had to do an in-flight shutdown on final approach into ABC. It was discovered that a 10-32 nut was left in the throttle box, and that prevented the flight crew from retarding #2 engine throttle.

Aviation Safety Reporting System report

Tips for dealing with the WOCL (window of circadian low: 2–5am)

- If possible, avoid the most safety-critical tasks during the WOCL. For example, if you have a choice of rigging flight controls or checking the expiry dates on life jackets, leave the flight controls until later
- If you can, keep the lights bright and the temperature slightly cool
- Try to avoid monotonous or tedious tasks
- Ask someone to check your work
- Stretch, walk around. Get some fresh air. But don’t expect this to help for more than a few minutes
- If you can, take a brief nap. Even a few minutes will help
- Use caffeine carefully, and be aware that it may make it more difficult to sleep when you get home.

Factors that increase the impact of fatigue

Certain conditions in the workplace can make the effects of fatigue more severe. These include:

- **Low light.** A work environment with low illumination reduces alertness and makes it harder for a fatigued person to fight the urge to sleep
- **Passive activities.** Tasks that do not involve physical activity, or are performed while seated, are more likely to be affected by fatigue
- **Boring or monotonous tasks.** Tasks requiring continuous monitoring or long tedious inspections tend to be more susceptible to fatigue-related errors
- **Warm temperature.** A fatigued person will find it even harder to stay alert if their work environment is warm.

Case study

Two of us worked together that night on the fan lube. My partner cleaned and re-sprayed the dampers. Unknown to him, one damper fell off the shelf where he was working, and landed on a lower portion of the work table, out of sight. Upon reassembly, I sat in the inlet installing blades and dampers. Apparently I missed installing a damper under #20 fan blade. This occurs occasionally, and you'll have an extra damper left over after all the fan blades are installed. Then you spin the fan slowly and find where the missing damper is, and install it. But in this case, we had no 'extra' damper because, unknown to us, it had fallen to a lower shelf on the work table. Inspection looked over the blade installation (they don't look at dampers) and gave us an OK to install front spinners. The aircraft left the station on a revenue flight the next morning, and upon reaching XXX, the pilot wrote up a vibration on #2 engine … I think the major factor in this instance was alertness. The human body is not designed to work [nightshift]. I cannot function at my best during the night. I routinely get four hours of restless sleep a day, and I'm constantly tired and irritable.

Aviation Safety Reporting System Report

How tired are you?

Epworth sleepiness scale

Developed by Dr Murray Johns of Epworth Hospital in Melbourne

How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired? This refers to your usual way of life over recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation:

no chance of dozing	slight chance of dozing	moderate chance of dozing	high chance of dozing
0	1	2	3

Situation	**Chance of dozing**
Sitting and reading	
Watching TV	
Sitting inactive in a public place (e.g. a theatre or a meeting)	
As a passenger in a car for an hour without a break	
Lying down to rest in the afternoon when circumstances permit	
Sitting and talking to someone	
Sitting quietly after a lunch without alcohol	
In a car, while stopped for a few minutes in traffic	

1 – 6. Congratulations, you are getting enough sleep!
7 – 8. Your score is average
9 and up. Seek the advice of a sleep specialist without delay!

Managing the risks of fatigue in aviation maintenance

Over 40 per cent of adults in the general population report that daytime sleepiness is affecting the quality of their work.[26] Maintenance workers tend to be even more fatigued than the general population. In fact, 82 per cent of maintenance personnel worldwide consider that fatigue is a safety issue in aircraft maintenance.[27]

In 2001, a study using sleep monitoring equipment showed that maintenance personnel:

- Sleep an average of only five hours per 24-hour period
- Tend to over-estimate the amount of sleep they are getting
- Work an average of 48 hours per week
- Ten per cent say they have fallen asleep at the wheel while commuting.

A survey of Australian aircraft maintenance engineers found:

- Fifteen per cent had worked a shift longer than 18 hours in the previous 12 months
- Some LAMEs had worked for 24 hours or longer at a stretch.[28]

Sleep inertia (AKA 'sleep drunkenness')

In the few minutes after waking up, we may experience a brief period of confusion, poor memory and grogginess. This effect, which can last up to 15 minutes, is known as sleep inertia. It can be an issue in workplaces where people have to wake up shortly before they get to work, for example pilots who sleep in onboard crew-rest facilities, or ambulance officers. It can also be an issue in maintenance if you are on call during the night, or if you nap at work. Be aware that after waking from a deep sleep it might take 15 minutes or so before you are alert enough to get to work.

Fatigue cannot be eliminated, but the risks associated with it can be managed through a partnership between employer and employee. Some of the causes of fatigue originate with company policies and practices; for example, hours of work, the extent to which work is performed during the night, and the predictability of work schedules. Other causes stem from the employee's personal situation, including commuting time, family responsibilities, and the demands of second jobs. The diagram opposite shows some of the main sources of fatigue. Employer and employee share responsibility for managing fatigue to the best of their abilities.

[26] Gertler, J. , Popkin, S., Nelson, D, & O'Neil, K. (2002). Toolbox for transit operator fatigue. Transportation Research Board. National Research Council.

[27] Hackworth, C., Holcomb, K., Banks, J., Schroeder, D., & Johnson, W. (2007). A survey of maintenance human factors programs around the world. International Journal of Applied Aviation Studies, 7, 212-231.

[28] Hobbs, A. & Williamson, A. (2001). ATSB Survey of Licensed Aircraft Maintenance Engineers in Australia. 2001. Research report, Australian Transport Safety Bureau.

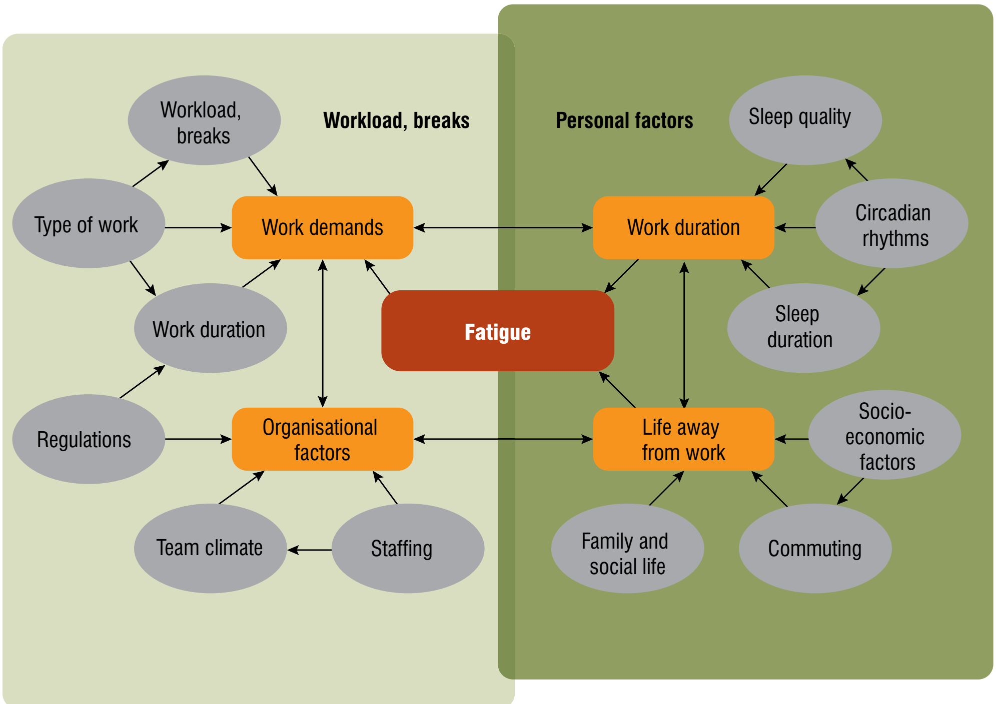
Responsibilities of the employer

- Schedule work hours and time off to give the employee sufficient opportunity for restorative sleep
- Manage workload and breaks.

Responsibilities of the employee

- Manage their personal time to make sure they are rested and fit for duty
- Not to put other people in danger by performing maintenance when excessively fatigued
- When reporting incidents, to note if fatigue was a factor.

Employer and employee responsibilities for managing fatigue



Adapted from Australian National Transport Commission

Some strategies to deal with fatigue

In this section, we consider some actions that can be taken to manage fatigue. Some of these might be considered common sense, but others may not be as obvious.

Get more sleep!

The first and most obvious way to prevent fatigue is to get more good-quality sleep. This is easier said than done, of course, particularly if you work irregular hours, have a second job, or have young children. Here are some tips on getting better sleep:

Tips for better sleep

- Set, and stick to, a sleep schedule as much as possible. Try to go to bed and wake up at the same times each day
- Expose yourself to bright light in the morning, but avoid it at night. Exposure to bright morning light energises us and prepares us for a productive day. Alternatively, dim your lights when it's close to bedtime
- Exercise regularly. Exercise in the morning can help you get the light exposure you need to set your biological clock. Avoid vigorous exercise close to bedtime if you are having problems sleeping
- Establish a relaxing bedtime routine. Allow enough time to wind down and relax before going to bed
- Create a cool, comfortable sleeping environment, free of distractions. If you are finding that entertainment or work-related communications are creating anxiety, remove these distractions from your bedroom
- Treat your bed as your sanctuary from the stresses of the day. If you find yourself still lying awake after 20 minutes or so, get up and do something relaxing in dim light until you are sleepy
- Keep a 'worry book' next to your bed. If you wake up because of worries, write them down with an action plan, then forget about them until morning

- Avoid caffeinated drinks, chocolate and tobacco at night
- Avoid large meals and beverages right before bedtime
- No nightcaps—drinking alcohol before bed can rob you of deep sleep and cause you to wake up too early
- Avoid medicines that delay or disrupt your sleep. If you have trouble sleeping, ask your doctor or pharmacist if your medications might be contributing to your sleep problem
- No late afternoon or evening naps, unless you work nights. If you must nap, keep it under 45 minutes and before 3.00pm
- Place a 'Do not disturb' sign on your door. Ask all family members to be as quiet as possible while you are sleeping
- Make sure that your room is dark. Blackout curtains can help
- Use an answering machine or voicemail for phone calls. Turn down the ringer.

Controlled naps

Numerous research studies have shown that even a brief nap can result in performance improvements. Napping used to be widely discouraged by employers, but now pilots, air traffic controllers and others are being allowed to take brief controlled naps when workload permits. Here are two types of naps:

- Preventative nap—a brief sleep before you report for work, particularly before starting a night shift
- Restorative nap—a brief sleep during a break at work can sharpen your performance for the next couple of hours.

There are two problems to watch out for with naps:

1. Avoid taking naps in the hours before you go to bed so as not to interfere with your main sleep period
2. Naps lasting more than about 40 minutes may produce sleep inertia, (a feeling of grogginess and disorientation that may persist for up to ten minutes after awakening), and may impair performance. The best nap duration appears to be about 20-25 minutes (Also known as the 'NASA nap').

Caffeine

Caffeine is one of the most widely used stimulants, and if used carefully and in moderation, can be part of an overall fatigue management strategy. Caffeine has a half-life in the body of around five hours, so shiftworkers should be careful to avoid caffeine in the hours leading up to sleep. If you use caffeine to stay alert at work, use it selectively, and cut down on caffeinated drinks at other times. If you develop a tolerance to caffeine, it will not be as effective in keeping you alert.

Breaks

If the situation allows it, a brief break or a stretch can help to focus your attention and provide temporary relief from fatigue. Do not be afraid to call time out for a few minutes to clear your head. Breaks, however, only provide a short-term benefit. The only real remedy for fatigue is sleep.

Progressive restrictions

One way to deal with fatigue in maintenance is to keep those who are most fatigued away from the most safety-critical tasks, an approach sometimes called 'progressive restrictions'. Some companies have internal policies progressively limiting the tasks an engineer can perform the longer they have been at work. For example, a LAME who has been on duty for longer than 12 hours might not be permitted to certify for the work of others, or may not be permitted to perform engine runs or other critical tasks. If they have been working for longer than 16 hours, they might be prevented from working on critical systems such as flight controls.

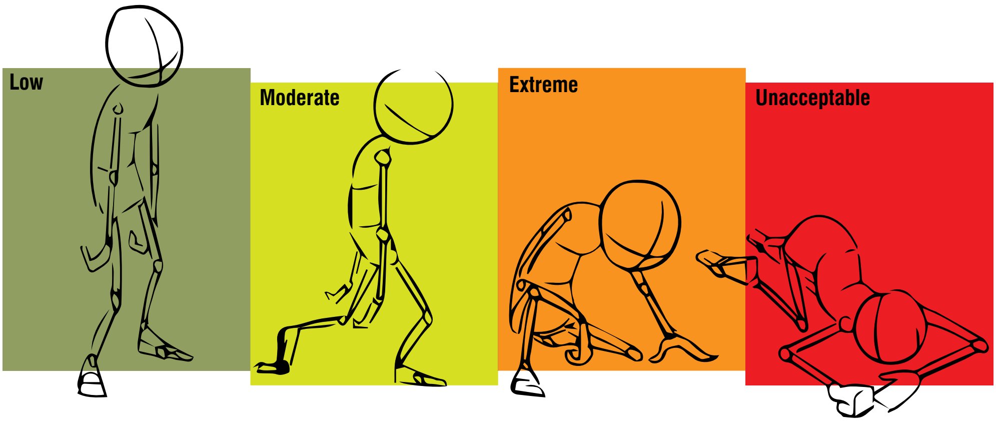
A general illustration of the progressive restriction approach in maintenance is shown below.

In your own operations:

- Where would you draw the line between low and moderate fatigue?
- What would you define as 'unacceptable fatigue'?
- What tasks would you want to keep out of the hands of very fatigued engineers?

Example of the progressive restriction approach

Level of fatigue



Work in accord with normal privileges and limitations.

All work must be dual inspected.

Operational/Functional checks must be carried out whenever a critical system has been disturbed.

Previous restrictions and:

No sign-off authority.

May not interact with critical systems such as flight controls.

May not work on ETOPS tasks.

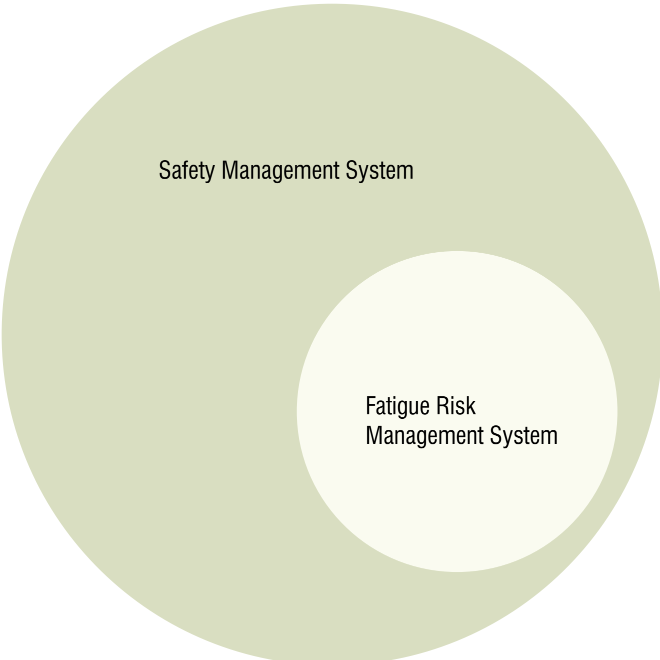
No maintenance tasks may be performed.

From Hobbs, A., Bedell Avers, K., & Hiles, J. (2011). 'Fatigue Risk Management in Aviation Maintenance: Current Best Practices and Potential Future Countermeasures' (Report No. DOT/FAA/AM-11/10), Washington, DC: Federal Aviation Administration, Office of Aerospace Medicine.

Fatigue risk management systems (FRMS)

Around the world, safety-critical industries such as railways, road transport and airlines are beginning to introduce scientifically based risk management approaches to dealing with fatigue-related hazards. These approaches are known as fatigue risk management systems (FRMS), and are often part of an organisation's overall safety management system (SMS). If your organisation does not have an SMS, it can still have an FRMS. A typical FRMS includes education and training for staff, incident reporting systems, and work schedules that take into account current knowledge of human fatigue.

A fatigue risk management system (FRMS) can be part of a safety management system (SMS)



CASA defines an FRMS as: 'A scientifically-based, data-driven, documented management system used to identify, record, track and manage the risks to aviation safety that may arise from fatigue. This may form part of an operator's safety management system (SMS).'

Worldwide progress towards FRMS in maintenance has been slow. In an FAA survey of the worldwide airline maintenance industry in 2007:

- Most maintenance personnel recognised that fatigue had an impact on safety.
- Fewer than 25 per cent worked for an organisation with a fatigue management system.
- Most organisations did not provide any training on fatigue management.[29]

[29] Hackworth,C. Holcomb, K., Banks,J., Schroeder, D., and Johnson, B. (2007). A survey of maintenance human factors programs across the world. *International Journal of Applied Aviation Studies, 7*, 212-231.

An FRMS can often include the use of commercial computer software systems to design shift rosters. Software models take into account the sleep a person is estimated to have obtained, as well as circadian variations in alertness, to produce an estimate of the fatigue level that might result from a particular shift pattern. Commonly used models include the following:

- Fatigue audit InterDyne (FAID)
- Fatigue avoidance scheduling tool (FAST)
- Circadian alertness simulator (CAS).

Even though computer software is widely used to design shift rosters, maximum limits on duty times are still an important part of managing fatigue in maintenance. In 2003, the UK Civil Aviation Authority asked a sleep expert (Professor Simon Folkard) to develop duty time guidelines for maintenance engineers. The guidelines he developed have been widely accepted as reasonable and are included at the end of this chapter.
Key items from Folkard's guidelines are:

- There should be a 12-hour limit on shift duration
- No shift should be extended beyond 13 hours by overtime
- A break of at least 11 hours should occur between shifts
- There should be a work break every four hours.

The following elements are common to most formal FRMS. In some cases, an organisation's fatigue risk management interventions involve only some of these elements, such as training or work schedule re-design.

- Organisational policies

  Commitment from management and staff

  Safety reporting culture policy to enable staff to report incidents
- Education and training

  For front line staff, as well as managers, supervisors and scheduling personnel
- Risk assessment

  Identifying tasks at greatest risk from fatigue

  Developing strategies to reduce the risk to these tasks

  Determining how much fatigue can be tolerated to get the job done
- Changes to work schedules to reduce fatigue

  Applying maximum duty time limits

  If necessary, using software modeling to fine-tune schedules and estimate fatigue levels
- Continual monitoring and assessment of fatigue and fatigue-related events

  Incident and event reporting system
- Periodic evaluation and continuous improvement of the FRMS program

Key points

- Fatigue is not only a threat to aviation safety, but can also put the health and safety of aircraft maintenance personnel at risk. Fatigue seriously impairs work performance and increases the chances of human error.
- With no legally imposed duty time limits for LAMEs and AMEs, maintenance personnel are often pressured to work extremely long hours, and almost certainly experience greater levels of fatigue than most other sectors of the aviation industry.
- In the past there was a common attitude that people should just tough it out, but it is now increasingly recognised that fatigue can produce performance impairments comparable to those produced by alcohol. Drink driving is no longer tolerated by society, and there are signs that social attitudes are also shifting in the same direction when it comes to fatigue. In the near future, performing a safety-critical task while fatigued may be seen as a reckless act, akin to drink-driving.
- There is a worldwide move towards comprehensive fatigue risk management systems (FRMS) in maintenance operations. These systems typically include awareness training for personnel, incident reporting systems, risk assessment and controls to limit the impact of fatigue. Even without a full FRMS, maintenance organisations can still take steps to manage fatigue through simple steps such as company duty time limits.

Further information

The U.S. Federal Aviation Administration maintains a website devoted to resources on fatigue in aircraft maintenance, including regular newsletters on maintenance fatigue:

- https://hfskyway.faa.gov/hfskyway/fatiguehome.aspx
- *Grounded* is an entertaining video about maintenance fatigue. As the DVD notes say: 'There is trouble on the home front and fires at work! Gregg is an airline manager who needs some rest. Can he get the aircraft back in the air and also correct his poor sleep habits? Or, will he go through life grounded?' This video is about sleep but is not a sleeper. Available free of charge at: https://hfskyway.faa.gov/HFSkyway/FatigueEducation.aspx
- The report *Fatigue Risk Management in Aviation Maintenance: Current Best Practices and Potential Future Countermeasures* summarises the world's best practices (details above) on fatigue management in maintenance. The report is available on the FAA fatigue website.

You can find Information on fatigue modeling software on the following websites:

- Fatigue Audit InterDyne (FAID) www.faidsafe.com
- Fatigue Avoidance Scheduling Tool (FAST) www.fatiguescience.com
- Circadian Alertness Simulator (CAS) www.circadian.com

If you are concerned that you might be suffering from a sleep disorder, speak to your doctor.
You can find Information on sleep and sleep disorders at:

- Australia's Health Direct Website: http://www.healthinsite.gov.au/topics/Sleeping_Well
- U.S. National Sleep Foundation
- http://www.sleepfoundation.org/

Folkard's recommendations on aircraft maintenance hours of service

a) No scheduled shift should exceed 12 hours.

b) No shift should be extended beyond a total of 13 hours by overtime.

c) A minimum rest period of 11 hours should be allowed between the end of a shift and the beginning of the next, and this should not be compromised by overtime.

d) A maximum of fours hours work before a break.

e) A minimum break period of ten minutes, plus five minutes for each hour worked since the start of the work period or the last break.

f) Scheduled work hours should not exceed 48 hours in any period of seven successive days.

g) Total work, including overtime, should not exceed 60 hours or seven successive work days before a period of rest days.

h) A period of rest days should include a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off). This limit should not be compromised by overtime.

i) To comply with the European Union working time directive, four weeks annual leave should be allowed.

j) A span of successive night shifts should be limited to six for shifts of up to eight hours long, four for shifts of 8.1 to 10 hours long, and two for shifts of 10.1 hours or longer. These limits should not be exceeded by overtime.

k) A span of night shifts involving 12 or more hours of work should be immediately followed by a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off) and this should be increased to three successive rest days (i.e. 83 hours off) if the preceding span of night shifts exceeds three or 36 hours of work. These limits should not be compromised by overtime.

l) The finish time of the night shift should not be later than 08.00.

m) A morning or day shift should not be scheduled to start before 06.00, and wherever possible should be delayed to start between 07.00 and 08.00.

n) A span of successive morning or day shifts that start before 07.00 should be limited to four, immediately following which there should be a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off). This limit should not be compromised by overtime.

o) Wherever possible aircraft maintenance engineers should be given at least 28 days notice of their work schedule.

p) Employers of aircraft maintenance personnel should consider developing risk management systems similar to those required by Western Australia's code of practice for commercial vehicle drivers.

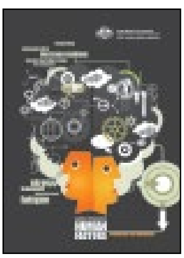
Don't make the graveyard shift a reality

q) Educational programs should be developed to increase aircraft maintenance engineers' awareness of the problems associated with shiftwork. In particular, it is important to draw their attention to the objective trends in risk, with a view to increasing their vigilance at points where risk may be high despite the fact that fatigue may not be. It is also important to provide information on how to plan for night work, and to give guidance on the health risks which seem to be associated with shift work, particularly at night.

r) Aircraft maintenance personnel should be required to report for duty adequately rested.

s) Aircraft maintenance personnel should be discouraged or prevented from working for other organisations on their rest days, and hence from exceeding the proposed recommendations on work schedules, despite their implementation by their main employer.

From: Folkard, S. (2003). 'Work hours of aircraft maintenance personnel' (UK CAA Paper 2002/06). West Sussex, UK: Research Management Department, Safety Regulation Group.



When you are ready, please turn to page 33 of the *Workbook for Engineers* and complete the exercises.


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 6

STRESS, WORKLOAD AND TIME PRESSURE

Stress is the high level of emotional arousal typically associated with an overload of mental and/or physical activity. Stress is often associated with anxiety, fear, fatigue and hostility. It can also arise as a result of feelings of inadequacy, where we may feel we don't have the appropriate experience, knowledge or capability to complete our allocated tasks. All these feelings can have a direct and negative impact on an engineer's performance.

Workload is a problem for safety-critical operations if it's too low—and an even bigger one if it's too high.

Understanding Human Factors. ***Rail Safety & Standards Board UK***

What is stress?

Stress is the high level of emotional arousal typically associated with an overload of mental and/or physical activity. Stress is often associated with anxiety, fear, fatigue and hostility. It can also arise as a result of feelings of inadequacy, where we may feel we don't have the appropriate experience, knowledge or capability to complete our allocated tasks. All these feelings can have a direct and negative impact on an engineer's performance.

Stress is an inevitable and necessary part of life. It can motivate us and heighten our response to meeting the challenges we face. In fact, our performance will generally improve with the onset of stress, but will peak and then begin to degrade rapidly as stress levels exceed our adaptive abilities to handle the situation.

High levels of stress are a problem for any individual or maintenance team, since the effects of stress are often subtle and difficult to assess. Although complex and difficult maintenance activities can generate stress, there is also the stress, both physical and mental, that a team member may bring to the situation and which others may not be able to detect.

Characteristics of stress

Stress is insidious

Stress is often described as being insidious; that is, it develops slowly, and has a gradual and cumulative effect. It can be well established before we are aware that it is degrading our performance. We may think that we are handling everything quite well, when in fact there are subtle signs that our performance has degraded to a point where we can no longer respond appropriately.

Stress is cumulative

We are all under a certain level of stress at any given time, but there is a limit to any individual's capability to adapt to increasing stress. This stress tolerance level is based on our ability to cope with a given set of circumstances. If the number or intensity of stressors becomes too great, we can become overloaded. At this point, our performance begins to decline and our judgement deteriorates.

Causes of stress

Any changes in personal circumstances such as divorce, marital separation, bereavement, difficult family affairs, or financial concerns can lead to stress and affect our emotional state. Then there is also work-related stress, which may include real or imagined commercial pressures: the need to juggle deadlines to get the aircraft on line and balance economic considerations with the understanding that lives depend on the quality of our work. To complicate matters even further, admitting to suffering from these stresses is often viewed by work colleagues as an admission of weakness or failure. Therefore, early symptoms of stress such as depression or sleep disruption are often denied. In this situation we tend to look for other ways to cope with our high levels of stress, such as aggression, drugs or alcohol.

Stressors

Different stressors affect different people to varying extents. Typical stressors include:

- Physical, such as heat, cold, noise or the onset of fatigue
- Psychological, such as worries about real or imagined problems (e.g. financial problems, ill health, etc.)
- Reactive, such as events occurring in everyday life (e.g. working under unrealistic time pressure, bullying, encountering unexpected situations, etc.)

Domestic stress

Domestic stress typically results from major life changes such as divorce, the birth of a child or the death of a family member or close friend. Pre-occupation with domestic stress can play on our mind during working hours, distracting us from our tasks. This inability to concentrate fully may affect task performance, error rates and our ability to pay due attention to safety.

Work-related stress

Carrying out tasks that are new, or very challenging or difficult, can make us feel stressed. Time pressure, lack of standard procedures or appropriate resources, lack of guidance or supervision, and interpersonal conflicts all intensify this stress. Some of these stressors can be reduced by appropriate workload management, good communication, good training etc. The social and managerial aspects of work can also be stressful; for example, if you feel your job is under threat due to a company re-organisation.

Symptoms of stress

The symptoms of stress can include:

- Physiological symptoms, such as sweating, dryness of the mouth etc
- Health effects, such as nausea, headaches, sleep problems, stomach upsets
- Behavioural symptoms, such as restlessness, shaking, nervous laughter, taking longer over tasks, changes to appetite, excessive drinking, or smoking etc
- Cognitive effects, such as poor concentration, indecision, forgetfulness etc
- Subjective effects, such as anxiety, irritability, depression, moodiness, aggression etc.

Consequences for engineers

Inappropriately high levels of stress can significantly degrade your performance and as a result, can also compromise safety. Under high levels of stress, the following behaviours can be evident:

- Poor judgement
- Compromised, or accepting of lower standards
- Inattention, loss of vigilance and alertness
- Preoccupation with a single task at the expense of others
- Forgetting or omitting procedural steps
- Greater tendency towards missing things
- Misreading maintenance manuals and procedural steps
- Loss of time perception
- Loss of situational awareness.

Managing stress

If we all work with a certain level of stress, how can we manage stress to ensure it is kept to an appropriate level?

Firstly, you must be able to recognise when your stress levels are getting too high. If you are suffering from domestic stress; if you are undergoing divorce or separation, if you have suffered bereavement; if an argument with your spouse or your boss is still rankling; if worries are building to an unbearable level; if you have been despondent and moody; then the hangar floor or workshop is probably not the place for you.

Even when you have low levels of domestic stress, stress levels can build up in the workplace, particularly when there is a multitude of decisions to make and tasks to complete. Before this occurs, we need to be proactive in managing the stress load so that it does not become unmanageable. As engineers we need to learn how to reduce or prevent those stressors we can control.

You can control physiological stressors by strategies such as:

- Maintaining good physical fitness and bodily function
- Engaging in a program of regular physical exercise
- Getting enough sleep to prevent fatigue
- Eating a balanced diet
- Learning and practising relaxation techniques.

You can reduce the physical stressors by making your work environment as stress free as possible.

In high-pressure situations, relieve stress by establishing priorities and by appropriately delegating tasks and responsibilities to other members of the team. In a low-pressure situation, where fatigue, boredom and over-familiarity with the task are the greatest hazards, paying careful attention to environmental conditions such as heat, humidity, noise and lighting can help to maintain alertness.

Stress coping strategies

If coping strategies are to be effective, we need to identify and deal with the source of the stress, and not just the symptoms; for example, delegating workload when necessary, appropriately prioritising tasks and sorting out problems rather than letting them fester. We cannot always change the situation—it may be outside our control—but even when this is the case, there are a number of coping strategies we can use.

Achieving relaxation

There are almost as many techniques, practices, and treatments for dealing with stress as there are causes of it. From ancient relaxation techniques to the latest thinking on proper nutrition, from breathing exercises to repetitive prayer, there are numerous tools to help people cope. Some techniques can be especially beneficial under certain circumstances, but not as helpful under others. Understanding what works for us as individuals, and for the stressful circumstances at hand, can require an exploration of a number of stress-reduction methods. And as always, it is important to know when to seek professional help.

These efforts can reward you richly with better health, greater peace of mind, and a smoother course through life.

Mini-relaxations

Mini-relaxations can help allay fear and reduce pain while you sit in the dentist's chair or lie on an examining table. They're equally helpful in thwarting stress before an important meeting, while stuck in traffic, or when faced with people or situations that annoy you. Here are a few quick relaxation techniques to try:

When you have one minute. Place your hand just beneath your navel so you can feel the gentle rise and fall of your belly as you breathe. Breathe in slowly. Pause for a count of three. Breathe out. Pause for a count of three. Continue to breathe deeply for one minute, pausing for a count of three after each inhalation and exhalation.

Or alternatively, while sitting comfortably, take a few slow deep breaths and quietly repeat to yourself 'I am' as you breathe in and 'at peace' as you breathe out. Repeat slowly two or three times. Then feel your entire body relax into the support of the chair.

When you have two minutes. Count down slowly from 10 to zero. With each number, take one complete breath, inhaling and exhaling. For example, breathe in deeply saying '10' to yourself. Breathe out slowly. On your next breath, say 'nine,' and so on. If you feel lightheaded, count down more slowly to space your breaths further apart. When you reach zero, you should feel more relaxed. If not, go through the exercise again.

When you have three minutes. While sitting down, take a break from whatever you're doing and check your body for tension. Relax your facial muscles and allow your jaw to fall open slightly. Let your shoulders drop. Let your arms fall to your sides. Allow your hands to loosen so that there are spaces between your fingers. Uncross your legs or ankles. Feel your thighs sink into your chair, letting your legs fall comfortably apart. Feel your shins and calves become heavier and your feet grow roots into the floor. Now breathe in slowly and breathe out slowly. Each time you breathe out, try to relax even more.

From *Aviation Human Factors Industry News*, 23 August 2007, Vol. 3. Issue 30

Applied exercise

Background

Several studies over the past few years have examined whether there are particular stressors that are more likely than others to precipitate an aircraft accident. Robert Alkov, an aviation psychologist, studied flight-related mishaps in the U.S. Navy during the early 1980s. Alkov investigated the psychological background of over 500 personnel involved in aircraft incidents or accidents.

The study showed that various situational factors, such as recently getting engaged, or being involved in disputes with loved ones, peers or authority, significantly pre-disposed personnel to involvement in accidents where human error was a contributory factor. While his findings indicated that there are substantial differences in the ability of personnel to cope with stress, the study concluded that many of the errors committed by personnel were symptoms of inadequate stress coping behaviour.

Alkov based his study on work conducted by two psychiatrists, Dr Thomas Holmes and Dr Richard Rae, who created the SRRS (social readjustment rating scale), a list of 43 events that can cause stress. These were ranked in order of the impact they might have on a person's life, and a severity level (stress points) was assigned to each event. Holmes and Rae suggested that any stressful events could be linked with higher chances of illness, and indeed their research found that many diseases in their patients were linked with life changes.

How stressed do you think you are?

This quick quiz may make you more aware of the impact of significant life events on your level of stress. The following table lists a number of life events the average person could expect to experience. To test yourself, just go through the list and add up the points of the events you have experienced in the last year. Add the points allocated to each of these events in the right-hand column to find your total cumulative score.

What your score means

Each of us has personal stress-adaption limitations. When we exceed this level, stress overload may lead to poor health or illness. Although different people have different capacities to cope with stress, for the average person, a score of 250 points or more may indicate that you are suffering from high levels of stress.

Studies revealed that people who had become ill had accumulated a total of 300 stress points or more in a single year. Look at the last twelve months of changes in your life. It is important to understand that 'ripples of stress' can circulate a long time after the actual change has taken place. High stress levels will adversely affect your immune system and lead to mental or physical illness if something is not done about them. It is very important to lighten your stress load and develop mechanisms to cope with stress before something gives. The message for the engineer is clear. If stress brought on by life changes is not managed well, and is added to the stresses in the workplace, your performance will be adversely affected.

Life event	Score	Cumulative score
Death of spouse	100	
Divorce	60	
Menopause	60	
Separation from living partner	60	
Jail term or probation	60	
Death of close family member other than spouse	60	
Serious personal injury or illness	45	
Marriage or establishing life partnership	45	
Fired from work	45	
Marital or relationship reconciliation	40	
Retirement	40	
Change in health of immediate family member	40	
Work more than 40 hours per week	35	
Pregnancy or partner becoming pregnant	35	
Sexual difficulties	35	
Gain of new family member	35	
Business or work role change	35	
Change in financial state	35	
Death of a close friend (not a family member)	30	
Change in number of arguments with spouse or partner	30	
Mortgage or loan for a major purpose	25	
Foreclosure of mortgage or loan	25	
Sleep less than eight hours per night	25	
Change in responsibilities at work	25	
Trouble with in-laws, or with children	25	
Outstanding personal achievement	25	
Spouse begins or stops work	20	
Begin or end school	20	
Change in living conditions (visitors in the home, change in roommates etc.)	20	
Change in personal habits (diet, exercise, smoking, etc.)	20	
Chronic allergies	20	
Trouble with boss	20	
Change in work hours or conditions	15	
Moving to new residence	15	
Presently in pre-menstrual period	15	
Change in schools	15	
Change in religious activities	15	
Change in social activities (more or less than before)	15	
Minor financial loan	10	
Change in frequency of family get-togethers	10	
Have been, or are about to go, on holiday	10	
Presently in Christmas season	10	
Minor violation of the law	5	
Total score		

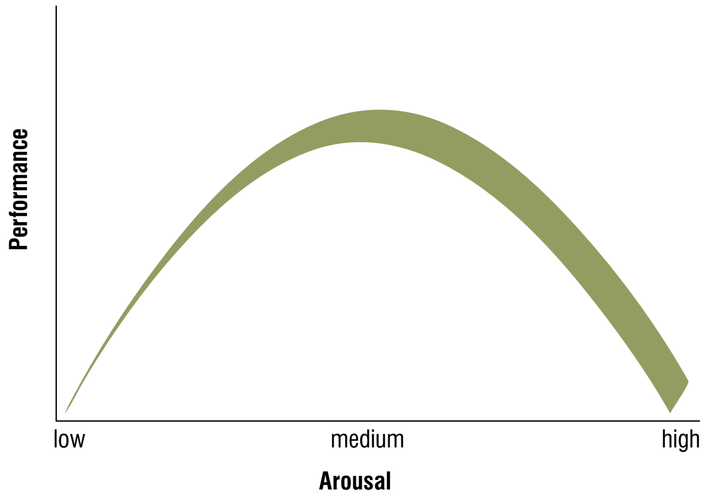
'Social Readjustment Rating Scale' by Thomas Holmes and Richard Rae

Workload—overload and underload

Both arousal and alertness are necessary for us to achieve our optimum performance, but too much, or too little, arousal can adversely affect our ability to function effectively. It is therefore important for us to be aware of the symptoms of stress in ourselves and others— we also need to understand the effect of stress on team performance as a whole.

The Yerkes Dodson curve demonstrates that our performance is directly related to the level of arousal. The graph below shows that there is typically a level of arousal which aligns with the optimum level of human or task performance. At very low levels of arousal (boredom) and very high levels of arousal (stress, anxiety and overload) our performance is very much degraded.

Yerkes Dodson curve



Factors determining workload

Maintenance tasks are highly process driven and usually follow a fairly standard pattern and order, some of which we can control, and some of which we cannot. We have limited mental capacity to deal with information. We are also limited physically, in terms of visual acuity, strength and dexterity. Therefore, workload reflects the degree to which the demands of the task fall within our mental and physical capacities.

Workload is therefore a relatively subjective measure (i.e. experienced differently by different people) and is affected by:

- The nature of the task, such as its physical and mental demands
- The circumstances under which the task is performed—the standard of performance required, the time available to accomplish the task and the prevailing environmental factors
- The individual and their situation—their skills both physical and mental; their experience, particularly familiarity with the task in question; their health and fitness levels; and their emotional state.

Work overload

Work overload occurs when there is a lot of work to be done and the individual's or team's workload exceeds their ability to cope. As performance deteriorates, we are forced to shed tasks and focus on key information. In these situations error rates may also increase. As we carry out our assigned tasks, over a given time, the normal effects of fatigue will also produce a decline in our mental and physical capacity. This will mean that tasks within our capacity early in a work period feel like a higher workload (or overload) later on, particularly towards the end of a long shift. Added to this, momentary workload spikes within a shift may strain or exceed our individual (or team) capacity, increasing the risk of errors.

Work overload can occur for a wide range of reasons, and may happen suddenly or gradually. It is good practice to plan maintenance tasks so that individuals (or the maintenance team as a whole) are not expected to perform at an unacceptable level of workload to complete their tasks within the allocated time. Specific task allocation between maintenance team members can reduce the likelihood of one person within the team being overloaded.

Maintenance personnel under excessive workload (often associated with unrealistic time pressures) can exhibit or experience the following issues:

High workload

Omission and filtering	Ignoring some signals or responsibilities that are not seen as immediately relevant or necessary.
Reduced ability to think logically	Limited capability for the consideration of other possibilities, or to process information correctly
Queuing	Delaying required actions/responses in the hope that you will be able to catch up as the task progresses.
Confirmation bias	The tendency to automatically confirm a decision we have made, ignoring other information to the contrary
Approximation	Near enough becomes good enough
Regression	Reverting to a previously well-learnt procedure or action which may or may not be appropriate for the current task

Causes of high workload

Typically, high workload within the aviation maintenance environment flows from the following issues:

- Poor task planning
- Unexpected events
- Inadequate manning/high tempo
- Changing task requirements
- System design/access problems
- System/task complexity

The following case study demonstrates how inadequate staffing can lead to poor maintenance practices:

Short handed!

Shoddy maintenance by an overworked mechanical staff has been cited as a significant contributing factor in the crash of a helicopter in Ponte Vedra Beach, Florida on 27 March 2007 that fatally injured two people, according to the National Transportation Safety Board (NTSB).

A mechanic told the NTSB that the crew was understaffed and forgot to check parts.

The pilot instructor and student passenger were killed when the single-engine Robinson R44 helicopter crashed minutes after leaving the airport. An initial crash report said key bolts, nuts and washers were missing from the flight control system.

The NTSB report said a mechanic with the company that owned the helicopter told investigators that missing and loosened hardware that caused the chopper to crash near the ocean was the result of understaffing and staffers being 'pulled in all directions by company personnel'.

In response to the accident, the operator has changed policies and procedures to ensure more mechanics per shift, more thorough inspections and fewer interruptions for mechanics.

The mechanic who worked on the helicopter told NTSB investigators that the operator had too few maintenance personnel and that, a few nights before the crash, an apprentice wanted to stay late with the mechanic and finish a section of the inspection. 'As a result, the mechanic forgot to go back and secure the hardware,' the report says. A 30-minute test flight didn't reveal the problem.

The operator's lead mechanic told investigators that staff were being pushed to get the helicopter ready to fly while also being involved in working on several other aircraft, shopping for tools and preparing an estimate for a crash repair in Melbourne.

Adapted from 'Short Handed' in Aviation Human Factors Industry News*, 24 February 2008, Vol. IV. Issue 08*

Work underload

Although rare in the maintenance environment, work underload does occur. Work underload can result from menial, simple or very repetitive tasks that we find boring, or indeed from a lack of tasks to do. We are likely to be less attentive when carrying out repetitive tasks; boredom may set in and we may begin to raise the level of mental stimulation by thinking about things not related to the task, (e.g. what to do at the weekend). Under these conditions, situational awareness is degraded and errors and omissions will increase.

Interruptions and distraction management

Interruptions and distractions are common in aviation maintenance. What simple steps can we take to minimise their effect?

Perhaps the first step in this process should be to educate those who work in and near the maintenance environment. They must be trained so that they understand it is inappropriate to interrupt an engineer/technician conducting a maintenance task. Before interrupting, they should ask themselves: 'Is the interruption really necessary? Can it wait until a more appropriate time? Is it possible to leave a message? Can I get the information I need from someone else?'

The following case study looks at the effects of disruptions on maintenance inspection.

Interruptions and distractions

In the aviation maintenance environment, technicians may be asked to play dual roles, depending on staffing and availability of resources.

In this case study, a maintenance upgrade inspector made several inspection errors while trying to train a new-hire mechanic (engineer).

Maintenance upgrade inspector's comment:

'I was an upgrade inspector (I am an alternate) on RON (remain overnight) shift. I 'received' (verified tyre, make, and wheel half) approximately 100 mixed tyres and brakes that evening … While receiving the tyres, one of our new-hire mechanics asked if I would be able to help him with a pressurisation issue he had on his RON aircraft. I was about halfway through the tyres and had the nose and brakes left to inspect when I went and helped this mechanic for about two hours with his aircraft. After that, I returned and continued my inspection work.

'I was subsequently notified by another mechanic that several of the nose tyres I had inspected had improper parts tags on them. Three tyres had been inspected by me. I then verified the three tyres were in fact incorrect, and retagged them appropriately. I also rechecked the stack of tyres and found no other discrepancies.

'I fully understand that while working as an inspector, I work under the umbrella of quality control and not as a mechanic. The upgrade inspectors are expected to help out with the normal RON workload and act as mechanics when they can. Management never forces this, but they routinely request it and we routinely help when we can.

'A contributing factor was that I was working outside the inspection work area and losing focus on the task at hand … To prevent this becoming an issue in future, I will focus solely on my inspection duties.'

Could something like this happen to you?

How do you manage interruptions and distractions in your workplace?

Adapted from a case study on interruption and distraction in Aviation Human Factors Industry News, *Vol VII. Issue 06, February 11, 2011.*

The focused maintenance environment for safety-critical maintenance

Maintenance operations include tasks on safety-critical items and systems. These safety-critical maintenance tasks, unless carried out strictly according to authorised procedures, can directly affect aircraft or personnel safety. Therefore it is essential to reduce the potential for distraction and interruption during these tasks as much as possible.

Can we, or should we, accept interruptions and distractions during high-risk, safety-critical maintenance? Would you interrupt a surgeon carrying out open heart surgery to tell her that her husband is on the phone and wants to know what he should pick up for dinner? One way of minimising interruptions and distractions during safety-critical maintenance is by introducing the 'focused maintenance environment'[30].

The focused maintenance environment would be established when work is being done on items or systems the maintenance supervisor, maintenance manager (or OEM) deem to be safety-critical. The aim of the focused maintenance environment is to minimise maintenance team interruptions and distractions during specific safety-critical work. This technique should in no way infer that any other maintenance carried out is less important; rather the technique helps to ensure an environment of minimal distraction and heightened focus and awareness during work on safety-critical systems.

During a safety-critical maintenance task, conversation should be only task-or safety-related. Interruptions from internal or external sources should occur only if they relate to the task at hand; if there are safety implications; or to communicate an emergency. Due to the safety implications of these tasks and to emphasise the importance of this practice, discuss the process for, and requirements of, the focused maintenance environment during the task pre-brief. Include the specific time or point in the procedure at which the focused maintenance environment will begin, and where it is expected to finish.

For the focused maintenance environment to work, all personnel must understand the concept and be aware of its purpose and application. And so that all external personnel are aware that a particular team is working on a safety-critical task, consider using some type of signage, (or clothing) to show that the focused maintenance environment is in place. Place standardised signage in obvious positions around the work area, rope off the work area, or have the maintenance team wear particular high-visibility vests, armbands, or other identifiers.

30 Sellers, R (2011) 'Managing the risk of interruptions and distractions during safety-critical maintenance'.

What to do if interrupted or distracted during a task

Even with procedures such as the focused maintenance environment, interruptions may still occur. If you are interrupted during a safety-critical maintenance task, take appropriate steps to ensure you have not omitted any maintenance actions or procedural steps. This may involve going back at least three steps from where you were in the procedure before the interruption/distraction, or to a logical point in the task that allows you to assess the aircraft or system state accurately and to recheck your work before continuing.

Use your publications to keep track of where you are in the procedure. This technique should ensure that critical steps, actions or information have not been missed or bypassed as a result of the interruption or distraction. This recovery process should be trained and pre-briefed to ensure everyone in the maintenance team understands, and to consistently achieve the appropriate response. After completing a safety-critical maintenance task, there should be a comprehensive de-brief, to identify any interruptions or distractions that might have occurred during the procedure, and to ensure correct recovery actions were taken.

Time pressure and self-imposed pressure

There are two types of pressure that maintenance engineers or teams may experience—actual pressure and self-imposed pressure. The first is real pressure—applied directly or indirectly—for the task to be completed in a given time. On the other hand, individuals or teams may feel self-imposed pressure to complete a task within a given time, even when the time available may be unrealistic, or the task may not be achievable within the allocated resources and timeframe.

The following case study deals with self-imposed pressure, and its effect on aviation safety.

Self-imposed pressure

During the replacement of a BAC 1-11 no. 1 cockpit window, the shift maintenance manager ,who performed the task himself during the night shift, inadvertently installed the incorrect diameter retaining screws around the window's frame.

One of the screws that was removed was an A211-7D type, of which only one is used in the installation. The remainder were A211-8Ds, of which several are used. Noting that the majority of the screws removed had small amounts of removal damage and paint in their heads, he decided to replace the entire set, using the removed A211-7D as a sample. He was not aware that this was the only 7D required and that the rest were 8Ds.

Instead of referencing the illustrated parts catalogue for the BAC 1-11 to determine the correct screws required, he proceeded to obtain an entire set of 7Ds from a 'free issue carousel' in another hangar, as there were not enough in the hangar where the aircraft was being maintained. This added to the time taken for the task, which began at around 0200.

One of his main motivations for going straight to the 'free issue carousel' and not checking the manual was that the aircraft needed to be serviceable before going for an exterior wash at 0600.

For an individual, the self-imposed pressure is real. For them it is no different from any actual pressure being applied to the completion of the task. All pressure (self-imposed or otherwise) will affect the performance of those subjected to it.

Inappropriate pressure applied to an individual or maintenance team to achieve a task is a safety risk. Actual and self-imposed pressure can be significant drivers for error and maintenance short cuts/work arounds.

How can inappropriate actual or self-imposed pressure be managed?

- Allocate appropriate time for all maintenance tasks
- Carry out a comprehensive pre-task briefing to outline the task priorities
- Ensure open two-way communication to identify and mitigate the effects of pressure on performance and behaviour.

Communicating any problems encountered during the task is vital, particularly when you cannot complete the task safely because insufficient time and resources have been allocated. If this occurs you should:

- Ask for help, particularly when the task requirement is outside your expertise and/or capabilities
- Communicate the ramifications of any unusual or unexpected results
- Not deviate from procedures or take short cuts because of time pressure
- Just do what you can. If you cannot do the job safely in the time available, complete the work that you can do, safely and professionally.

Managing stress and time pressure in shift and task handovers

Ironically, one of the busiest times in the maintenance environment is during shift and task handovers. Generally during this time, paperwork is being completed (in a rush) and a briefing prepared for the oncoming shift. Often, shifts and supervisors do not get the opportunity for a face-to-face handover.

The quality of information in shift and task handover notes varies from organisation to organisation, and sometimes is of a very poor standard. Where possible, it is best to have an overlap between shifts to ensure a face-to-face handover. In all cases, however, provide a written handover to the oncoming shift, or the team, or individual, taking over a specific maintenance task. All organisations should have a formal process of providing clear information for task/shift handover to the incoming maintenance team.

The following case study illustrates how important thorough shift handovers are.

Poor shift handover almost results in loss of aircraft

In August 1993, an A320 taking off experienced an uncommanded roll to the right as it became airborne. Initially, the crew thought that this was due to the crosswind, but the handling pilot had to apply full left sidestick to maintain heading. Believing that his sidestick might have been faulty he passed control to the other pilot. The second pilot also found that he had to maintain almost full left sidestick to contain the roll. Because in this aircraft most warnings are inhibited below 1500ft radio height, the ECAM (electronic centralised aircraft monitoring) system did not signal any faults until the flaps were retracted at 1700ft. It then sounded a repetitive chime indicating a serious fault, displaying messages that flight control had reverted to alternate yaw and that some of the spoilers were inoperative.

The aircraft was reconfigured and ATC was informed that a higher speed, flaps 1 approach would be made. This proved successful and the aircraft landed 37 minutes after take-off. As the aircraft was taxiing, it was noted that several spoilers on the starboard wing were up.

As a result of bird strike damage, the aircraft's right hand outboard flap had been replaced only hours before this flight. The work was carried out by a maintenance organisation contracted by the airline. Although the job was within the organisation's capability, it had not previously been performed by the nightshift engineer allocated the task—a licensed aircraft engineer with certificate of release to service authorisation on the A320—or any of his assistants.

The events documented and the engineer's statements demonstrated that the requisite maintenance manual was not complied with at several stages. The only demonstrable non-compliance by the night shift was failure to follow the procedure to extend and lock the spoilers. The day shift did not carry out the subtask reinstating the spoilers, nor did they perform a function test of the spoilers.

Company requirements were also not complied with in connection with the shift handover and the production of the reinstatement stage sheets. These were not merely academic deviations from the letter of the requirements, as each significantly contributed to eroding the safety system and creating the resultant flight hazard.

Adapted from an edited and abbreviated version of AAIB Aircraft Accident Report 2/95

How can we manage stress and time pressure during shift handovers?

Manage stress and time pressure during the shift handover by planning appropriately, and communicating. Before the shift ends, you should identify an obvious and appropriate point in the maintenance process to complete the work, also allowing sufficient time to complete the paperwork and brief the shift/maintenance supervisor. The shift/maintenance supervisor also needs to allow adequate time for all tasks (including completing any outstanding maintenance documentation) and a comprehensive written shift handover log to be completed before the incoming shift's arrival.

An example of a shift/task handover log is included below:

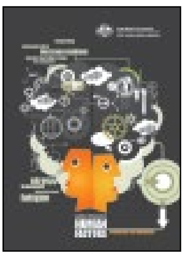
SHIFT – TASK HANDOVER SHEET	
COMPANY	
SHIFT/TASK	
TIME/DATE	
Aircraft registration	
Maintenance procedure reference	
Task details	
Steps completed	
Steps required	
Power restrictions	
Items/equipment disconnected for access	
Test equipment in use	
Equipment/tooling/GSE deficiencies identified	
Fault finding conducted	
Additional information/comments	
NAME	**TRADE/POSITION**

Key points

- High levels of stress are a problem for any individual or maintenance team: the effects of stress are often subtle and difficult to assess.
- Stress is often described as being insidious, that is, it develops slowly, and has a gradual and cumulative effect. It can be well established before we are aware that it is degrading our performance.
- Inappropriately high levels of stress can degrade your performance significantly. As a result, safety can also be compromised.
- Fitness for work is not just a physical condition, but also a psychological one. It involves being able to perceive, think and act to the best of our ability without the hindering effects of stress, anger, worry and anxiety.
- Work overload occurs when the number and complexity of the tasks allocated to an individual or team exceed their ability to cope. As performance deteriorates, we are forced to shed tasks and focus on key information; error rates may also increase.
- If you are interrupted during a safety-critical maintenance task, take appropriate steps to ensure you have not omitted any maintenance actions or procedural steps.
- To an individual, self-imposed pressure is real, and is no different from any actual pressure being applied to get the job done.
- Where possible, it is always best to have an overlap between shifts to ensure a face-to-face handover. In all cases, however, a written handover should be provided to the oncoming shift, or the team or individual taking over a specific maintenance task.
- Before the shift ends, identify an obvious and appropriate point in the maintenance process to complete the work, also allowing sufficient time to complete the paperwork and brief the shift/maintenance supervisor.

Further information

Sellers, R, (2011): *Managing the risks of interruptions and distractions during safety-critical maintenance*



When you are ready, please turn to page 37 of the *Workbook for Engineers* and complete the exercises.


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 7

ALCOHOL AND OTHER DRUGS (AOD)

The use of alcohol and other drugs (AOD) can have a negative effect on aviation maintenance safety. They can affect an engineer's ability to think, to process information quickly and efficiently, and to respond to new situations appropriately. This chapter looks at the effects of alcohol and other drugs, risk factors and CASA's AOD program.

Above the influence.

Anonymous

Introduction

Alcohol and other drug use (AOD) by engineers can affect the critical decision making necessary for safe maintenance. This chapter discusses the effects of alcohol and other drugs, AOD risk factors, and symptoms to be aware of.

CASA's AOD program also includes further information, such as a random testing regime and an outline of what makes up a drug and alcohol management plan (DAMP).

Are alcohol and other drugs (AOD) a problem in aviation maintenance?

Well, according to a study of drug use in air transportation in the United States, aviation engineers are no different from any other cultural group. In other words, recreational drug use is a small part of any sample of the general population. When analysing the results of pre-employment drug tests and random tests between 1991-1992 for all U.S. transportation employees, by far the highest number of positive drug test results came from maintenance personnel (1,586 in 1991 and 1,598 in 1992), with marijuana being the most prevalent positive drug test result (over 50 per cent)[31]. However, it must be stressed that positive random test results remained below one per cent, which is considered a very low rate.

While there does not appear to be any documented aviation incident investigation reports citing drug use by aviation engineers as a causal factor, this does not mean that engineers are not affected by alcohol and other drugs while at work. Consider the following scenario:

What would you do?

One of your colleagues has arrived at work for an early shift, appears to be tired, has bloodshot eyes, and smells of alcohol. You have worked with this person a number of times before, and this behaviour appears uncharacteristic. Your colleague acts as if things are normal and is preparing to start the shift.

Do you:

1. Turn a blind eye, ignore him, and hope for the best?
2. Pull him aside and have a quiet chat, asking if anything is wrong? In your conversation, you suggest that if he has been drinking some time before work, he should call sick and go home.
3. Go straight to your supervisor, saying you think your colleague may be under the influence and his ability to do his normal job could be impaired.
4. Quietly suggest that he sees the supervisor himself, as you think he might be unfit for work. Remind him that being 'not fit for work', is unacceptable, given the potential safety implications.

Let's look at each of these options to see what might be the best and safest course of action.

Taking professionalism, personal standards and most importantly safety into consideration, turning a blind eye is not advisable, and would even play on our own conscience. How would you feel if an incident involving your colleague, which you had the power to avoid in the first place, occurred later?

Pulling him aside for a quiet chat may address the immediate problem on the day, but does nothing to address a potentially greater problem. Suggesting that he go home sick conveniently avoids the issue, and may mask problems with AOD dependence. Also, by allowing him to go home, you have not considered the risk factor of that person getting into their vehicle and becoming a danger on the road.

[31] James Hall (1997). Alcohol and other drug use in commercial transportation. NTSB Washington DC.

Advising your supervisor passes on your responsibility to a higher authority and allows the issue to be dealt with according to organisational policies and procedures. However, the downside of this option is that you may be labelled a 'dobber', which could create personal consequences for you and other work mates in the future.

This then leaves you with the only choice—the last option. Should you suggest that he tell the supervisor himself?

This is a difficult choice as it raises internal debates about what is right for them, right for us, right for the organisation, as well as what is right and best in the interests of safety. The challenge for the organisation is managing the situation through their drug and alcohol management plan (DAMP), which should outline a process for dealing with this type of situation. One of the main challenges, for individuals and organisations, is maintaining trust: the situation must be handled with maturity and sensitivity. Your colleague, whom you perceive is unfit for work, needs to understand that he has not considered the safety implications by turning up to work in an unfit state.

Not only is turning up for a shift while still under the influence of alcohol or drugs against the company's (CASA-approved) DAMP, but it is also a serious risk to aviation safety. However, the reason for someone being affected by drugs could vary widely—from a one-off, silly mistake such as a big night out the night before, to a chronic drug dependency problem. By not addressing the problem, you are not helping your workmate get the help he needs.

Having the ability to approach your supervisor about your fitness for work should be seen as a safety-first measure, acknowledging that you may have made an honest mistake. Whether you choose to stay at work but not do any safety-critical tasks, or take a taxi home, depends on the procedures in your company's DAMP for managing such circumstances.

Overview

The drugs most commonly used by Australians are alcohol, coffee, nicotine and various prescribed medications. Less commonly used are illegal drugs such as cannabis (marijuana), ecstasy, heroin and methamphetamines (speed). The largest collection of information about AOD use by Australians is the annual National Drug Strategy Household Survey (released by the Australian Institute of Health and Welfare). The most recent survey tells us that:

- Eighty-six per cent of Australians aged 14 and over consumed alcohol during the previous 12 months
- Of these, approximately 20 per cent drank at short-term risk levels; intoxication or hangover leading to falls, burns, injuries, accidents, alcohol poisoning etc. Just over 10 per cent drank at long-term risk levels—heavy drinking over a long time leading to liver and brain damage, cancers, circulatory problems etc.
- Cannabis was the most commonly used illegal drug in Australia (2007). At that time, over 5.5 million people said they had used it.
- Approximately one in 10 had used cannabis in the last 12 months, while one in 20 had used it in the previous month.

What is a drug?

A drug is any substance, (solid, liquid or gas) that brings about physical and/or psychological changes. The drugs of most concern in the community are those affecting the central nervous system. They act on the brain and can change the way you think, feel or behave. These drugs are known as psychoactive drugs.

When we use substances such as alcohol, our capacity to think and move is generally impaired. The changes may be slight, but when engineers are involved in safety-sensitive aviation activities, AOD use can lead to dangerous errors.

The effects of alcohol and other drugs include:

- Slowed processing of information
- Slowed perception
- Longer reaction time. Responses to hazards are slower, and the number of inappropriate avoidance manoeuvres increases
- Reduced coordination and ability to track or follow movement
- Reduced ability to concentrate
- Reduced ability to see alternative solutions, to think flexibly
- Attention problems
  - Focused attention—concentrating on a single task
  - Divided attention—coping with a number of sources of information at once
  - Sustained attention—concentrating on one thing for some time
- Memory (including short-term memory, and the memory store for visual and spatial information)
- Increased risk taking.

How are drugs classified?

Drugs are commonly classified according to their legal status, or their effects on the central nervous system.

Legal drugs

Laws and regulations control the availability, quality and price of legal drugs. For example, alcohol may not be sold to persons under the age of 18.

Illegal drugs

Because they are illegal, there are no price or quality controls on illicit drugs such as heroin and ecstasy. This means that users can never be sure that the drug they are taking is in fact what they think it is. For example, PMA (paramethoxyamphetamine), a toxic form of amphetamine, has been sold as ecstasy. The user also cannot be sure of a drug's strength or purity. Various batches of an illegally manufactured drug may have different mixtures of the drug and additives such as talcum powder, caffeine or even poisons.

Central nervous system

There are three main types of drug affecting the central nervous system: depressants, stimulants and hallucinogens.

1. Depressants

slow down the functions of the central nervous system. Depressant drugs do not necessarily make a person feel depressed. In small quantities, depressants can cause the user to feel more relaxed and less inhibited. In larger quantities they can cause unconsciousness, vomiting and even death. Depressants affect concentration and coordination. They slow down the ability to respond to unexpected situations.

They include:

- Alcohol
- Cannabis
- Barbiturates, including Seconal™, Tuinal™ and Amytal™
- Benzodiazepines (tranquilisers), such as Rohypnol™, Valium™, Serepax™, Mogadon™, Normison™ and Eupynos™
- GHB (gamma-hydroxybutrate), or fantasy
- Opiates and opioids, including heroin, morphine, codeine, methadone and pethidine
- Some solvents and inhalants, many of which are common household products.

2. Stimulants

on the other hand, act on the central nervous system to speed up the messages to and from the brain. They can make the user feel more awake, alert or confident. Stimulants increase heart rate, body temperature and blood pressure. Other effects include reduced appetite, dilated pupils, talkativeness, agitation and sleep disturbance.

Large quantities of stimulants can 'over-stimulate' the user, causing anxiety, panic, seizures, headaches, stomach cramps, aggression and paranoia. Prolonged use of strong stimulants can mask some of the effects of depressant drugs, such as alcohol, making it difficult for a person to judge their effects.

Mild stimulants include:

- Ephedrine (used in medicines for bronchitis, hay fever and asthma)
- Caffeine (in coffee, tea and cola drinks)
- Nicotine (in tobacco).

Stronger stimulants include:

- Methamphetamines, including illegal methamphetamines
- Cocaine
- MDMA/ecstasy
- Slimming tablets (such as Duromine™, Tenuate™, Dospan™ and Ponderax™).

3. Hallucinogens

affect perception. People who have taken them may believe they see or hear things that aren't really there, or what they do see may be distorted in some way. The effects of hallucinogens vary a great deal, so it is impossible to predict how they will affect a particular person at a particular time.

Some effects of hallucinogens include dilation of pupils, loss of appetite, increased activity, talking or laughing, emotional and psychological euphoria and wellbeing, jaw clenching, sweating, panic, paranoia, loss of contact with reality, irrational or bizarre behaviour, stomach cramps and nausea.

Hallucinogens include:

- Datura
- Ketamine™
- LSD
- Magic mushrooms
- Cannabis is a hallucinogen as well as a depressant. Ecstasy can also have hallucinogenic qualities.

How do drugs affect people?

The effects of a drug depend on the type of drug, how much is used, how it is taken, the characteristics of the person taking it (body type and mood), the situation or place at which the drug is taken, and other drugs used at the same time.

Some factors to consider include:

- How much of the drug is taken and how often
- How the drug is taken
- A person's physical characteristics, such as height, weight and gender
- The person's mood and their environment
- Tolerance to the drug
- Other drugs used (poly/multiple drug use).

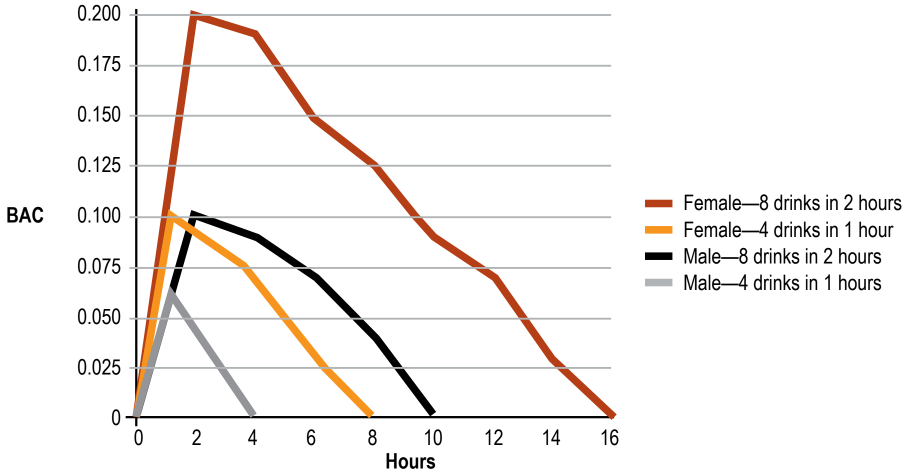
What is alcohol?

The term alcohol describes a series of organic chemical compounds, but only one type, ethyl alcohol or ethanol, is found in drinks intended for human consumption. Alcohol is a central nervous system depressant—the central nervous system is the bodily system most severely affected by alcohol, as illustrated in the table below summarising the stages of alcohol intoxication.

The degree to which the central nervous system function is impaired is directly proportional to the concentration of alcohol in the blood.

Stages of alcohol intoxication

BAC (g/100 ml of blood or g/210 l of breath)	Stage	Clinical symptoms
0.01 - 0.05	Subclinical	Behaviour nearly normal by ordinary observation
0.03 - 0.12	Euphoria	▪ Mild euphoria, sociability, talkativeness ▪ Increased self-confidence; decreased inhibitions ▪ Diminution of attention, judgement and control ▪ Beginning of sensory-motor impairment ▪ Loss of efficiency in finer performance tests
0.09 - 0.25	Excitement	▪ Emotional instability; loss of critical judgement ▪ Impairment of perception, memory and comprehension ▪ Decreased sensory response; increased reaction time ▪ Reduced visual acuity; peripheral vision and glare recovery ▪ Lack of sensory-motor coordination; impaired balance ▪ Drowsiness
0.18 - 0.30	Confusion	▪ Disorientation, mental confusion; dizziness ▪ Exaggerated emotional states ▪ Disturbances of vision and of perception of colour, form, motion and dimensions ▪ Increased pain threshold ▪ Decreased muscular coordination; staggering gait; slurred speech ▪ Apathy, lethargy
0.25 - 0.40	Stupor	▪ General inertia; approaching loss of motor functions ▪ Markedly decreased response to stimuli ▪ Marked decrease in muscular coordination; inability to stand or walk ▪ Vomiting; incontinence ▪ Impaired consciousness; sleep or stupor
0.35 - 0.50	Coma	▪ Complete unconsciousness ▪ Depressed or abolished reflexes ▪ Subnormal body temperature ▪ Incontinence ▪ Impairment of circulation and respiration ▪ Possible death
0.45 +	Death	▪ Death from respiratory arrest



How long does alcohol take to be eliminated from the body?

The figure above demonstrates how long it takes for alcohol to be eliminated from the body, taking into account factors such as the different rates for men and women, the number of drinks consumed, and the time over which drinking occurs. The calculations refer to standard drinks.

- A standard drink is any drink containing 10 grams of alcohol. One standard drink always contains the same amount of alcohol regardless of container size, or alcohol type (i.e. beer, wine, or spirit).

  So:

  - A stubby of full-strength beer is about 1.5 standard drinks
  - A stubby of mid-strength beer is about 1.2 standard drinks
  - A stubby of light beer is just under one standard drink
  - One 30ml nip of spirits (a standard full nip) is one standard drink
  - A glass of wine is about two standard drinks, and a bottle of wine contains about eight standard drinks.

Hours required to return blood alcohol concentration (BAC) to zero

Blood alcohol concentration depends on the amount of alcohol consumed and the rate at which the user's body metabolises alcohol. Because the body metabolises alcohol at a fairly constant rate (somewhat more quickly at higher and lower alcohol concentrations), ingesting alcohol at a rate higher than the rate of elimination results in a cumulative effect and an increasing blood alcohol concentration.

Alcohol and safety

Alcohol is a depressant drug, even though it may feel stimulating at first. Within minutes of drinking, some alcohol will be absorbed into the bloodstream. Certain things, such as eating, affect the alcohol absorption rate; eating slows down absorption. Even a small amount of alcohol affects decision-making skills. If alcohol were to be present in your system, your ability to perform certain maintenance, such as trouble-shooting, could be affected.

AOD consumption and the workplace

In general, community consumption patterns are also likely to be mirrored in the workplace. However, for some industries and occupations, there are likely to be particularly high levels of use of either alcohol or other drugs, or both. As the majority of Australians who use alcohol or illicit drugs are employed, it follows that patterns of harmful alcohol use and illicit drug use are evident in the Australian workforce. Harmful alcohol consumption and illicit drug use can be found at all levels in organisations.

Workers employed in some industries and occupations report higher levels of AOD consumption compared to others. For example, tradespeople, farm managers, labourers, hospitality industry workers, and agricultural industry workers report higher levels of risky drinking. In the transport industry, some drivers report using methamphetamines to stay awake. Similarly, nurses and others in health-related occupations are more likely to misuse pharmaceuticals compared to other occupations. In some cases, the manufacturing industry has higher levels of cannabis use than to other industries.

Risk factors

Variations in alcohol and illicit drug consumption patterns between industries and occupations indicate that workplace environmental and cultural factors may influence these consumption patterns. For example, research indicates the following factors may contribute to employees' alcohol or other drug use:

- The physical environment of the workplace, including:
  - hot or dusty conditions
  - hazardous or dangerous work
  - inadequate training
  - poor quality equipment
  - lack of appropriate resources.
- Availability, including:
  - availability of alcohol and other drugs at the worksite
  - social and peer pressure to drink on site
  - demands of the job, which make use obligatory (e.g. socialising with clients)
  - lack of a clear alcohol and other drug policy.

- Stress, resulting from:
  - poor/volatile industrial relations climate
  - lack of control over the planning, (or pace) of work
  - heavy responsibility
  - unrealistic performance targets and deadlines
  - overwork/underwork
  - fear of retrenchment
  - workplace bullying/harassment.
- Characteristics of the job, including:
  - extended or excessive hours
  - shiftwork
  - low visibility/working offsite
  - boring, repetitive, or monotonous work
  - lack of job security
  - low job satisfaction
  - poor promotion opportunities
  - level of income.
- Management style, including:
  - absence of clear goals
  - lack of supervision
  - lack of accountability
  - poor feedback on performance
  - lack of, or inconsistent, performance standards.

Impact of AOD on the workplace

Alcohol and other drug use can have a substantial negative impact on the workplace. For example, studies show that lost production from harmful AOD use is costing Australian industry in excess of $4.5 billion per year. Research from 2003 also indicates that up to 15 per cent of all Australian workplace accidents may be associated with alcohol use, and that at least five per cent of all Australian workplace deaths are associated with alcohol use.

Alcohol and other drug use can have a variety of negative outcomes that are costly for both employers and employees:

- Accident costs, including:
  - accidents resulting in injury or death
  - lost employee work time
  - damage to tools and equipment repair costs
  - increased insurance costs/WorkCover levy
  - possible bad publicity

- reduced productivity
  - lower quantity and quality of work
  - loss of business
  - loss of skills when employee terminated/injured/ill
  - co-workers covering for affected employees
  - costs associated with prosecution.
- Absenteeism costs, including:
  - lost production
  - disruption of operations
  - covering for lost employee time.
- Staff turnover costs, including:
  - costs of dismissal or premature retirement
  - replacement of employees
  - training of new employees
  - loss of skills and experience
  - loss of investment in employees.
- Cost to the individual employee, including:
  - possible injury to self and others
  - demotion/discipline/dismissal
  - problems with family, friends and workmates
  - loss of self-esteem
  - loss of wages
  - cost of medical expenses.

AOD in aviation maintenance

In a safety-critical environment such as aviation maintenance, optimal performance is required for safe operations and work practices; it is an ethical and professional necessity. Safe performance of maintenance requires high-level cognitive function and psychomotor skills. Anything impairing these functions and skills threatens safety, so AOD use by maintenance engineers is a major potential risk.

Avoidance is the best strategy. If you know you are required to work within around 10 hours of your last drink, adopt this as a minimum personal standard. While 10 hours 'bottle to spanner' may be a guide, remember that we process alcohol differently, depending on factors such as age, weight, gender and overall health.

The important thing is to be professional about the work you do. Perhaps restricting the amount you consume is a worthwhile strategy. For example, limit your consumption to two or three drinks, knowing that your body needs time to process the alcohol out of your system, so that you are fit and safe for work the following day.

You also need to consider the medications you take and how they may impair your performance. The following are some of the over-the-counter and prescription types of medication in common use and how they may affect you. This list is not exhaustive; you should take care to find out the likely effects of any prescribed drug before you take it. Always seek advice from your doctor and pharmacist, and in particular, declare what kind of work you do, so they can take that into account when prescribing medication.

1. **Sleeping tablets:** these can dull the senses, cause mental confusion and slow reaction times. How long this effect lasts varies from person to person and may be unduly prolonged. You should seek expert medical advice before using them.
2. **Anti-depressants:** these can depress the alerting system and have contributed to errors, in turn leading to fatal accidents. You should stop work when starting anti-depressants and only return when it is clear that there are no untoward side effects. It is recommended that individuals seek medical advice from their general practitioner or appropriate medical specialist before returning to work.
3. **Antibiotics:** antibiotics (penicillin and the various mycins and cyclines) and sulphur drugs may have short-term or delayed effects, which can affect work performance. Their use indicates that a fairly severe infection may well be present and, apart from the effects of these substances themselves, the side-effects of the infection will almost always render a person unfit for work.
4. **Anti-histamines:** such drugs are widely used in cold cures and in the treatment of hay fever, asthma and allergic skin conditions. Many easily obtainable nasal spray and drop preparations contain anti-histamines. Most anti-histamines tend to make the user feel drowsy, making operation of equipment or vehicles not recommended. Admittedly, very mild states of hay fever etc. may be adequately controlled by small doses of anti-allergic drugs, but a trial period to establish the absence of side effects is essential before going on duty. When individuals are affected by allergic conditions requiring more than the absolute minimum of treatment, and in all cases of asthma, you should seek medical advice.
5. **'Pep' pills:** (e.g. containing caffeine, dexedrine, benzedrine) used to maintain wakefulness can be habit forming. Individuals vary in their susceptibility to each drug, but all of them can create dangerous over-confidence. Overdosage may cause headaches, dizziness and mental disturbances. The use of 'pep' pills whilst working cannot be permitted. If tea or coffee is insufficient, you are not fit for work.
6. **Drugs for the relief of high blood pressure:** these are proving to be very effective in controlling this condition. However, antihypertensive agents all have some side effects, and should not be administered before adequate assessment of the need for treatment. Your prescribing practitioner should be able to advise of any side effects you should consider.
7. **Anti-malarial drugs:** prescribed in normally recommended doses do not usually have any adverse effects.
8. **Oral contraceptive tablets:** in the standard dose do not usually have adverse effects, although regular supervision is required.
9. **Sudafed™** is the trade name of a preparation often containing pseudoephedrine hydrochloride. Your doctor may prescribe this for relief of nasal congestion. Side effects reported, however, are anxiety, tremor, rapid pulse and headache. The preparation does not contain anti-histamines, which could sedate and cause drowsiness, but it can nevertheless affect skilled performance. Sudafed™ or similar medications, therefore, should not be taken when making engineering decisions or performing safety-critical tasks.

CASA's alcohol and other drugs program

Background

The decision for the introduction of the aviation alcohol and other drugs program was based on a joint report prepared in 2005 by the Department of Transport and Regional Services (DOTARS) and the Civil Aviation Safety Authority (CASA), at the direction of the Australian Transport Safety Bureau (ATSB), into the safety benefits of introducing drug and alcohol testing for safety-sensitive aviation workers.

Safety benefits

The ATSB has noted that key cognitive functioning and psychomotor skills are generally impaired following the use of substances such as alcohol and illicit drugs. The use of such substances can therefore compromise our ability to undertake tasks safely, with clear negative implications for other aviation personnel and passengers who depend on the integrity of our work.

The joint CASA and DOTARS report found:

> '… that alcohol and other drugs testing offers a number of safety benefits. Most importantly, it offers a mechanism to measure, manage, prevent and recover from the use of these substances. A testing regime provides an opportunity to quantify an issue that to date relies on anecdotal evidence in an Australian context. It also provides a tool, together with self-referral, for dealing with usage by individuals, and applying a exclusion from safety-sensitive roles and remedial action focusing on return to duty through range of responses including Employee Assistance Programs (EAPs) ... Without a testing program, substance abuse continues to exist and is more likely to be undiscovered, unrecognised and unreported.'

Under CASA Regulations (CASR Part 99) a range of organisations, and some individuals, must have a drug and alcohol management plan (DAMP). These organisations are those whose employees, contractors or subcontractors perform, or are available to perform, safety-sensitive aviation activities (SSAA). This includes aviation maintenance activities.

In particular, Part 145 organisations servicing RPT aircraft, must have a DAMP.

Key considerations in developing a DAMP

The particular industry member or their advisers can develop their DAMP, or you can base it on the template DAMP included in these guidelines, and available on the CASA AOD website: http://aod.casa.gov.au/aod/

What does a successful DAMP look like?

Consultation

A key part of an effective program is consultation with key stakeholders, including management, unions and other employee representative organisations, occupational health and safety representatives, supervisors and other employees. Consulting with these stakeholders as you develop and implement the program is vital for its credibility and acceptance.

Coverage

The program must detail clearly those whom it covers. There is evidence that programs which apply to all employees are more effective. Part 99 of the CASR only applies to those undertaking safety-sensitive aviation activities, as CASA only regulates flight safety, but organisations may choose to apply their policies and/or programs to all employees.

Organisation specific

You can use generic or template programs as the basis of your organisation's program, but they are most effective when you adapt them to suit the specific requirements and resources of your workplace. Organisational, social and environmental factors specific to individual workplaces are likely to influence how effective a program is.

Comprehensive policy

A program should not only set out rules about consumption of alcohol and other drugs in relation to workplace safety. Good practice programs also include policy on manufacture, possession, use, sale and distribution on any worksite or organisation's premises. The policy can also clearly specify under what circumstances (if any), alcohol consumption can occur on site (e.g. workplace social functions).

Responding to AOD-related incidents

For the benefit of both supervisors and other staff, an effective program should include procedures for managing personnel with AOD-related problems, such as: guidelines for managing those who are intoxicated; information on treatment services and counselling procedures; and the details of any disciplinary action taken as a result of problematic AOD use.

Drug and alcohol testing

Although testing is one component of a program, it should not be the only way of reducing AOD harm. The DAMP policy document should include the rationale and procedures for testing, as well as explaining what a positive test means, and its consequences.

Communication of the program

Effective communication, using a variety of communication strategies appropriate for the target audience, is essential for successful implementation. This communication needs to use media all employees have access to and understand. You will probably need to use several different forms of communication, such as an intranet, staff bulletin, toolbox talks, posters, or even a note attached to employees' payslips—electronically or physically. For your overall AOD program to be effective you need effective change management techniques—clear and timely communication is vital for this.

Defined roles and responsibilities

Employees need to know exactly what their roles and responsibilities are. Your policy should define these, and affected employees should receive training. Training and communication can also raise awareness of your program, and improve supervisors' and other employees' capacity to implement it.

Evaluation

Implementing any safety program is an ongoing process: following initial implementation, it is good practice to evaluate if its objectives are being met. This ensures compliance and accountability, and provides important feedback to further improve the program. Under Part 99, organisations must review their DAMP periodically, record outcomes and provide reports to CASA. CASA will also conduct DAMP audits to evaluate compliance. This audit process also provides an opportunity to continue to improve your DAMP's effectiveness.

Ten AOD facts to remember

1 0.02 is effectively zero*

2 Each standard drink you consume takes one hour to clear your system

- one drink = one hour
- two drinks = two hours
- three drinks = three hours, and so on.

It all adds up.

3 The effects of alcohol can last up to 48 hours

4 So, you can be under 0.02, but still be disoriented and dehydrated

5 Over-the-counter does not necessarily mean safe#

6 Beware of codeine

7 You can be tested any time, anywhere (where safety-sensitive aviation activities take place)

8 Drugs tested for are: cannabis, cocaine, methamphetamine and opiates

9 'Rebound fatigue,' following lengthy periods of methamphetamine use, presents a considerable risk to safety

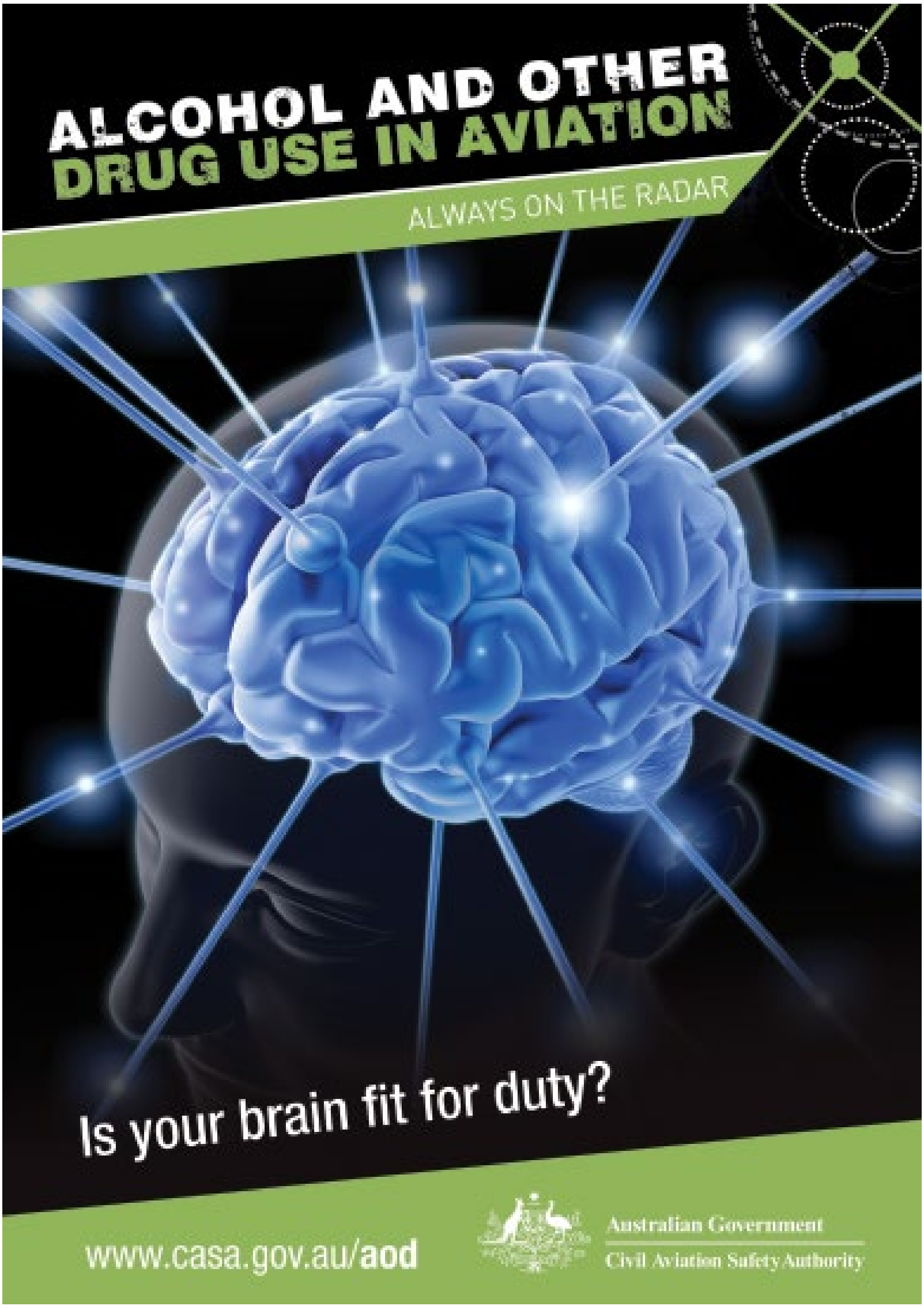
10 www.casa.gov.au/aod has all this information and more.

* Some query the 0.02 blood alcohol figure. The AOD program uses this figure because it gives scientific certainty that the person has actually consumed alcohol. This is distinct from what can happen in some people, whose bodies produce small amounts of alcohol naturally. The 0.02 figure therefore effectively means zero consumption of alcohol.

\# A range of over-the-counter, or prescription, drugs may result in a positive sample. You should always seek the advice of your doctor or pharmacist before using any medications or therapeutic substances. They can recommend alternatives.

Some of the over-the-counter or prescription drugs which may result in a positive sample are:

- Positive for opiates: preparations containing codeine (e.g. Panadeine™, Codis™, Codral Cold and Flu™, Nurofen Plus™), and preparations containing morphine (e.g. MS Contin™).
- Positive for amphetamine-type stimulants: preparations containing dexamphetamine.
- Positive for cocaine: some preparations used during ear/nose/throat surgery may contain cocaine.


ALCOHOL AND OTHER
DRUG USE IN AVIATION
ALWAYS ON THE RADAR
Is your brain fit for duty?
www.casa.gov.au/aod
Australian Government
Civil Aviation Safety Authority

Key points

This chapter has addressed the following key points:

- The effects of AOD are numerous—even mild alcohol ingestion or impairment can degrade relevant skills and abilities, in turn increasing the risk of errors and subsequent incidents/accidents.
- A blood alcohol content of zero does not ensure safe operations. Post-alcohol impairment must be acknowledged and managed as well.
- Maintenance personnel do safety-critical work—and should ensure that safety is put first. You have a duty of care to ensure that any medication you take will not put you or others at risk. There is no danger in seeking medical advice!
- CASA's AOD program aims to reduce the significant impact of alcohol and other drug use on aviation safety.

Further information

'AOD 12 months on'—CASA *Flight Safety Australia* magazine issue #76 Sep-Oct 2010 www.casa.gov.au/fsa

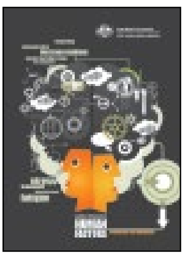
CASA AOD website: www.casa.gov.au/aod/

'Aircraft Maintenance Engineers' Personal Responsibility when Medically Unfit or under the influence of Drink or Drugs'. OTAC 66-1, 145-9

UK CAA Civil Aviation Publication 715, Chapter 4—'Factors Affecting Performance'.

UK CAA Civil Aviation Publication 716, Chapter 4—'Factors Associated with the Individual'.

FAA Federal Air Surgeon's Medical Bulletin, Vol. 48, No. 3 2010-3, *Aviation Safety Through Aerospace Medicine*, for FAA Aviation Medical Examiners, Office of Aerospace Medicine personnel, flight standards inspectors and other aviation professionals.



When you are ready, please turn to page 41 of the *Workbook for Engineers* and complete the exercises.


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 8

COMMUNICATION

Regardless of whether you work in a one-person operation or a large organisation, effective communication is a critical part of maintenance work. Misunderstandings and communication failures cost money, and at worst, can compromise safety. Clear communication can be the difference between getting a job right the first time, or expensive re-work; doing the job safely, or injury to maintenance personnel; and of course, safe flight or aircraft accidents.

The single biggest problem in communication is the illusion that it has taken place.

George Bernard Shaw, Irish dramatist

Barriers to effective communication in aviation maintenance

Communication problems are at the heart of many coordination breakdowns in maintenance, as the following example illustrates:

> Two of us were dispatching the aircraft. The nose steering bypass pin was left in. The aircraft began to taxi, but stopped as soon as no steering recognised. We removed pin and ops normal. This is a repetitive maintenance task; both of us assumed the other had the pin.
>
> *Anonymous report*

We often think communication is easy. After all, we do it all the time. Yet everyday communication is not as simple as it seems, and there is room for most of us to improve our communication skills. When maintenance supervisors in the U.S. were asked to name the most important skill needed to be effective in their current position, half mentioned people skills and communication. Many of them also said this was the part of the job they were least prepared for.

Managing communication

Communication can be defined as achieving shared meaning, and to be effective, requires four elements working together.

- The individual sending the message must present that message clearly, with the necessary detail, and should have credibility.
- The person receiving the message must be prepared to, and decide to, listen; ask questions if they don't understand something; and trust the person sending the message.
- The delivery method chosen must suit the circumstances and needs of both sender and receiver.
- The content of the message has to resonate and connect, on some level, with the already-held beliefs of the receiver.

If communication is to be effective, therefore, it has to be worked upon, and refined.

Communication channels

When we think of communication, we tend to think first of oral/spoken communication, but in the maintenance environment, as elsewhere, communication takes place via several channels, not just the spoken word.

Maintenance is heavily reliant on documentation for information transfer; for example, logbooks, maintenance manuals and parts catalogues. However, important information is also transferred via other means, over the phone, via face-to-face communication, and even through body language and other non-verbal cues. Communication in maintenance also occurs via physical cues such as the placement of tools and parts and the location of ground servicing equipment, tags or lockout devices. In some cases we consciously transmit or seek information, such as signing off a logbook entry, or referring to a maintenance manual. In other cases, however, we are still sending or receiving information without necessarily being aware that communication is occurring.

The main communication channels in maintenance can be summarised as oral—speech; written—documentation; non-verbal (wordless) cues; and physical cues.

Speech

Speaking is the most natural form of communication, yet oral communication is often far from perfect. The error rate for oral communication in industrial settings is estimated to be around 3 per cent[32]. In other words, approximately one out of every 30 spoken exchanges in workplaces involves a misunderstanding! In aviation, such communication errors can be catastrophic.

In 1989, a 747 freighter crashed into terrain when air traffic control told the pilot to 'descend two four zero zero', meaning 2400ft, but the pilot interpreted this as an instruction to descend to 400ft. Whenever oral communication occurs in maintenance, those conveying the message need to make sure the message has been understood, and those receiving it must listen, confirm that they have received the message, and ask questions if they have any doubts.

Documents

Maintenance is driven by paperwork, and communicating via documentation is such a part of the job many LAMEs spend more time wielding a pen than they do a spanner or a screwdriver. Communication via written material usually means there are few opportunities to clarify or query the message once it is 'sent'. This is a particular issue with pilot write-ups, a topic that will be dealt with later in this section.

In the English language, many words can have more than one meaning. Generally, this is a strength for the richness of the language, but for aviation maintenance, a potential problem. For example, in everyday English the word 'tap' has several different meanings, including: a tap above a sink, the action of removing fluid from something, to listen in on a telephone conversation, or to hit/strike gently.

The European Association of Aerospace Industries[33] has developed a form of simplified English to create brief and unambiguous text for aerospace manuals, and both Boeing and Airbus are now using the system. Simplified English limits the number of words used to describe steps and also ensures that each word only has one meaning. In simplified English, 'tap' has the meaning only of 'to hit something', as in 'tap with a hammer'. Information on simplified English is available at www.aecma.org

---

32 Kirwan, B. (1994). A practical guide to human reliability assessment. London: Taylor and Francis.

33 AECMA (1989). A guide for the preparation of aircraft maintenance documentation in the international aerospace maintenance language. Paris: Association Européenne des Consructeurs de Matériel Aerospatial.

Non-verbal communication

Non-verbal communication is important in maintenance, particularly in situations where speech cannot be used, such as in noisy environments, or where people are wearing hearing protection. Non-verbal cues include gestures, facial expressions, tone of voice, and body language. If you see a colleague walking in the direction of an aircraft carrying a toolbox, it probably sends you a message about their intentions, but of course it is possible to misinterpret such messages.

Particularly under time pressure or stress, we may see or hear what we expect, rather than what is actually there. The following maintenance incident illustrates the problem of misinterpreted body language.

> The aircraft flight manual and pilot's operations manual, which were removed from the aircraft earlier, were on a table inside the hangar. The pilot placed his hand on the two manuals on the table noting that they were, or had been, looked at. After a few minutes I went back into the hangar where I saw the cabin door being closed and latched by one of the crew from the inside. I recall looking over at the table and seeing the manuals not there any more, suggesting the crew had taken them with them. Just after that I noticed them on a chair.
>
> *ASRS Report*

Physical cues

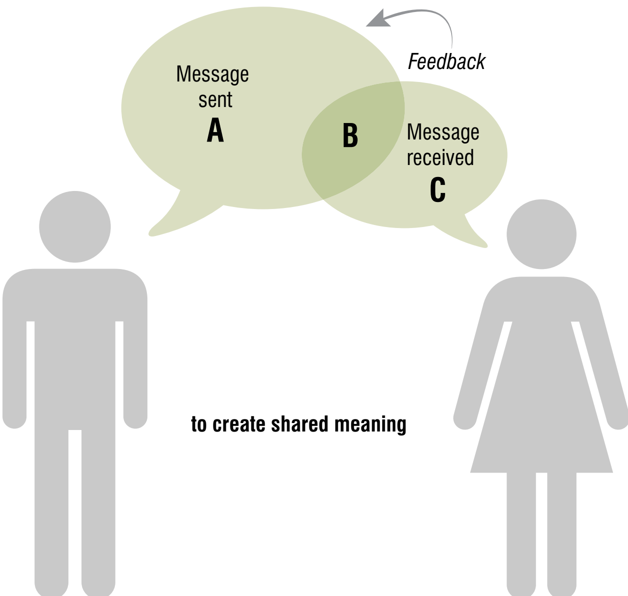
Maintenance also relies on physical cues to communicate information between maintenance personnel and to pilots.Some objects such as placards, tags or streamers attached to lock-out pins have been designed specifically to communicate information.

Information is also communicated by informal cues. An open cowl, or the position of a work stand, might send a message that maintenance is underway, but sometimes the message does not get through, or we do not realise that people have come to rely on these informal cues for communication. In the following example, a chain of communication issues nearly led to an unserviceable aircraft being operated. The example involves two communication channels—first the failure to use appropriate documentation, and second an unintended message sent by the apparent physical state of the aircraft.

> Aircraft arrived on Friday midday, and no time was stated when it had to be serviceable by. A job was started on an engine magneto with oral instructions, but not written in the maintenance release. At 5.00pm, no one had asked for the aircraft to be completed, so the cowls were fitted and the aircraft placed outside without the maintenance being finished. On Sunday, I was at the airport and a pilot was doing a daily check before departure. I was able to finish the timing and refit the cowls and sign for the job. The aircraft could have been operated unserviceable.
>
> *(LAME, respondent 315)*

What communication failures occurred in this example?

A model of communication



The figure above presents a simple model of communication. The diagram shows the message sent by the sender (A) and the message from the point of view of the receiver (C). The overlapping area (B) represents effective communication. The process of communication occurs in a context of 'noise', which means not only unwanted sound, but also other impediments to communication such as unclear speech, time pressure or distraction. The relative size of the areas in this diagram is for illustrative purposes only. We would hope that in your workplace effective communication is much more extensive than shown in the diagram! The diagram also shows that, in many cases, there is a potential for useful feedback from the receiver to the sender, as the receiver clarifies the message.

Communication errors can take several forms:

Errors by sender

- Message not sent—sender has a hidden agenda, and keeps information to themselves
- Incomplete or ambiguous message sent—sender uses inappropriate method (message left on phone, face-to-face communication not used for important/sensitive messages)
- Inconsistency between oral and non-verbal cues—sender's attitude/body language does not reinforce an urgent, safety-critical message.

Errors by sender and receiver

- Failure to reach clear understanding—shared meaning
- Wrong mode used (e.g. oral message when documentation required, or email sent assuming it would be read).

Errors by receiver

- Message not received
- Message understood incorrectly
- Message not clarified when necessary.

It is worth asking why these errors occur. For example: why would a sender not send a message? Or why would a receiver interpret a message differently from the sender? Some of the reasons for these communication breakdowns follow.

© Rolls-Royce plc 2013

Why does communication fail in aviation maintenance?

Failure to verbalise decisions a sender may decide to keep their plans to themselves, sometimes referred to as 'having a hidden agenda'.

Cultural barrier to speaking up a sender may fail to communicate because of a perceived barrier to communication, particularly between professional groups such as LAMES and pilots. The example below reflected a barrier between avionics, engine and airframe disciplines.

> 'An airframe and engine tradesman did not properly secure an oil line. I did not say anything, though I seem to remember noticing, as electrical instrument LAMEs comments on engine airframe systems are unwelcome/unheeded.'
>
> *Incident report*

Lack of assertiveness Assertive communication is direct and open, without being either aggressive or excessively polite. Assertiveness is a skill all maintenance engineers can develop. In the mid-1990s, a 747-300 landed with the nose wheel retracted. After the main wheels had touched down, and reverse thrust had been selected, the captain briefly considered applying power for a go-around. The flight engineer recognised that this would be unsafe and assertively stated 'No, you won't', which alerted the pilots that they were now committed to continuing with the landing.

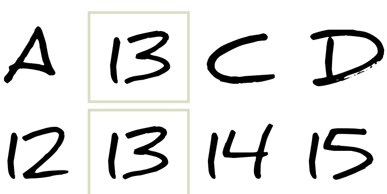
The following incident could have been prevented by just a small degree of assertiveness.

> While investigating a report of vibration near the left-hand over wing escape exit on an A319, my lead decided to check the hatch seals. He asked me to open the hatch. I believed that this aircraft had a slide, but due to noise and the approaching departure time, I opened the hatch as requested. The slide deployed as designed. If I had been more assertive and communicated my belief that the lead was incorrect, this incident could have been prevented.
>
> *ASRS report*

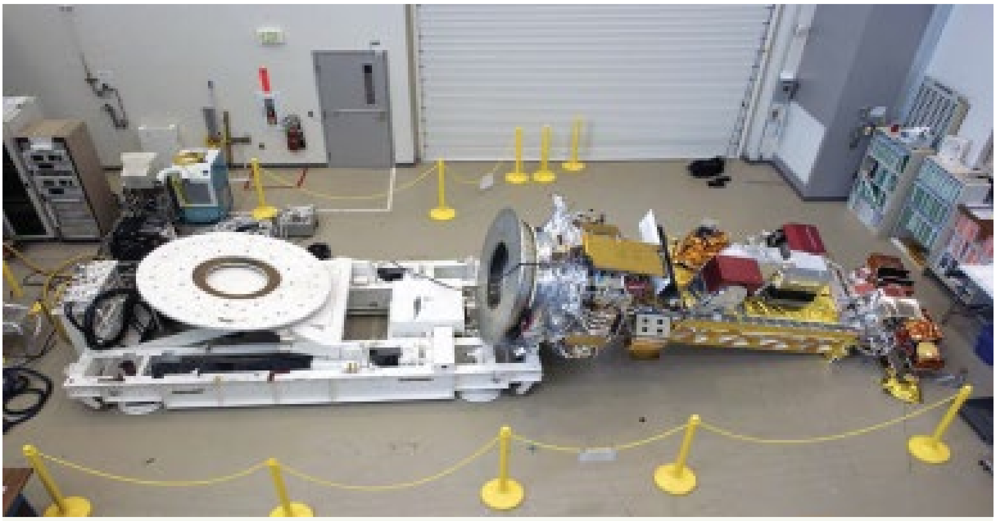
Passive listening A receiver who does not repeat, (or paraphrase) the message cannot be sure that they have completely understood it. If you phone through a delivery order to the local pizza parlour, chances are they will read back your order to confirm they have got it right. Yet a basic read-back such as this is often skipped in safety-critical workplaces such as hospitals and aircraft hangars, despite the potentially serious consequences of communication errors.

Expectancy errors Our expectations set the context for communication and influence the messages we receive. If you expect you are about to be told about an oil leak, but are told about a fuel leak instead, you may unconsciously continue to think about an oil leak. The following example shows how context can influence how we interpret a piece of information.

What do you see in the box on each line below? In fact, the symbols are exactly the same, but in each case the context leads us to see the symbols as either 'B' or the number '13'.



Inappropriate non-verbal cues If a colleague warned you that there was a fire in the building, but told you in a relaxed voice, and were making no apparent effort to do anything about it, you might assume that you had misheard them. Perhaps they were asking to borrow a file, or were telling you about a news story on TV. When there is a disconnect between non-verbal cues (such as tone of voice and facial expression) and the content of a message, we sometimes pay more attention to the non-verbal part of the message.
In maintenance operations, critical information is sometimes communicated without the necessary dramatic emphasis.



Satellite worth $500 million dropped due to communication error

An aircraft falling off jacks is bad enough, but what if you dropped a satellite worth $500 million? In 2003, a weather satellite known as NOAA-N Prime was dropped from a work stand during pre-launch preparations in California. The satellite fell about a metre to the ground while it was being turned from a vertical to a horizontal position.

Work stands at the facility were shared between two different satellite projects, and were kept in a storeroom when not being used. A couple of weeks before the accident, workers from the other satellite program had decided to use the work stand because their own stand was red-tagged with a problem. They went to the storeroom and began to prepare the stand by removing 24 bolts that held the special adaptor plate for the weather satellite, so they could fit an adaptor plate for their own satellite. After they had removed the bolts however, they decided it would be easier to repair their own stand, and use it to work on their satellite.

The stand in the storeroom was then left with its adaptor plate in place, but not connected by any bolts. There was no requirement to attach a red tag to the stand as it was understood that all personnel had a responsibility to verify that ground service equipment (GSE) was properly set up for use.

Two weeks later, the weather satellite needed to be attached to a work stand and rotated to a horizontal position to enable a piece of onboard equipment to be replaced. Almost all crew members said that they thought this was ‘just another routine operation’. The supervisor was required to conduct a pre-task briefing to make sure that all team members understood their roles, potential

Dropped satellite. Source of image: *NOAA N-PRIME Mishap Investigation, Final Report. September 13, 2004. National Aeronautics and Space Administration.*

problems had been identified, and the equipment was set up correctly. After the accident, some team members said that a pre-task briefing had been held, others did not remember a briefing.

The work stand was retrieved from the storeroom and the weather satellite was bolted to the adaptor plate, but the fact that the adaptor plate was not bolted to the work stand was overlooked.

The engineer in charge was required to check that the work stand was in the correct configuration through a visual and physical check, but instead he referred to paperwork from a previous operation to confirm that the stand was ready to rotate the satellite. Finally, the lead technician and an inspector signed the paperwork to verify that the satellite was ready to be rotated, without personally conducting or witnessing the operation.

Shortly before the satellite was rotated, one member of the team was overheard to remark that there were empty bolt holes on the work stand, but no one seems to have paid any attention to the comment. In general at this organisation, there was a strong reluctance to speak up and hold up an operation unless an individual was absolutely sure something was wrong.

The crew then began to rotate the satellite, but as it reached 13 degrees of tilt from the vertical, it slipped off the work stand and fell approximately a metre to the floor, tipping over in the process. Fortunately, nobody was injured.

The satellite was finally repaired (at a cost of $217 million) and was launched in 2009.

What communication problems do you think led to this accident?

Do any of these communication issues exist in your workplace? Which ones?

What could have been done to prevent the accident?

© Rolls-Royce plc

Communication with flight crew

There is often room to improve communication between pilots and maintenance personnel. In a recent study, pilots and maintenance personnel on two U.S. air carriers were asked about their use of the aircraft logbook. The results indicated a distinct split between the two groups.

Maintenance engineers frequently wanted more information from pilots' logbook entries, yet pilots were generally satisfied with the level of detail in maintenance write-ups. A common complaint from the maintenance personnel was that pilots made logbook entries in which a component was simply described as 'INOP' (inoperative) with no further details. Of interest was that pilots reported that they made logbook entries primarily to give information to maintenance personnel. Maintenance personnel, on the other hand, considered that their logbook sign-offs were made primarily for the regulator.[34]

The following incident report dealt with coordination between engineering personnel and flight crew.

> Difficulties with refuelling the aircraft had made us late. The captain was buzzing on the ground call while we were doing final checks; he interrupted the final walk-around inspection twice to ask us how much longer. The forward hatch was opened on transits on hot days to cool the electrical equipment. But this procedure is not used often, and this was not a hot day. We were not aware that the forward hatch had been opened and the warning light in the cockpit was unserviceable. This was in the log, but we didn't have access to the log and the problem had not been communicated to us. The aircraft failed to pressurise after departure, had to dump fuel and return to blocks. This happened earlier in my career. At the time we were young and naïve, didn't have the necessary skills to manage our time. Had too much respect for the captain's authority.
>
> *Anonymous report*

What communication failures occurred in this example?

[34] Munro, P., Kanki, B. and Jordan, K. (2008). Beyond 'INOP': logbook communication between airline mechanics and pilots. International Journal

Managing task handover, pre-task briefings and task changes

Task briefings

Task briefings can help to make sure all members of a team are ready to work together. Pre-task briefings are standard practice for surgeons and pilots, and should be for maintenance personnel as well.

Pre-task briefing

- What is the objective of the task?
- How will it be carried out?
- What equipment will be used?
- Does each person have a clearly assigned role?
- What could go wrong—what are the risks?

Briefing during the task where necessary

- Critique and update existing plans
- Evaluate results of previous decisions
- Inform crew of changes in task.

Post-task debrief

- Critique entire task
- Give all crew a chance to comment
- Feedback to crewmembers
- Identify areas for improvement.

Shift handovers

A critical area of maintenance communication is the shift handover. Even if you work alone or in a small team, there will still be times when a task is left partially completed, and either handed to another engineer, or resumed by you later. Studies have found that some of the most serious maintenance errors have resulted from communication problems during handovers.

An accident related to a shift handover

In 1991, an Embraer 120 experienced a structural breakup in flight and crashed near Eagle Lake, Texas, resulting in 14 fatalities. The night before the accident, the aircraft had been scheduled to have the de-ice boots replaced on the left and right horizontal stabilisers. The work was started by the evening shift, and was going to be completed by the midnight shift. Two supervisors were on evening shift that night; one was supervising the work on the accident aircraft, while the other was overseeing a C-check on another aircraft. The aircraft scheduled for the de-ice boot change was brought into the hangar at around 21.30 by the evening shift. Two mechanics and a quality control inspector then used a hydraulic lift platform to get access to the aircraft's T tail, which is about 20 feet above the ground. (Under the U.S. system, inspectors oversee the work of mechanics [LAMEs] but they are not usually expected to assist mechanics with tasks.) The mechanics started removing the screws that attached the leading edge/de-ice boot assembly to the underside of the left horizontal stabiliser, but were slowed down by some stripped screws. Meanwhile, the inspector removed the attaching screws from the top of the left horizontal stabiliser, and then moved across to the right side and removed those screws as well, anticipating that both de-ice boots would be changed that night, as planned.

The hangar supervisor for the midnight shift arrived early for work and saw the evening shift mechanics working on the right de-ice boot. The supervisor checked the evening shift inspector's turnover form and found no write-up on the aircraft—the inspector who had removed the upper screws had not yet made his log entries. The midnight shift supervisor then asked one of the evening shift supervisors (who had been working on the C-check) whether work had started on the left de-ice boot. The evening shift supervisor looked up at the tail where the mechanics were working and said 'no'. The midnight shift supervisor decided that the work on the left hand replacement boot would have to wait for another night.

At 22.30, the inspector who had removed the upper screws from the leading edges of both stabilisers filled out a turnover form with the entry, ‘helped the mechanic remove the de-ice boots’. He then clocked out and went home. Later, the inspector stated that he had placed the screws he had removed from leading edges of the stabiliser in a bag and had placed the bag on the hydraulic lift.

As the evening shift prepared to go home, one of the mechanics (M1) who had removed the screws from the underside of the left horizontal stabiliser gave a verbal handover briefing to an arriving mechanic (M2) from the midnight shift. However, M2 was then assigned to work on another aircraft and was instructed to verbally brief another midnight shift mechanic (M3) on the de-ice boot replacement task. Then yet another mechanic (M4) was told to work on the de-ice boot replacement. He was told to speak with a supervisor from the evening shift to find out what work had been done. Unfortunately, this mechanic (M4) approached the C-check supervisor from the evening shift, who told him that he did not think that there would be sufficient time to change the left de-ice boot that night.

Personnel on the midnight shift then proceeded to remove the leading edge assembly from the right horizontal stabiliser, attach a new de-ice boot to it, and then re-install the right leading edge assembly to the aircraft. The final stages of the work were done outside in the dark, as the aircraft had been pushed out of the hangar to make room for other work. None of the personnel involved noticed that screws had been removed from the upper surface of the left horizontal stabiliser, and they would have had no reason to suspect that the screws would have been missing.

Subsequently, the aircraft was cleared for flight. The first flight of the morning passed without incident, except that a passenger later recalled that vibrations had rattled his drink. He asked the flight attendant if he could move to another seat. The passenger did not tell anyone about the vibrations, and the other passengers did not notice them. The accident occurred on the next flight.[35]

What handover procedures might have helped to avoid this accident?

Did problems with verbal communication contribute to the accident?

Have you ever observed any of these problems in your own workplace?

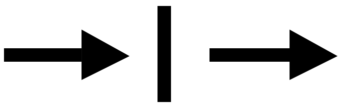
---

[35] National Transportation Safety Board Aircraft Accident Report, NTSB/AAR-92/04 1992, Continental Express Flight 2574, Embraer 120

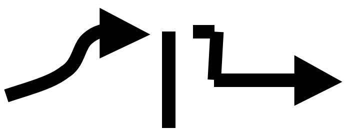
Effective and ineffective handovers

There are at least four types of maintenance shift handover, as shown in the diagrams below. In each case, the handover is indicated by a vertical line. The first shift is represented by the arrow on the left, and the second shift by the arrow on the right. Shift handovers are often focused on the transfer of information from one shift to the next, yet handovers also serve an important role as opportunities to catch and correct errors. A healthy level of scepticism can help to ensure that the incoming shift reviews the work of the outgoing shift, making as few assumptions as possible about its work.

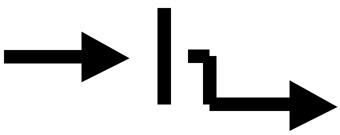
Four types of handovers



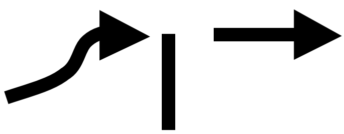
Ideal handover. This is the ideal shift handover, where the task is proceeding normally before the handover and proceeds normally afterwards.



Error recovery handover. Although not ideal, this is also an example of an effective handover. The task had gone off track during the first shift, but the handover provided an opportunity to identify the problem and correct it. An example is where an error made by the first shift is detected and corrected by the second shift.



Problem starts at handover. In this case, the task was performed correctly by the first shift; however, a problem began when the second shift took over. An example is a case where the first shift removed a faulty component for replacement. Instead of ordering and installing a serviceable component, the second shift then re-installed the faulty component.



Problem starts before handover. In this case, an error was made on the first shift, and personnel on the second shift continued the error.

Four ways to improve shift handovers

NASA researcher Dr Bonny Parke has studied what makes a successful handover, whether the setting is a drilling rig, a maintenance hangar, or a hospital.[36] She has made the following recommendations to improve handovers:

1 Use the handover as a chance to catch errors, not just communicate information

Critically check the work of the previous shift.

2 Improve shift handover documentation

In some cases there is a reluctance to produce written records beyond the minimum requirements. However, temporary sources of information such as whiteboards can still be an important source of task handover information.

3 Have direct verbal briefings between incoming and outgoing technicians

Face-to-face handovers are standard operating procedure in many high-risk industries such as nuclear power, offshore oil and air traffic control.

4 Communicate 'next steps,' not just 'work accomplished'

A good handover not only covers the work that has been accomplished, but also captures problems, possible solutions and future intentions.

[36] Parke, B., Patankar, K. & Kanki, B. (2003). *Shift turnover related errors in ASRS reports*. Proceedings of the 12th International Symposium on Aviation Psychology, April 14-17, Dayton OH. (pp 918-923)

Tips for improving communication and avoiding errors

When you are the sender

- Provide information as required
- Deliver information clearly and concisely
- Verbalise plans—surprises belong at birthday parties, not in hangars
- Use appropriate non-verbal communication
- Provide relevant information without being asked
- Ask for confirmation that message is understood

When you are the receiver

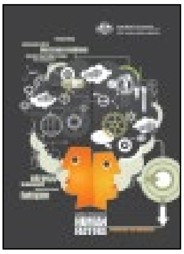
- Be an active listener
- Acknowledge and repeat information as required
- Paraphrase what you have heard
- Pay attention to non-verbal as well as verbal communication
- Clarify uncertainties, ask questions as necessary
- Provide useful feedback

Both sender and receiver

- Never assume
- Don't let the conversation end with unresolved ambiguities
- If a disagreement exists, take the most conservative action until more information is available

Key points

- Communication in maintenance involves not just words, whether written or spoken, but also non-verbal cues (e.g. body language and tone of voice) and physical cues (e.g. the positioning of tools and equipment).
- Some of the most serious maintenance-related accidents have resulted from poor communication. Communication can be surprisingly error-prone.
- Pre-task briefings should be a routine feature of maintenance tasks. Make sure everyone understands what the task will involve.
- Poor shift handover threatens maintenance quality. Consider what you can do at your workplace to prevent errors on tasks that extend over more than one shift.
- When you are the sender of a message, make sure the receiver has understood it.
- When you are the receiver, clarify the message and provide feedback to the sender. Be an active listener, and paraphrase what you are hearing.



When you are ready, please turn to page 47 of the *Workbook for Engineers* and complete the exercises.


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 9

TEAMWORK

Aviation maintenance is based mainly on maintenance teams carrying out a myriad tasks in cooperation with supporting management and regulatory structures. Effective teamwork is especially important for aviation maintenance, because it can help to avoid breakdowns in communication, defuse conflict and coordinate activity.

Coming together is a beginning.
Keeping together is progress.
Working together is success.

Henry Ford, American industrialist and founder of the Ford Motor Company

Safe and successful performance of the maintenance team

Successful teamwork is achieved when the output of the team is greater than the output that could be achieved by the sum of the efforts of the individual team members acting in isolation—a process known as synergy. Synergy occurs when each individual maintenance team member efficient maintenance relies on is empowered—in other words, encouraged to contribute in the most effective way to the overall task of the team. Interaction between maintenance team members creates a positive environment, increasing efficiency and productivity.

This interaction is unlikely to occur, however, unless all individual members of the team fully understand their role within the group, and how this role might vary depending on circumstances. Consequently, good communications within the group; a high degree of situational awareness; and a comprehensive understanding of the decision-making process by all members, are pre-requisites for creating synergy and effective performance of the team as a whole. Sound teamwork in aviation maintenance is a vital error management tool. There are many examples where maintenance teamwork failures have been found to be major contributing factors in aviation accidents.

Characteristics of teams

Good teams have certain characteristics. Typically, individual team members have high levels of task proficiency and good team skills. A team has good synergy when it performs at a higher level than would be expected of the same group of individuals working independently.

So what are the characteristics of teams with good synergy? These teams:

- Share and understand a common goal
- Have effective and balanced leadership
- Have effective followership (or team) skills
- Have a shared mental model
- Practise clear and effective communication
- Have clear delegation/role definition
- Have clear operating procedures
- Allocate workload appropriately
- Have an appropriate authority gradient
- Resolve conflict effectively.

Conditions for effective teamwork

A shared and understood goal

This is closely linked with providing a clear pre-task briefing. It is often assumed that everyone in the team knows what the goal is. However, this is not always the case. For a team to be effective, all team members need to know what the specific goal is, as well as what they need to do to achieve it. When the team has a shared and understood goal, all members of the team are 'pulling in the same direction' to achieve the stated goal, rather than working in isolation.

Effective leadership and followership

Good balanced leadership and followership skills are critical for effective team performance. The team leader needs to manage the workload, keep the team motivated, provide appropriate direction when required, and coordinate activities aimed at achieving the team goal. The follower is expected to act professionally, work towards the team goal and raise issues if they are unsure or disagree.

Effective teamwork will occur when team members have confidence in their leader and are consulted about, and involved in, making decisions. A good team leader takes the time to listen to, and evaluate, input from team members, and decides the best way to achieve a safe and efficient result, even if this course of action might not have been their first choice.

Leadership

Team leadership is all about coordinating team activities, so all members work well together. Good team leaders assess performance, assign roles, and develop knowledge and skills. Leadership requires specific skills such as the ability to motivate team members, to plan and organise work towards a specific goal, and keep the team focused on that goal. The team leader's ideas and actions influence team members' thoughts and behaviour.

Research[37] has shown that the most effective leaders of multi-disciplinary teams, whose team members must work together in risky, uncertain, dynamic situations, are those who communicate a motivating rationale for change and minimise concerns about status differences. This helps their team members to speak up and engage in a more coordinated, proactive way. The team leader must build the team from the individuals in it, motivating them towards the required shared goal and cementing team cohesion.

A study of the effectiveness of military teams[38] found the following leadership skills were essential:

- Defining the social structure, encouraging open communications and exhibiting self-disclosure to develop team cohesion
- Communicating effectively and informing other team members about matters affecting team performance
- Planning, structuring and coordinating the team
- Maintaining team focus on the task
- Asking for input from other team members and openly discussing potential problems
- Maintaining coherence within the team by managing situational awareness

---

[37] Flin, R., O'Connor, P., & Crichton, M. (2008). *Safety at the Sharp End. A Guide to Non-technical Skills*. Ashgate Publishing.

[38] Salas, E. and Cannon-Bowers, J. A. 1997. *Methods, tools, and strategies for team training, Applications of Psychological Research* (Washington, DC: American Psychological Association).

- Providing feedback to the other team members, the degree of successful feedback depending on the leader's style
- Adjusting their role to match team progress
- Defining and encouraging team goals and performance to promote commitment and consensus.

An effective leader has to be open to feedback from other team members and to evaluate that feedback objectively, even when they might not agree with it. (Leaders can make mistakes, and get it wrong just as often as any other team member.) Remember too, that any team member may need to show leadership when they have specific knowledge or experience relevant to the task, or if they perceive a hazard or risk.

Followership

Followership is the ability to contribute to task and goal accomplishment through supportive, technical, interpersonal and cognitive skills. Without followers, there are no leaders or leadership. Followers exercise their skills to support the leader, not to undermine their authority. Good followership means not challenging the team leader's authority, but it does not mean unthinking compliance with directives. Good followership is proactive without diminishing the authority of the team leader. Team performance can also be affected if followers do not actively participate, increasing the workload of other team members; or if they fail to monitor (or seek clarification of), task requirements, or speak up if safety is compromised.

The follower's role is to:

- Follow and support the leader
- Speak up about any safety concerns
- Participate in achieving the team's goals
- Provide leadership when required
- Seek clarification when in doubt
- Maintain an open, independent perspective
- Communicate effectively
- Coordinate actively with others in the team.

A shared mental model

For a team to be effective, each member should be aware of the expected outcomes of their work. Supervisors therefore have to communicate what is required, how they expect it to be achieved, and allocate appropriate tasks and responsibilities. The shift or task supervisor should communicate before the team begins the task. It may then require frequent briefing during the task, so the whole team remains aware of, and focused on, what needs to be achieved. Regular briefing and informal discussion with team members during the task should ensure that all team members share the same mental model. Such briefings could be carried out at the following times:

- At the beginning of every shift
- When the work priorities change
- When another task is issued
- Whenever important information needs to be communicated to the team.

it is vital that throughout, the maintenance team maintains an understanding of what they are trying to achieve, what processes they will follow in order to achieve it, its current status and what should happen next.

Communication

Individuals develop and coordinate activities to achieve goals by communicating with each other—by exchanging information. (See also Chapter 8—Communication)

Effective communication is a complex process. Some have somewhat simplistically summarised the process in these four steps:

- Someone transmits information
- Someone else receives that information
- That receiver understands the information, and finally
- Confirms to the transmitter that they have received, and understood, the information.

However, there are numerous places where this communication can break down. 'Someone transmits information' and 'someone else receives that information' sounds quite straightforward, but the person communicating the information may not be using the most appropriate means for their audience. Sending information in an email may be effective for one group, for example, but not for others, for whom a face-to-face toolbox talk would be more appropriate.

The choice of delivery method also depends on what has to be communicated. If it is simply technical information, or task instruction, an email or written briefing may be appropriate. However, more sensitive team building or motivational communication will require a more personal, face-to-face delivery, where both parties can use visual and verbal cues, such as body language, to understand how what is being said is being received.

Adapting the tone and language of your communication to your audience is also vital. The language of an academic journal, for example, is very different to that of a daily news bulletin. Academic journals are more formal, and are often written in more technical language for a narrow, specialist audience. The daily news bulletin needs to be written in accessible, plain English, to reach as broad an audience as possible.

For maintenance teams to work effectively, anyone passing on information to the team needs to ensure that the individual team members understand the meaning and context of what is being conveyed.

Regular, effective communication is vital to forming and maintaining a shared mental model, and ensuring everyone is on the same page. Good communication is also necessary for maintaining a high level of situational awareness—and having high levels of situational awareness will help teams to be more effective.

Clear delegation/role definition

There must be a clear outline of who is responsible for what. Clear delegation and role definition helps to minimise duplicated effort and ensures that each team member knows what they have to do and who is responsible for what. Delegating responsibilities appropriately within the team, and defining individual team members' roles, ensures activities are coordinated and no one team member is overloaded—they will have the capability to assist other team members when necessary. Delegating responsibilities and defining roles also ensure that team members have the capability to monitor each other's performance and provide support as required.

Clear operating procedures

Aviation maintenance is highly process driven; however, sometimes there is little guidance to the maintenance team on how they should do the job. Having standardised operating procedures means all members of the maintenance team know what is expected—how a task should be carried out, and also what other members will be doing in accordance with those operating procedures. Clear operating procedures are one of the hallmarks of a well organised and efficient maintenance organisation. They provide a baseline of how personnel will carry out a given procedure and encourage consistency in team performance.

Appropriate allocation of workload

We tend to be most reliable under moderate levels of workload that do not change suddenly and unpredictably. When the workload becomes excessive, the likelihood of human error increases. The term 'workload' can be summarised as the task demands placed upon an individual, and the corresponding ability of that individual to cope with those demands.[39] An individual's ability to cope with demands will be affected by their inherent capabilities, training, skill level, tiredness and a multitude of other factors. This has several implications:

- Different people will experience different workloads for the same task. Remember how difficult it was when you were learning to drive? Changing gears required massive concentration and effort, while experienced drivers can change gear almost without thinking
- Workload levels will vary as time passes. For example, you will tend to become more fatigued and/or bored as the shift progresses.

High workload and inappropriate/unrealistic time frames in which to achieve tasks can have an adverse effect on team performance. Maintenance teams that experience consistently high levels of workload, or are confronted with conflicting demands to complete maintenance within an unrealistic time frame, often use shortcuts and workarounds. Workload, therefore, must be appropriately balanced within the team.

Appropriate authority gradient

Workplace gradients (status/age/experience) may discourage inexperienced personnel from engaging with, or questioning, someone who is more experienced, or of a higher perceived status. Conversely, more experienced personnel, or those of a higher organisational status, may feel they do not need to listen to the views or opinions of those with less experience.

Differences in position, experience and age between members can lead to an inappropriate authority gradient within the team. An inexperienced team member may then find it difficult to express their doubts about a decision made by a more experienced supervisor or team member.

---

[39] Wickens, C.D., *Engineering Psychology and Human Performance*, Harper Collins, New York, 1992.

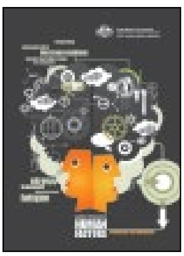
Conflict resolution

Conflict will arise from time to time. It can destroy team cohesion when the argument is over who is right, rather than what is right. Conflict resolution requires assertiveness; a willingness to confront what is often an emotional issue; effective communication skills; and a real desire to resolve the issue. People will not always agree. Differences of opinion, brought out into the open, based on facts and discussed within the team, are healthy, and can be a useful part of making and reviewing decisions. Disagreements between team members show that all team members feel that they have a right to express their views, and ensure that decisions and alternative courses of action are reviewed. However, you need to manage such disagreements, and deal appropriately with even minor or implied conflict within the team.

The key issue in resolving a conflict is first to determine 'what is right?' (the facts) and not necessarily 'who is right?' (the emotions). To achieve this, actively listen to, acknowledge and try to understand the other's perception of the situation/facts. Don't threaten the feelings or competence of other team members and avoid emotional statements.

Key points

- Safe and efficient maintenance relies on the successful performance of the maintenance team. Successful teamwork is achieved when the output of the team is greater than that which could be achieved by the sum of the efforts of the individual team members acting in isolation.
- For a team to be effective all its members need to know the specific goal, as well as what is required to achieve it.
- Poor leadership or followership will negatively affect team performance. The team leader needs to manage the workload, keep the team motivated, provide appropriate direction when required and co-ordinate activities aimed at achieving the team goal.
- For a team to be effective, each member should be aware of the expected outcomes of their work. This can and should be communicated by the shift or task supervisor and may require frequent briefing during a task, to ensure that the whole team remains aware of the goals.
- Effective communication is vital for teamwork, and for situational awareness, so that everyone knows who is responsible for what.
- Standardised operating procedures allow all member of the maintenance team to know what is expected and also what actions other members will be taking.
- When workload is excessive, the likelihood of human error increases.
- The key issue in resolving a conflict is to determine the facts: 'what is right?' and not necessarily the emotional 'who is right?'. To achieve this, actively listen to, acknowledge, and try to understand, the other's perception of the situation/facts.



When you are ready, please turn to page 51 of the *Workbook for Engineers* and complete the exercises.


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 10

LEADERSHIP

This chapter looks at the important role of leadership in aviation maintenance, the difference between leadership and management, and … the role of the follower. Leadership is about helping to ensure that people will work safely—leaders provide consistent feedback to people when they are doing the right kinds of things around safety, they make safety meetings engaging and relevant, they model safe behaviours in all they do, they make the connection they and balance between production, quality and safety, and they celebrate successes.

Great leaders are almost always great simplifiers, who can cut through argument, debate and doubt to offer a solution everybody can understand.

General Colin Powell

What makes a good leader?

Ideally, a leader should have infinite flexibility. That means you can adapt your leadership style according to the situation and/or the status of the team. For example, when a team is forming, you can be an *executive leader,* but when a team is performing, you act as a *participative leader*.

An *executive leadership* style is when a leader can organise, plan, set goals and coordinate the work of the various people involved in the task or objective. This can be very useful before a maintenance task is started and when there is a lack of task goals or direction. A practical example of this is the decision about who will do what maintenance activity and when.

A *participative leadership* style is important when work is progressing. This requires a degree of people skills to motivate and build a coherent team that can work together. Good communication and people skills certainly help at this point to understand the needs of different individuals as the task progresses.

Realistically, the ideal, flexible leader does not always exist; this is especially so in the aircraft maintenance environment. Everyone has their strengths and weaknesses, and there is a need to strike a balance between the individual's preferred personal style and meeting the needs of the situation at hand. Engineers tend to develop technical skills rather than people skills, as the former are used all the time when performing maintenance.

One of the most important leadership qualities is setting an example; doing what you say. Consider the common elements in the following quotes:

'Example is not the main thing in influencing others; it is the only thing.'

Albert Schweitzer

'I think that the best training a top manager can be engaged in is management by example. Don't believe what I say. Believe what I do.'

Carlos Ghosn, CEO of Renault-Nissan

'People ask the difference between a leader and a boss. The leader works in the open, and the boss in covert.'

Theodore Roosevelt

'I think leadership comes from integrity—that you do whatever you ask others to do. I think there are non-obvious ways to lead. Just by providing a good example as a parent, a friend, a neighbour makes it possible for other people to see better ways to do things.'

Scott Berkun, author and public speaker

An example of good leadership

Most engineers have been in this situation before. The aircraft is delayed because one of its essential systems is not serviceable; parts are taking longer than usual to arrive and the customer is waiting. This can be frustrating, especially when the maintenance supervisor seems to be siding with the customer—again—expecting the impossible. Sometimes that supervisor simply wants to keep abreast of what is happening so as to provide some control. This, however, can also be counter-productive, as an inquisitive supervisor can cause the same distraction as the customer.

A good leader needs to be aware of what is happening, but at the same time can protect engineers while they are dealing with the task. If the supervisor communicates with the customer and manages potential distractions, including other activities on the aircraft such as flight crew, aircraft refuelling and loading functions, the engineer can concentrate on the job, thus reducing the opportunity for human error.

What leadership is not

- Leadership is not power. The thug who sticks a gun in your back has power, but not leadership.
- Leadership is not status. Some may have status or position, yet do not have a shred of leadership. Position is assigned from above ... leadership is conferred from below.
- Leadership is not authority. Bosses will naturally have subordinates, but, if bosses do not lead, they will not have followers.
- Leadership is not management. Managing is a planned activity: leadership is more spontaneous. Managers do things right. Leaders do the right things.

Management is about making sure people CAN work safely; that is, we provide the right tools and equipment, have good policies and procedures for safety, hold safety meetings and safety training, and so on. Leadership, on the other hand, is about helping to ensure that people WILL work safely—we provide consistent feedback to people when they are doing the right kinds of things around safety, we make safety meetings engaging and relevant, we model safe behaviours in all we do, we make the connection and balance between production, quality and safety and we celebrate successes.

As an engineer is chosen to lead other people, challenges soon appear:

Leadership under stress

Aviation maintenance often requires the skills of a good leader in situations that present the individual and team with various challenges. As human beings we have to deal with these challenges in various ways, which can sometimes create stressful conditions in which good leadership qualities need to prevail. Having all the available information at the time and communicating with those involved directly and indirectly with the task poses significant challenges to getting the job done.

Consider the following scenario.

You are the senior engineer at a maintenance organisation that supports an in-house charter operation consisting of seven 10-seater, twin-engine aircraft. One of the aircraft has been chartered to take two mining engineers to a remote airfield two hours away and return. This is the only aircraft available on the day as the others are either in service elsewhere, or are in the middle of maintenance checks in the hangar. The pilot who flew this particular aircraft that morning reported the fuel quantity indicator had been not operating properly and that it should be replaced. It is still readable, but some of the bar lights on the digital display are not working properly. A maintenance manual test of the unit confirms this. You then discover a replacement instrument is not in stock—getting another will take 24–48 hours from an overhaul company. As this aircraft is the only suitable type available and the client is a potentially lucrative source of further business, the operations office asks if there is an alternative to releasing the aircraft in this condition. Even the chief pilot has offered to operate the flight, despite the fuel quantity indicator not functioning fully, reasoning 'If it's only a couple of lights on the display, it should be okay, because I can still read it'.

Do you weigh up the possible outcomes of releasing the aircraft, while considering the value this client could bring to the flight operations side of your business? Or do you set an example to your team and your employer by insisting the flight does not begin unless a serviceable indicator is installed as per the manufacturer's requirements.

The answer should seem obvious. However, such stressful situations, with competing demands and pressures, can test our leadership skills.

Followership

Leadership is not one-dimensional; leaders are part of a system. Leaders are only responsible for about 20 per cent of the work completed in an organisation: the followers (the organisational performers) complete the remaining 80 per cent. There are different styles of followers—mainly the model of follower provides for a self-leadership style from within the follower themselves.[40]

The combination of two or more people working together implies the leader-follower scheme exists and, as with leadership styles, followers exhibit styles of followership.

To succeed, leaders must teach their followers not only how to lead, but more importantly, how to be good followers. Regardless of the composition of the work team, supervisors are more likely to form trusting, high-commitment working relationships with subordinates who are similar to them in personality. To develop typical followership in the work team, leaders must educate organisational performers to become exemplary followers by demonstrating exemplary followership attributes themselves.

---

[40] Kelley, R. E. (1992). *The power of followership: How to create leaders people want to follow and followers who lead themselves*. New York: Currency Doubleday.

Exemplary followers have the following characteristics. They:

1. Think for themselves
2. Go above and beyond the job
3. Support the team and the leader
4. Focus on the goal
5. Do an exceptional job on critical path activities related to the goal
6. Take initiative in increasing their value to the organisation
7. Realise they add value by being who they are, their experiences and ideals
8. Structure their daily work and day-to-day activities
9. See clearly how their job relates to the business
10. Put themselves on the critical path toward accomplishment
11. Make sure the tasks they are to perform are on the critical path
12. Review their progress daily or weekly
13. Increase their scope of critical path activities
14. Develop additional expertise
15. Champion new ideas

Building relationships while identifying with the group's leader and their vision is essential to good followership. Followership builds relationships between leaders and other followers, encouraging all organisational members to focus on a common goal. Good followers may be a catalyst for change in an organisation, inspiring others to strive towards a common goal, and creating enthusiasm and the desire to excel.

The balance of power between leader and follower, however, must be maintained in order to provide a culture of openness and fairness that promotes self-engagement.

As long as there have been leaders, there have been followers: leaders cannot do what they do without followers. A growing leadership trend is to inspire followership—coaching and mentoring leaders to develop their followers is essential in today's maintenance environments.

Say you were part of a team involved in the repair of damage to a customer's aircraft. This work could require a small team of engineers to be able to complete the job in a timely manner. One individual in the team will be responsible for completing this task. Whether they are the lead engineer, LAME or even the chief engineer—they become the team leader. It is soon apparent that for the team to achieve a given goal they require direction (the leader) and that the leader needs the support of others in the group—the followers; for example, knowing that the task requires certain data or tooling, and obtaining these at the beginning of the task.

For most tasks, engineers with reasonable experience on certain equipment types will anticipate what will be required as soon as they are aware of the task. Their followership then supports the task leader.

Leadership from below: assertiveness for followers

Good followership enables teams to meet their objectives, providing the leader has set the right direction, and allocated adequate resources.

Assertiveness

During a maintenance check on a Cessna Citation, the shift leader coordinating the check told the two engineers allocated the aircraft that they were to replace both leading edge de-icing boot devices on the left and right installations of the horizontal stabilisers. This work also required preparation and installation of replacement units.

Given that work could not commence until the aircraft was inside the hangar and appropriate platforms were also positioned around the horizontal stabilisers, the two engineers felt that they would not be able to complete the task on both sides adequately before the end of their shift. They discussed the possibility of meeting the required workload safely and decided that while they would attempt to complete the task on the right-hand side, where they had already positioned work platforms, they would ask for the left side to be deferred to another hangar visit. Although the replacement had been requested due to the condition of the rubber, according to the manufacturer's requirements, the leading edge devices were still within limits to be deferred for another 10 calendar days.

The more senior of the two engineers asked for the shift lead to come over to the work area so that they could discuss their situation. They explained the need to ensure that the task could at least be completed on the right-hand assembly, including function tests enabling them to certify completion of their work. Starting the left-hand side as well would require additional manpower not available at the time. The two engineerswould have to work separately, making the task more difficult and therefore at risk of error; or rush the task to enable them to finish before going home. Rushing the job was obviously an error risk and could lead to violation of safe procedures.

In this case, by being assertive and pointing out the risks of induced error from lack of time and resources available for the task, and suggesting a suitable plan that put safety first, the engineers were able to complete some of the check. The shift lead discussed the deferred work with the maintenance planner, and in turn the aircraft's customer, who decided to reschedule the aircraft's next flight so that both sides of the horizontal stabiliser could be completed in an acceptable time.

Managing conflict

Conflict can occur when a disagreement cannot easily be resolved. Although conflict can be a normal part of our relationships and is healthy if well handled, it can sometimes escalate and become destructive. We often feel strong emotions when a disagreement continues. It may be hard to keep a clear head and listening calmly to the other person's point of view can also be much harder.

It is normal for people to respond differently to conflict. Some people want to retreat and hide, physically or emotionally. Others may become determined to get their own way. To manage conflict in a healthy way, you need to be aware of how you respond, and ask yourself if you could handle it differently.

How do you approach conflict?

- Do all people involved feel heard, including you?
- Is the conflict leading to compromise ('win-win') or confrontation ('win-lose')?
- Is the communication respectful?
- Are you listening and thinking before responding, or merely reacting?
- Does the communication have positive or negative outcomes?

When conflict escalates, it can become impossible to consider the other person's perspective. This might be the time to bring in a third person, such as a counsellor or mediator.

Some issues to be aware of:

- No one has the right to abuse another person, and no one should accept it. Physical aggression, or emotionally controlling behaviour are never OK
- Physical violence against anyone is destructive and illegal
- The responsibility for your communication lies with you alone. No one can make you say or do anything. You always have a choice in how you react
- Restricting or controlling another person's opinion is never acceptable
- If this is what you are doing, or if this is being done to you, it might be time to talk to someone about it. If abuse, violence or controlling behaviours are part of any conflict in your life, seek help immediately.

Some useful tips for handling conflict:

- Listen to the other person's point of view and make sure you understand what they are trying to say
- Respect the other person's point of view, even if it is hard to listen to or understand
- Look for areas where you can compromise—what are the most and least important things to you?
- Try to keep your communication respectful. Avoid insulting or putting others down
- Use 'I' statements such as: 'When you say that, I feel ...'
- If things are heating up, ask for time out. Come back to the discussion when both of you are calmer
- If old patterns of communication are not working, try new ones
- Try to communicate through a different medium, such as letters or email
- Commit yourself to making positive changes to the way you handle conflict.

Practical safety leadership tips

How we conduct ourselves as safety leaders has a major impact on safety culture and performance. Effective safety leaders consistently show the following behaviours:

Safety leadership attributes	
Vision	The great safety leader has a clear picture of the future state of safety and articulates it in a compelling way.
Credibility	Great safety leaders have high levels of credibility with direct reports and with the larger organisation.
Action orientation	Great safety leaders are willing to take decisive action on safety issues.
Collaboration/ consultation	Great safety leaders work in collaboration and consultation with all members of the organisation to create buy-in.
Communication	Effective communication is a critical skill of effective safety leaders to create buy-in and foster meaningful conversations across the organisation.
Recognition and feedback	The great safety leader is tuned into the behaviours of subordinates and the larger organisation, sets expectations for practices and behaviours and provides timely, certain and positive feedback.
Accountability	Great safety leaders hold everyone, including themselves, accountable for doing the right things with respect to safety.

If you lead teams in your aviation maintenance work, think about what tools, processes and procedures you could use daily to actively lead by example. For example, consider how you would answer the following questions:

- Do you involve your team actively, by encouraging them to ask questions and provide constructive criticism?
- Do you allow them to tell you something that you would rather not hear, to work out how you can fix a problem, here and now, together?
- Do you lead by example and praise people when they do well?
- When they haven't done such a good job, do you ask them if they are satisfied with what they have done? (Ideally, you do not criticise them, but allow them to comment on their own performance.)
- Do you, as the team leader, immediately acknowledge when you have done something wrong?
- Do you provide an open forum for worker input?

What supervisors should be doing

What supervisors should be doing	Check
Planning work in sufficient detail so as not to be surprised by the unexpected	✔
Ensuring the work is completed according to the plan	✔
Reviewing what happened, learning from problems and how they were solved	✔
Giving feedback, i.e. encouraging learning for all concerned about what happened	✔
Implementing improvements to better manage risk and make processes more efficient	✔
Telling other people outside the team about any lessons learned.	✔

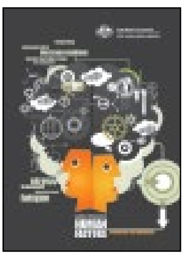
How many of these checklist items can you tick?

At a more practical level, you can help to improve safety culture at your workplace by actively following your responsibilities under workplace health and safety legislation, which broadly include:

Following the safety and health requirements for your job	✔
Doing your work safely	✔
Maintaining safety and health awareness in all tasks	✔
Maintaining a clear and orderly work area at all times	✔
Constantly checking your workplace for hazards and, when necessary, fixing them	✔
Coming to work free from the influence of drugs and alcohol	✔
Taking action when you see co-workers, contractors and members of the public not acting safely	✔
Looking for opportunities to improve workplace health and safety performance	✔
Taking part in workplace health and safety activities	✔
Reporting all near misses, incidents, injuries and occupational illnesses immediately.	✔

Key points

- Leadership is essential when more than one person is involved in carrying out a given task.
- Leadership is dynamic and not always easy to develop. Not only do you have to be able to give direction before the task starts, but also provide feedback during the task to ensure the goal is achieved.
- A good leader requires the support of all the others in the team. These followers usually have similar personal qualities to the leader. Without them, the leader would not be able to achieve the goal.
- Assertiveness is important too—sometimes the leader can make the wrong decisions. When that happens, an assertive follower can communicate with and support the leader and the team to prevent undesirable outcomes.



When you are ready, please turn to page 55 of the *Workbook for Engineers* and complete the exercises.


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 11

PROFESSIONALISM

Professionalism is the underpinning character of the aircraft maintenance engineer. It is the combination of specialist skills, personal feelings and our attitude to the work we do. Aviation maintenance safety depends on all those who perform the work required to enable aircraft to operate, especially those involved in repairs and inspection to determine the airworthiness and safety of the product, whether aircraft, engine or component. This chapter looks at the qualities of a ‘professional’ engineer.

Professionalism: It’s not the job you do: it’s how you do the job.

Anonymous

What is professionalism?

What qualities do you expect to see in effective aviation maintenance professionals? They may demonstrate professionalism by their:

- Discipline—they follow approved procedures to perform a given task
- Communication—they keep others involved in the task informed of progress and developments
- Teamwork— they work together well to resolve problems and maintain control
- Knowledge—they have a deep understanding of aircraft systems and their operation
- Expertise—they retain and transfer knowledge and skills
- Situational awareness—they know what's going on around them
- Experience— they call upon prior training and knowledge to assess new situations
- Decision making—they take decisive action/s
- Resource management—they allocate resources to ensure control of the larger situation is maintained while specific problems are being addressed
- Goal prioritisation—they prioritise safety above personal concerns.

The physical and technical side of maintenance seems to be relatively straightforward. However, one critical part of being an aircraft maintenance engineer is harder to pin down and define. That critical part we commonly call professionalism. We often sit in awe of an accomplished surgeon. Not only do we recognise that surgeon's technical skill, but also their instinctive awareness; the ability to work within a coordinated team and to make sound decisions for the benefit of the patient's safety. Just as professionalism in aircraft maintenance, this is difficult to define, but it is unmistakable when we see it.

Have you ever worked with an engineer who stood out from the crowd, or who had superior and unexpected knowledge and skill? Did they demonstrate a willingness to put the safety and airworthiness of aircraft before all else?

Professionalism is that 'something' separating the superior engineer from the average one. It is not simply a measure of skill or technique, but also a measure of the engineer's understanding of the overall maintenance system, and how they contribute to an airworthy product. One capability is physical skill, but equally important components are wise decision making and an elevated self-discipline.

Professionals, especially those involved in aviation maintenance, are recognised as having three essential characteristics:

1. their expert knowledge (as distinguished from a practical skill)
2. their self-control or self-regulation
3. their willingness to take responsibility for placing the safety and airworthiness needs of the travelling public ahead of individual self-interest.

Expert knowledge comes from experience developed over time, especially when that experience concentrates on particular product types such as specific airframes and components.

Self-regulation is based on beliefs, pride and enthusiasm, with individuals making conscious decisions based on the goals of airworthiness and safety.

Finally, aviation maintenance professionalism comprises those demonstrated practices, education, ethics, and values that sustain the interests of safety above one's own self interest.

Developing professionalism

Three major factors influence the development of professionalism: formal teaching, role modelling, and the culture of the organisational environment.

Broadly, engineers are shaped by the sum of their interactions with other AMEs/LAMEs, supervisors, customers, support staff, and one another, in workshops, hangars, and flight lines. As trainee engineers, apprentices are drilled on the high safety standards required to maintain an aircraft and its components. This is the beginning of professionalism. The attitude of others, especially mentors, will help to shape a novice's ability to recognise acceptable or unacceptable behaviour when making complex decisions about maintenance tasks. Professionalism can be developed at an individual level when working in isolation, but it can also be facilitated in team environments as a by-product of the organisation's safety culture.

Professionalism also requires a dedication to continuous improvement. Learning from past events, whether personal experiences (such as remembering the importance of tool control), or organisational and/or industry-wide learning from safety publications, accident reports, professional training etc., requires regular personal input.

Professionalism can be practised and reinforced every day. Professional behaviour often complements other's professional behaviour; for example when engineers consult with customers and aircrews about the progress of maintenance. Professional pilots would be quite receptive when engineers put the safety of pilots and passengers before schedules.

Establishing minimum personal standards

Personal standards include how you treat yourself, how you treat others, how you behave in front of others, and how you perform your work to the highest level.

Who we are, how we were raised, and how we were taught influence our personal standards. During their training, aircraft maintenance apprentices will adopt the behaviours of the more qualified and experienced people who mentor them. Instilling qualities of professionalism in the early stages of training is important—they can become the foundation of the individual's attitude and behaviour.

As an engineer you should draw a line where your (and your organisation's) minimum personal standards exist, thus establishing professional integrity. Any aircraft or component maintenance task requires attention to detail and adherence to procedure, as well as a duty to ensure the task is completed adequately. Sometimes engineers may find themselves challenged by not having the time or resources to meet this requirement. Occasionally, you may be challenged by normative behaviour where the methods used have become the accepted practice at your workplace. 'I did it this way because that's how everybody else does it around here'. Ideally you need to recognise this behaviour and decide if the task is being performed as safety requires, or as it normally 'gets done'. This is where personal standards become apparent/important, and especially what constitutes your minimum personal standards.

Personal standards

You are tasked with reassembling an exhaust manifold on the engine of a customer's aircraft. The aircraft is due out later that afternoon. As part of the reassembly task, you need to fit bolts securing the manifold assembly to the exhaust ports. According to the manufacturer's manual, these must be fitted and torqued to a set value. The torque wrench you need is one of two the company owns. They are normally stored in the tool cupboard, which is located at the back of the hangar.

While following the procedure, you get to the stage where the bolts are to be fitted. Although a specific torque figure is quoted in the manual, you have noted that others have installed this component without using the torque wrench. From memory, the last time you installed this component, the engineer you worked with at the time said 'once you've done a couple of these, you get to feel when the bolt is done up enough—the torque figure given in the book is only a guide'. Based on this previous advice and knowing that nothing untoward has happened on previous installations of this type in the past, you consider using a standard spanner from your toolbox instead of a torque wrench. Also, if you were to decide to use a torque wrench, you would have to leave the task and walk to the other end of the hangar to the tool cupboard, which is often obscured by aircraft parts and assorted ground equipment.

It's been done this way before by colleagues for whom you have a high level of respect, so what do you do?

Personal integrity—resisting at-risk behaviour

Would you certify on behalf of another engineer you hardly knew, who had completed a given task that you were responsible for, if you had not seen the work performed or completed (inspected)?

This dilemma is more common in aviation maintenance than one would imagine. Often an engineer will be overseeing multiple tasks on different areas of the aircraft and/or aeronautical product at the same time. Engineers may even be involved with other aircraft when this work is being performed, but are still responsible for it. They may have to certify that the work has been performed in accordance with approved standards. They may even be involved in one of the tasks requiring the certification oversight.

Sometimes this behaviour might be influenced by a lack of personnel and/or time. Personal integrity should empower the engineer to check that the work has been completed correctly, in accordance with the approved standards. This behaviour should be seen as promoting safety, integrity and professionalism but, above all else, it promotes resistance to at-risk behaviour.

Taking it for granted

During the reactivation of an engine thrust reverse mechanism after maintenance, an experienced AME reactivating the engine thrust reverser centre drive unit (CDUs) lockout needed a suitable platform to visually inspect the upper locking mechanism of the engine cowling reverser halves. As he left the task, another AME (who had recently joined the team) offered to complete the reactivation of the CDUs.

Returning to the engine with the required platform, the senior AME observed the engine's final cowlings being closed by the AME, with the help of a LAME who had been working on the opposite engine. The senior AME asked the newer AME if the CDUs were returned to flight condition. The newer AME informed the senior AME that the task was complete and that they just needed to latch the final sets of engine cowls (which was observed).

When it came time to complete the maintenance documentation, an entry for the thrust reverser lock-out had to be cleared. The newer AME had already left the aircraft to clean up, and as it was nearing the end of the late shift, the senior AME signed for the task being completed in accordance with the aircraft maintenance manual, believing the task had been completed competently. He did this without actually checking the CDUs, as the other engineers were closing the engine so that they could ready the aircraft, leaving it in a serviceable and released-to-service condition.

The aircraft was flown the next morning and when landing in gusty wind conditions on a shorter than usual runway, although full thrust reverse was applied, the affected engine did not respond accordingly. As a precaution, and to avoid asymmetric reverse thrust, which could lead to loss of control, both engines were selected to forward thrust and maximum wheel braking then applied. As a result of this action seven of the eight wheel brakes needed to be replaced before the next flight.

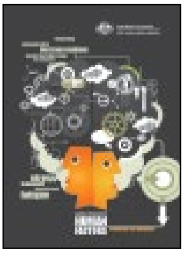
An investigation into the maintenance activities from the evening before revealed that the newer AME had not performed the reactivation of the CDU task before and merely observed the senior engineer removing the lock plate bolts. Not fully aware of why this action was being performed, the newer AME thought the bolts were being fitted, not removed, and therefore required tightening. This action left the lockout plate fitted with the drive lock inserted, thus mechanically deactivating the thrust reverser.

Key lessons

- All personnel involved in the task must be fully aware of its progress. This vigilance is an important part of professional behaviour.
- Good communication can avoid the potential for making risky decisions. Making risky decisions is not normally a sign of professional behaviour.
- Never sign for work you have not performed, especially if you have not inspected or observed it personally.
- Trust should not replace good communication and proper task vigilance. Again, if you did not do the work, you should not sign for it.

Key points

- Professionalism comprises those attitudes and behaviours that place the interests of safety above one's own self interest.
- Professionalism can be developed in isolated one-person operations, as well in as larger organisations with a number of engineers.
- Professionalism is a characteristic that can both drive (and be driven by), the safety culture of an organisation.
- Colleagues and mentors have a strong influence on professionalism, from the earliest days of an engineer's career.



When you are ready, please turn to page 59 of the *Workbook for Engineers* and complete the exercises.


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 12

HUMAN FACTORS WITHIN AN ORGANISATION

Of all the human factors influencing individual behaviour, one of the most powerful is an organisation's safety culture. The term safety culture is a broad expression often used to describe the significance safety has within any organisation. High-risk and high-reliability operational processes are usually considered to be driven by a culture of safety. Safety culture has been shown to be a key predictor of safety performance in a number of industries.

Every system is perfectly designed to achieve the results it gets.

Don Berwick, MD

Safety culture and human factors

So what is safety culture?

Safety culture basically involves the attitudes personnel hold about the company's approach to safety, their perceptions of the magnitude of the risks they face, and their belief in the necessity, practicality and effectiveness of measures to control risk. In this way, safety culture can be considered an enabler for safety.

Safety culture is made up of those shared beliefs, values and practices affecting the safety of our environment. Think about how your culture affects the way you think and act.

Is there such a thing as a national culture?

You can certainly identify a number of very strong cultural differences between people of different nationalities, or even between Australians of differing cultural backgrounds. It is even possible to recognise different sporting cultures within one sport (Compare the cultures of the various football codes, for example, in Australia—rugby union, rugby league, Australian rules, and soccer). These cultural differences are very strong drivers for how we think, feel and react in different situations.

Although you may not be aware of it, each organisation or workplace also has its own cultural norms, behaviours and practices. This organisational culture can have a significant effect—good and bad—on how we actually think and behave in the workplace.

How does the organisational culture affect your work as an engineer?

Let's assume that in your working environment, safe and professional practices are not only expected normal behaviour, but are reinforced and supported by management (even when under considerable pressure to get the aircraft serviceable and on line). In this type of culture, personnel will tend to 'do it by the book' and take the time to ensure the appropriate work, inspections and sign-offs are actually carried out. If, however, you work within a culture where shortcuts and work arounds are commonplace, and where 'near enough is good enough', even with good intentions we can be drawn into these workplace norms and begin to accept lower and lower standards.

The influence of organisational culture on safety

Continental Express Flight 2574 was a scheduled domestic passenger airline flight operated by Britt Airways from Laredo International Airport in Laredo, Texas to Bush Intercontinental Airport in Houston, Texas. On 11 September 1991, the Embraer EMB 120 Brasilia, registered N33701, crashed as it was approaching the runway to land, killing all 14 people on board.

The National Transportation Safety Board (NTSB) investigation revealed bolts had been removed from the horizontal stabiliser during maintenance the night before the accident and, following a shift change, the screws were not replaced. The plane crashed on its second flight of the day.

NTSB cited the failure of airline maintenance and inspection personnel to adhere to proper maintenance and quality assurance procedures.

The failure of Federal Aviation Administration (FAA) surveillance to detect and verify compliance with approved procedures was cited as a contributing factor. Following the accident, the FAA conducted a National Aviation Safety Inspection Program (NASIP) of Continental Express's maintenance program. It found very few safety deficiencies, and complimented the airline on its internal evaluation system. The NTSB expressed concern that the NASIP had not found deficiencies in shift turnover procedures and other matters relevant to the accident, and recommended that the agency improve its procedures.

The National Transportation Safety Board determined the probable causes of this accident as follows:

- The failure of maintenance and inspection personnel to adhere to proper maintenance and quality assurance procedures for the aircraft's horizontal stabiliser de-ice boots. This led to the sudden in-flight loss of the partially secured left horizontal stabiliser leading edge, and the immediate severe nose-down pitch over and breakup of the aircraft.
- A contributing cause of the accident was the failure of management to ensure compliance with the approved maintenance procedures.
- The failure of FAA surveillance to detect and verify compliance with approved procedures.

Role in developing the culture of safety

As a member of the National Transportation Safety Board (NTSB) at that time, Dr. John Lauber suggested that the probable cause of this accident included 'the failure of Continental Express management to establish a corporate culture which encouraged and enforced adherence to approved maintenance and quality assurance procedures'.

Adapted from NTSB report on Continental Express flight 2574 accident, 11 September 1991

How do you recognise an organisation with a good safety culture?

An organisation with a good safety culture is one where safe and professional behaviour is fully internalised as the way personnel think and act. It is one where safety is seen as a required outcome of all operations, and where safe and professional practices are not only endorsed by management, but are proactively demonstrated. We are not simply talking here about the number of safety posters around the workspace, but a realistic demonstration of support for safe and professional operations at all levels of the organisation.

Sometimes, due to commercial pressures to get the aircraft out under an unrealistic time schedule, engineers can be pressured to cut corners; for example, to sign off work that has not actually been checked or carried out strictly according to laid-down procedures. Under these circumstances, it is very easy for a poor safety culture to develop, where personnel are rewarded for getting the aircraft out on time, even though everyone knows that corners have been cut to achieve that. In turn, this can rapidly deteriorate into a culture where shortcuts and violations become commonplace and eventually become normal accepted practice within the organisation. These types of culture can be difficult and slow to change.

How do we build a generative safety culture?

Safety culture takes time to develop, and needs a proactive approach from all personnel if it is to grow. A generative safety culture can only flourish when good safety behaviours are actively encouraged, while poor safety behaviours are viewed as unprofessional, and dealt with accordingly. All members of the organisation must see safety and professionalism as 'the way we do business', and these views need to be internalised and demonstrated in the way all personnel think and act. For example:

- Is safe and professional behaviour evident and actively supported by management?
- Is the safety reporting system supported by management and used by staff?
- Is safety performance a stated organisational goal?
- Are the workplace norms positive toward safety?
- The hazard identification and risk management part of the organisational culture?

According to Hudson,[41] the evolution of a safety culture can be seen as progressing along a line from:

- Pathological, or caring less about safety than about not being caught, through
- Reactive, where safety is important, but the organisation's beliefs, methods and working practices are still quite basic
- Calculative, that is, blindly following all the logically necessary steps, to
- Generative, where safe behaviour is fully integrated into everything the organisation does.

At the pathological stage, safety is not a high priority for an organisation.

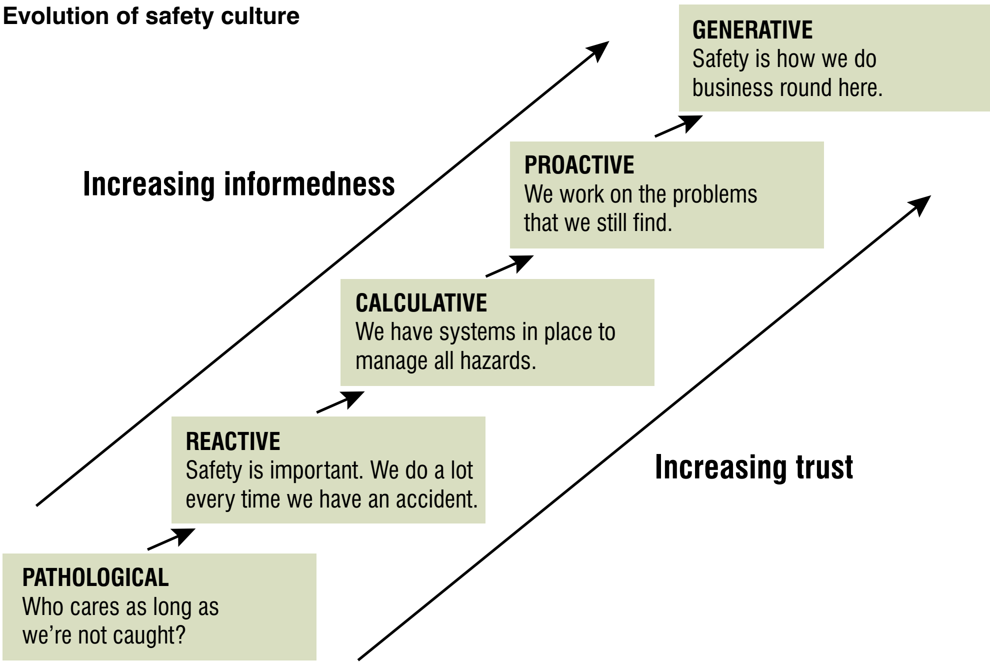
In the reactive stage, safety issues begin to acquire importance, often driven by both internal and external factors, and typically as a result of recurring safety incidents that have caused production delays. In this first stage of development, the organisation is beginning to acquire safety values but its beliefs, methods and working practices are still quite basic. Senior management within reactive organisations tend to believe accidents are mostly caused by stupidity, inattention or intentional rule breaking on the part of their employees. Safety is still seen as an add-on.

[41] Hudson, P. (2001). Safety Management and Safety Culture. 'The Long and Winding Road', as presented to CASA, 10 September, 2001, Canberra.

The calculative stage recognises that safety needs to be taken more seriously. The term calculative is used to stress that safety is calculated; the organisation uses quantitative risk assessment techniques and overt cost-benefit analyses to justify safety, and to measure the effectiveness of proposed measures. Despite this stance, and despite what can become an impressive safety record, safety is still primarily an add-on function and a mechanical application of a management system. A true safety culture is one that goes beyond calculative levels.

A safety culture can only be considered to have developed in the later proactive or generative stages of this evolutionary line. The foundation can now be laid for acquiring the belief that safety is worthwhile in its own right. With deliberate procedures, an organisation can force itself into taking safety seriously, but the values are not yet fully internalised, the methods are still new and individual beliefs generally lag behind corporate intentions. This demonstrates a significant characteristic of a true safety culture–that the value system associated with safety and safe working has to be fully internalised as beliefs, almost to the point of invisibility, and that the entire suite of approaches the organisation uses are safety based.

Evolution of safety culture



Organisational norms and peer pressure

Organisational norms—the way we do things around here

Organisational norms are those unwritten rules and workplace practices which are generally accepted as the way work is done within an organisation. These workplace norms can have a positive or negative effect on safety, and they can give an indication of the underlying organisational culture.

Take the following example of a positive organisational or workplace norm. An engineer is just wrapping up his work at the end of a very demanding shift. He is aware that more errors occur on night shift and that he may be feeling somewhat fatigued at the end of this long shift. Some of his completed work calls for a duplicate inspection to be carried out before sign-off. The workplace norm in his organisation is to schedule safety-critical maintenance for day shifts where possible. Where such maintenance has to be done during a night shift, there must be an extra level of inspection on all safety-critical maintenance. The engineer calls for the duplicate inspection of his work in line with this normal workplace practice. On the second independent inspection, the inspector finds that one of the fuel control rods linking the fuel control unit to the control lever has not been lockwired as per the maintenance publication. The fault is then rectified and the work subsequently signed off.

In this case, the workplace norm was safety positive—the organisation had implemented a procedure to manage the known higher error rates during night shift and the effects of fatigue.

Peer pressure

Peer pressure is the pressure we feel to do what our group or peers expect of us. Peer pressure is closely linked to organisational norms and culture. As with organisational culture, peer pressure or conformity can work for or against safety.

An organisation with a positive safety culture, for example, will exert pressure on newcomers to operate with a professional and positive attitude to safety. However, an organisation where shortcuts and non-compliance (violations) to achieve unrealistic goals are commonplace will have a negative influence on the behaviour of individuals. If individuals are expected to cut corners to get the job done, peer pressure can influence others to do the same.

The following case study illustrates the effects of organisational norms and peer pressure on aviation safety.

The power of organisational norms and peer pressure

While financial scandals on a corporate level are rare in aviation, there have still been significant events marked by the pursuit of excessive financial gain where integrity has been compromised.

The 1979 crash of American Airlines Flight 191 in Chicago, for example, was precipitated by events and procedures led by the airline's upper-level management. This management endorsed the use of a forklift (an unapproved procedure) to change engines on its fleet. What these managers were unaware of was that using a forklift in this way was creating an unseen crack in the accident aircraft's engine pylon. This crack continued to spread and eventually caused the left engine to fall from the aircraft as it was on its take-off roll. The aircraft crashed shortly after becoming airborne. Two hundred and fifty eight people (including 13 crew) on board the aircraft and two people on the ground were killed.

The crash of American 191 is an unfortunate example of the integrity line being crossed. The airline management was trying to save money, but in a dangerous manner. The unapproved forklift procedure ostensibly saved time and money, allowing the aircraft to spend less time in maintenance and more time generating income. When upper-level management endorses this type of behaviour and lower-level employees are, by default, along for the ride, a norm develops and the entire organisation is complicit in crossing the integrity line. This was also the case in the events that led to the crash of Continental Express Flight 2574 in 1991 (47 screws were not put back on the horizontal stabiliser during a shift turnover).

These organisational failures raise a fundamental question about personal integrity. Why would the respective airlines' employees go along with these breaches in integrity when they knew they were contrary to approved procedures?

Once again, it has to do with norms, or the normal way business is done (whether right or wrong). This may happen when an employee knows that an incorrect procedure is universally used, but at the same time does not want to speak up for fear of reprisal. Similarly, conformity is a strong social psychological driver—employees may choose to go with the crowd and give in to peer pressure rather than stand out as complainers, loners, or non-team players. While it is understandable that individuals may fear speaking up, there is still a moral responsibility to speak up if you see something happening that is not right. Otherwise, you are overstepping the bounds of integrity and your actions may be contributing factors to an aircraft incident or accident.

'THINK ABOUT THAT'

Adapted from an article on organisational norms in *Aviation Human Factors Industry News*, Vol VII. Issue 06, February 11, 2011

Group think

In a group you are more likely to agree with the majority, rather than disagree, or rock the boat (think back to peer pressure). The desire to reach unanimous agreement can result in what is known as *group think*, and may override any individual desire to put forward an alternative view. It is human nature to want to fit in with the group, but you must be prepared to challenge the group if you believe actions are irresponsible or unsafe.

One way of resisting group think is to ensure good two-way communication within the team, If you have doubts about a procedure, show professional behaviour: speak up and encourage others to do the same. The effects of group think can also be minimised if there is appropriate task supervision and/or mentoring. These help to ensure appropriate alternatives have been discussed and reviewed. Team members should also consider the hazards and potential risks that may affect, as well as flow from, their decisions. All team members share responsibility for the team's decisions and what happens as a result of those decisions.

Perceived pressure

Some feel that perceived pressure and actual pressure are different. For the individual however, it makes no difference whether the pressure is actual or perceived: both have the same result. The individual feels that they are under very significant and real pressure to achieve a specific outcome. For example, the helicopter tail rotor pivot bearing has to be replaced and paperwork completed by 16.00, so that the test flight can be completed prior to last light.

Perceived pressure is a significant driver for both error and maintenance shortcuts/work-arounds. You must ensure you allocate appropriate time to achieve your maintenance tasks (including the administration and paperwork these tasks involve). From the supervisor's perspective, the maintenance team must be briefed comprehensively beforehand so that they have an accurate understanding of the actual priorities (completing all the maintenance safely, and according to the documentation). Supervisors should also provide good direction and promote open, two-way communication to help identify and mitigate the effects of pressure on performance and behaviour.

Event and hazard reporting

To set up an effective event and hazard reporting system an organisation must establish a culture where personnel are happy to speak up when things go wrong; one which encourages open and honest safety reporting focused on identifying causes rather than culprits. Safety reporting allows the organisation to mitigate hazards and evaluate the reasons why incidents occur. This process aims to improve system defences so that the organisation can learn from incidents to prevent them recurring.

Focus on near misses

You've probably heard that old saying, 'That was a close call'. But for those of us in the world of workplace safety, close does count. The close I am talking about is the near miss. Let us talk about why it is so important and what we can do to take advantage of it.

The significance of a near miss

Safety professionals in aviation and other industries do their best. But they are human, like everybody else, and so are the people they work with and depend on. Flawed people produce flawed programs. What that means is that every safety program has a flaw somewhere. The important thing is to figure out where the flaws are and fix them. Unfortunately, it usually takes an incident to find the flaws. Not all incidents injure people and damage property. The incidents where nobody or nothing gets hurt are the close calls, or near misses. A near-miss incident is a free shot—a chance to identify and fix problems in a safety program before they do actual damage. It could be anything from someone walking in a hangar and almost hitting the wing of an aircraft, to a screwdriver being dropped by the maintenance technician working on a ladder and narrowly missing the maintenance technician's skull below. These near misses happen all the time.

Why don't we take advantage of near misses?

Let's say that an engineer almost hits his head on the wing of an aircraft in the hangar. The safety culture might take the following view: 'Wow; that was a close one! Thankfully, there was no injury, no first aid, no lost or restricted time. I almost had a boatload of paperwork, investigation, corrective action and training to do on that one.' Of course, that attitude is a terrible mistake. Neglect of near misses is a lost opportunity for prevention, and a recipe for future accidents. The fact that nobody was hurt, and no aircraft were damaged, was pure chance. What is important is realising that something went wrong; and it could go wrong again. So you need to fix the problem because the next time you might not be as lucky. And you need to be grateful the near miss happened because it gave you the chance to prevent an injury.

Doing something about near misses

Not knowing about near misses is a real problem. We should not be so naïve as to believe that all the near misses that happen on the hangar floor or ramp will be recognised and reported. But there are steps you can take to make it more likely for near misses to be reported. Establishing a safety-conscious attitude throughout the company, and explaining the importance of near misses goes a long way to getting people on the floor/ramp to recognise and report them. So the challenge is: to go out and create that work environment/atmosphere where workers think safety every day. They are the individuals who are visible, accessible, active and relentless. Safety is everyone's responsibility; by working with supervision and the safety department we strengthen the safety culture by using everyone as a resource.

Adapted from an article on 'Near miss' reporting in *Aviation Human Factors Industry News,* March 21, 2007, Vol. III, Issue 10

Why should you report safety incidents to management?

- So that safety reporting becomes what is expected—part of professional behaviour. It also becomes part of the organisational culture—a norm.
- More importantly, it may allow the organisation to identify systemic drivers for error or organisational norms affecting safety. Event and hazard reporting therefore become a vital part of the continuous improvement process.

For a good reporting culture, you need the following elements:

- Motivation and promotion. Staff must be motivated to report, and believe that the results obtained are worth the effort, because they contribute to a self-sustaining process.
- Ease of reporting. Reporting an occurrence must be as easy as possible for all employees. If staff see reporting as an extra burden, they will not do it.
- Acknowledgement. Acknowledging reporters, and giving them an update on the status of a report, makes them more likely to continue with their contributions. Feedback will generate substantial good will.
- Independence. Progressive organisations must allow a level of independence to its safety management practitioners so that they can operate in an environment that may be remote from routine business reporting systems.
- Trust. A good safety culture is built on trust. In simple terms, messengers must know that they will not be disciplined for delivering bad news to the organisation.

Foundations of effective reporting

Safety culture and accountability

The blame reporting culture

A blame reporting culture reflects an organisation that does not accept human error. In this type of reporting culture the organisation simply seeks to blame individuals or teams when things go wrong, or when errors are made. Because of this, there is little or no reporting of error because people want to protect their jobs/careers. There is also no opportunity for the organisation to learn from and mitigate previous incidents and errors.

The no-blame reporting culture

In the 1990s, many aviation organisations adopted a no-blame approach so that they could obtain as much intelligence about safety breaches (actual and potential) as possible. Basically, the no-blame concept implied, and many safety practitioners reasoned, that as long as someone admitted to an error, no disciplinary or punitive action should be taken against them. The weakness of this approach soon became apparent when deliberate (and sometimes repeated) violations were duly reported to management with an expectation of amnesty.

Take the example of an engineer who has been out all day at a party and then knowingly starts the night shift under the influence of alcohol. He subsequently signs for an inspection that he had not actually carried out so that he can knock off early. Is a no-blame culture approach appropriate in this case? This reporting culture is not really appropriate in the aviation maintenance environment: it provides no way of maintaining minimum acceptable standards, nor is there any requirement for individual professionalism, responsibility and accountability.

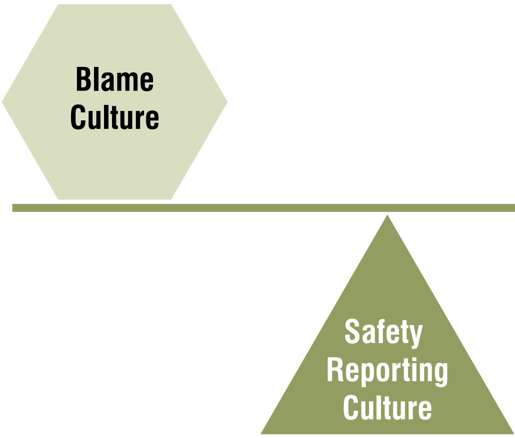
The fair-but-accountable, safety reporting culture

The fair-but-accountable, reporting culture (sometimes referred to as the 'just' culture) arguably provides an appropriate balance between punitive and non-punitive reporting cultures. The fair-but-accountable culture accepts that human error may occur, but it also means employees must perform their roles professionally. It reinforces the concept that everybody has a responsibility for their professional performance, and accountability for their actions. While reckless behaviour is unacceptable in a fair-but-accountable, reporting culture, it acknowledges error is a normal consequence of human activity and must be managed by systems and practices promoting learning from past errors or mistakes. It encourages open reporting of near misses and employee participation in safety issues and investigations.[42]

A safety reporting culture is transparent and establishes clear accountability for who does what. It is neither blame-free (it does not allow total immunity for actions), nor punitive (disciplining regardless of whether acts were unintentional or deliberate). It can therefore be considered a realistic and effective compromise between the extremes of blame and no-blame. Within a reporting culture workplace, management uses the safety reporting system to identify the underlying systemic drivers for error. This approach is not 'excuses 101'. Under a safety culture, individuals who consistently break the rules and flaunt the organisation's systems and processes are held accountable for their actions, while true (unintentional) human error is treated with an appropriate (non-punitive) level of response.

42 Merritt, A.C., & Helmreich, R.L. (1996). Creating and sustaining a safety culture: Some practical strategies. In B. Hayward & A. Lowe (Eds.), Applied Aviation Psychology: Achievement, Change and Challenge, Sydney: Avebury Aviation.

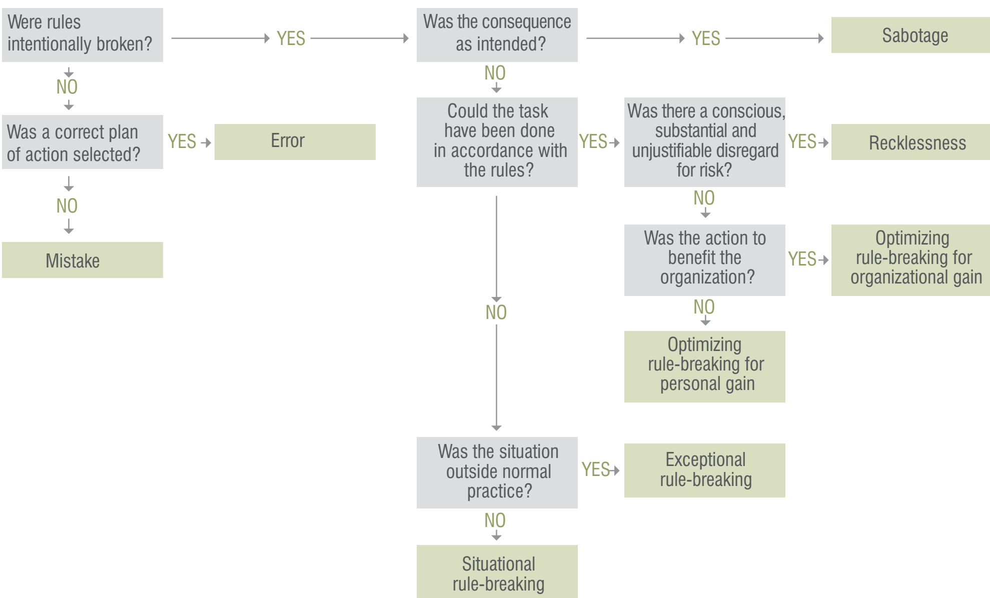
Safety reporting culture



Organisations that actively use safety reporting concepts implement formal policies to ensure that the process is applied consistently. Often behaviour is grey, not black or white, so you have to have a process to evaluate individuals' actions in context.

The FAIR[43] (flowchart analysis of investigation results) system is one such tool used in aviation maintenance.

The 'FAIR' system



Produced with permission from Baines Simmons.

43 Flowchart Analysis of Investigation Results User Guide, 'FAIR' system user guide, Version1.1, July 2009, Baines Simmons Limited

To see how the FAIR system might work, let us review two simple examples below, to decide how you would describe engineers A's, B's and C's actions.

Example 1

A relatively new tradesman (engineer A) inadvertently leaves a rag on a helicopter's transmission platform after performing a check and top-up of the main transmission oil level. The rag is subsequently found by the pilot during his pre-flight inspection. This is an unintentional error by engineer A. When questioned by his supervisor, he mentions that he was interrupted as he was wrapping up the task and thought that he had removed the rag after cleaning up a minor oil spill.

If we run through the 'FAIR' system, it shows that engineer A committed a simple error.

Example 2

An experienced engineer (engineer B) has several tasks underway and is rapidly approaching his programmed end of shift. He is meant to conduct an independent inspection on the propeller pitch control, a task conducted by engineer C. The inspector, engineer B, knows engineer C and feels that he is quite professional in his duties. Engineer B thinks about the time pressures and decides to sign for the inspection even though he has not actually carried it out. The aircraft is subsequently cleared to the line and during the pre-take off checks, the propeller pitch control is found to be unserviceable. The subsequent investigation reveals that the propeller control link was not fitted correctly. Engineer C had inadvertently made an error in re-connecting the propeller pitch control linkage, but thought he had done everything according to the documents. The experienced engineer (engineer B) who was meant to conduct the inspection then admits that, due to perceived time pressures, he intentionally signed for the inspection, even though he hadn't carried it out.

Under safety culture, a thorough investigation is carried out to determine the factors behind the incident. The investigation reveals that the propeller pitch control re-connect procedure is poorly worded and could easily result in the pitch control link being fitted incorrectly. A publication amendment is recommended.

The investigation also reveals that the experienced engineer (engineer B)—the task inspector—was overloaded with an inappropriate number of tasks at the time of the incident. He had also been directed to conduct an administrative review before an upcoming audit.

Various personnel were questioned about engineer B's propensity to violate and when questioned, engineer B and other personnel stated that this was the first time he had signed for an inspection he had not actually carried out.

So, why did engineer B sign for an inspection he had not carried out? In this case, management might have a certain responsibility in that it expected an unreasonable workload from engineer B, and this workload had been building over a considerable time. As a result, it is decided that his behaviour in this instance is almost certainly a one-off, promoted to a certain degree by unreasonable management expectations.

As a result of the investigation, the organisational workload is reviewed; task time frames expanded to be more realistic and achievable; and the audit preparation task is moved from engineer B up to middle management.

Again, if we run through the FAIR system, it reveals that engineer B committed an 'optimising rule-breaking for organisational gain' whereas engineer C committed a mistake.

The response to an individual's actions in accordance with just culture may be variable, and will always depend on the context at the time. It is not black and white! Normally any error should be treated with a non-punitive response and the organisational response to each violation will depend on the context and systemic drivers behind the violation.

Going beyond human error in event investigation

All incidents and accidents result from multiple factors. They do not result simply from just one factor, or one person's actions. (If this were the case, it would indicate that the system has insufficient safety controls in place). It is clear that major safety problems do not belong exclusively in either the human or technical realm.

Rather, they result from often complex interactions between people and technology and the environment in which these interactions take place. Therefore, accident investigations should extend from a simplistic analysis of individual behaviour to an examination of how the organisation managed the risk. The framework explains that there are two types of approaches to investigating occurrences, which can be described as the 'person approach' or the 'system approach',[44] These are illustrated in the diagram below.

Two Views of Human Error

Old View	New View
Human error is a cause of accidents	Human error is a symptom of trouble deeper inside a system
You must find people's: • inaccurate assessments • wrong decisions • bad judgements	To explain failure, do not try to find where people went wrong
To explain failure, you must seek failure	Instead, find out how people's assessments and actions made sense at the time, given the context

(after Dekker, 2002)

We tend to want to keep it simple and just blame somebody

The 'person approach' tends to focus on the errors and violations of individuals, while the 'system approach' traces the causal factors back into the system as a whole. The 'person approach' to investigations can only provide information that reveals *what* may have happened that led to an occurrence.

Such a restricted focus may find that an engineer did not follow a procedure. However, it does not consider the underlying background (or latent) issues in the system that may have contributed to, or allowed, the action to occur. For example, the engineer did not have the correct tooling available to complete the task in accordance with the maintenance publication. The system approach reveals more information explaining *why* the occurrence happened.

Simply focusing on the individual error tends to result in corrective actions directed at the individual only. Typical examples of this type of corrective action are when the engineer receives a warning not to do it again, is re-trained, or (in the worst case), is fired. However, this type of corrective action ignores the underlying deficiencies in the system.

---

[44] Reason, J.T. (1990). *Human Error*. Cambridge, UK: Cambridge University Press.

In a 'systems approach', any subsequent corrective actions focus on systems and processes, rather than on the individuals who may have made errors. In the case above, an update ensures all engineers have access to the specialised tooling required for the maintenance task. Training and education may also be provided on what to do if there are resource constraints.

This framework guides investigators and helps them to overcome one of the key historical limitations of safety investigation in aviation maintenance; the tendency to focus primarily on identifying errors made by engineers that may have led to an accident or incident. Expert contemporary research in human error stresses that if an organisation limits its investigation to the factors found at the sharp end of the accident/incident scene, it will dramatically limit the lessons to be learnt.

Professor James Reason studied a number of relatively high-profile accidents in the 1980s, and as a result of this work he developed the 'Reason model', which recognises that accidents have multiple causes. Crucially, Reason recognised there were multiple organisational and systemic drivers in the accident chain. The model also provides a framework for reviewing the factors in the development of an accident or incident. The 'Reason model' of accident causation looks at the following factors:

Organisational

These are the management decisions and organisational processes affecting the workplace environment—work planning, allocation of resources, equipment design, training etc.

Workplace conditions

The task and workplace conditions that affect individual performance. They include conditions that promote errors and violations such as organisational culture, weather, time pressure etc.

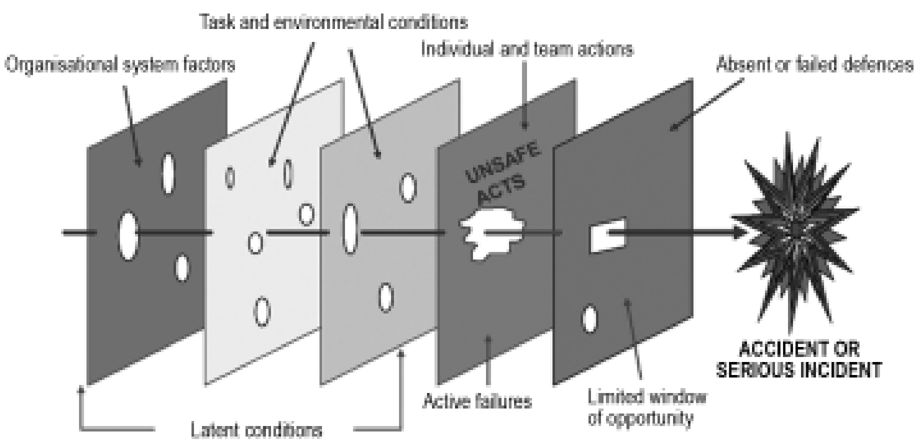
Individual and team actions

These are the actions (or inactions) of individuals and teams affecting safety, such as errors and violations.

The defences (risk controls)

These are the defences which may have failed, or were absent, such as duplicate inspections, shift handover checklists, warning systems etc.

The Reason model



The purpose of a safety investigation is to understand the circumstances surrounding an accident or incident, so that you can make recommendations to improve overall safety and prevent recurrence of the incident/accident. To accurately determine the contributing factors to an occurrence requires a systemic approach to the investigation. The Reason model helps to provide this systemic approach to the investigation process so that we can make appropriate recommendations.

The organisation's procedures for the conduct of safety investigations need to clearly show that human factors considerations are included. The main purpose of investigating an accident or incident should be to understand what happened, how it happened, and why it happened, to prevent similar future events. It is important that an appropriate investigative framework, such as the Reason model, is used to consider the drivers for human error, both at the individual and organisational levels.

Because of the vital importance to safety of accurate and concise incident investigation, at least one member of the maintenance staff should receive formal training in safety investigation techniques. The investigator training should also include training in human factors, so investigators can consider human performance factors that may have contributed to the incident under investigation.

Actions and recommendations

Once the investigation has been completed and the significant factors leading to the event have been determined, the next (and perhaps most important) part of the investigation process is to draft the actions and recommendations aimed at preventing a recurrence.

Well-written and well-considered actions and recommendations are a critical product of the investigation, to either prevent a recurrence, and/or to mitigate the hazard. It is where the rubber hits the road.

Note

Depending on what the safety investigation reveals, it may be necessary to take immediate action before the investigation is complete. In this case, the investigator should inform management, so that they can decide whether immediate safety action is appropriate.

Actions are those things the organisation can do (or put in place), immediately to improve safety and/or to prevent a recurrence. One example might be replacing defective lighting with more effective light stands. Recommendations are things which you or your management cannot action directly—which require approval at a higher organisational level. One example might be buying specific OEM-approved test equipment.

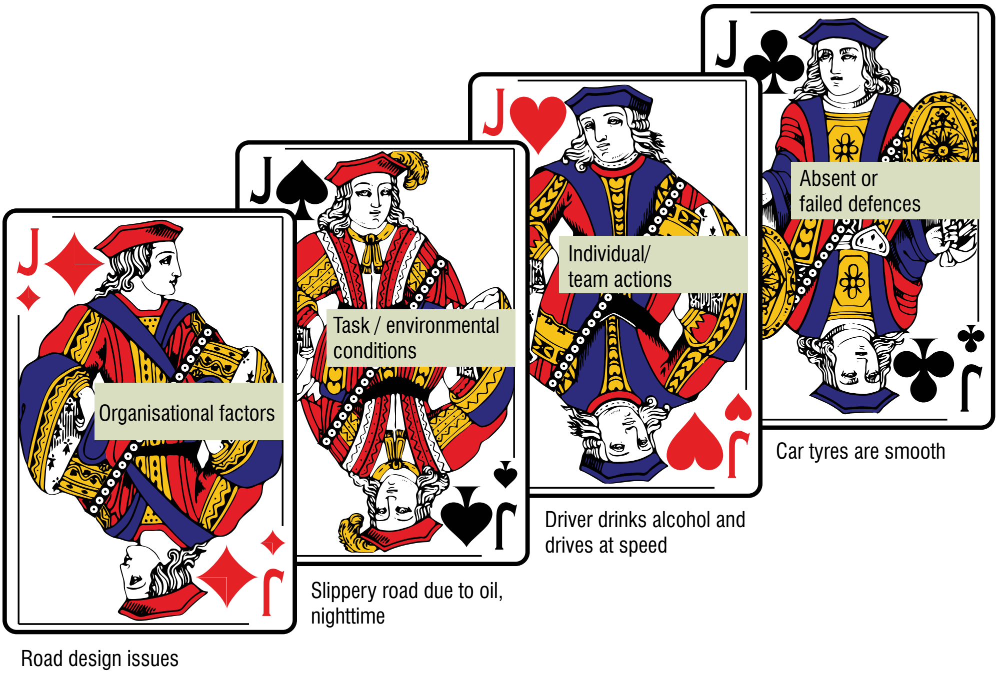
Reviewing an example using the 'Reason model' helps to understand how and why multiple factors are involved in the development of an accident or incident.

Car accident

A man has a long and heated argument with his wife. He storms out of the house to the nearest pub and rapidly downs four whiskies. He then decides to go for a drive. It is nighttime; there is an oil slick on the road, and his car's tyres are worn. In rounding a poorly banked curve at excessive speed, the right front tyre blows out. He loses control, goes over an embankment and the car rolls several times, ending up on its roof. He is badly injured.

How would we review this accident using the Reason model? It is a bit like sorting a deck of playing cards into their respective suits.

Reason model 'deck of cards'



Adapted from Safety Wise Solutions (2010) *ICAM Incident Investigation Reference Guide, Earth Graphics Melbourne.*

What we can see from the above pack of cards is that there is no one root cause. What led to the car accident was a series of factors (the concept of multiple causality) at different levels. For example:

- Absent failed defences: the car tyres were in poor condition. Had they been in better condition, they might have offered better grip to enable control of the vehicle
- Individual/team actions: the man decided to drive at excessive speed (violation) and while under the influence of alcohol (violation)
- Task/environment conditions: the road was slippery from the oil slick and the bend was difficult to see due to nighttime conditions
- Organisational factors: there are road design issues as the investigation determines that this is a known accident black spot, because of the poorly banked curve.

Risk management

It is important to actively look for hazards and risks in the work environment. Spinning propellers, jet blast, moving aircraft, high-pressure hydraulic systems and high voltage are part of the normal aviation maintenance environment. Risk management is an excellent tool to help us identify and mitigate risks in our work environment, particularly if we are faced with new or abnormal tasks and procedures.

Maintenance risk management does not have to be complex. It can be as simple as getting your maintenance team together to discuss the hazards, traps and risks inherent in the task you are about to start and how they could be mitigated.

One simple way of reviewing the hazards and applying a level of risk management to a task is known as the rule of three.[45]

The rule of three can help you to decide what action to take to mitigate a risk, or whether you should stop and review the situation before continuing. Using the rule of three, there are clear 'no-go' criteria, which are indicated by a **red** light (stop). Situations where you are approaching the limits are equivalent to an **amber** light (proceed with caution); and a **green** light (go) means that there are no restrictions to normal operations.

Under the rule of three, personnel must stop if they encounter a **red**. A number of problems where you are approaching the limit (**amber**) may be just as critical from a risk management/safety perspective. Three **amber** lights also mean that you should stop and re-evaluate the task/procedure. With this traffic light concept, you must always stop if you have a red, but too many **amber lights** may be just as risky!

The rule of three

No problems or concerns	Green	OK to continue
1 marginal condition	Amber	Proceed with caution
2 marginal conditions	Flashing Amber	Proceed with extreme caution
3 marginal conditions	Red	STOP and re-evaluate
1 unacceptable condition	Red	STOP and re-evaluate

The rule of three traffic lights

ALL GREEN MEANS – OK to continue

1 AMBER MEANS – Use caution

2 AMBERS MEANS – Use extreme caution

3 AMBER OR 1 RED MEANS – Stop and re-evaluate

[45] The 'Rule of three' adapted from the ADF Maintenance Human Factors Foundation course (AL1) 26 Nov 2009.

For the rule of three to be effective, all personnel need to be aware of it, and should agree in advance about how it will be used to manage risks during a task. Everybody needs to have a clear understanding of what constitutes ‘amber’ or ‘red’. As a team you should:

- Take time out to think about the issues and discuss them with the team. If necessary ask your manager/ supervisor
- Identify concerns about a situation. Add up all the factors classified as ‘ambers’
- Stop what you are planning to do (or are doing) if you get to three ambers or have any reds
- Review acceptable solutions and work out how the team is going to manage the risks
- Recognise what the team can or cannot do to mitigate the risks. Ensure the solutions are appropriate and authorised
- Re-assess any remaining ambers to see if the team can proceed with the task.

Using the ‘Rule of three’ in the field

One of the company’s Cessna 310s has encountered a propeller control problem en route and has diverted to an intermediate field for a precautionary landing. The pilot reports that the aircraft has diverted and is now AOG. The company has despatched you and the maintenance supervisor to sort out the problem. The passengers have been picked up and delivered to their destination in the spare aircraft. The chief pilot wants the aircraft repaired and returned to base as soon as possible the following day to pick up a charter the following evening.

The aircraft requires a prop change. It’s been a long day and you and the maintenance supervisor are approaching the end of your duty limits—a situation classified as ‘amber’. The aircraft is parked in the open beside the aero club hangar. The weather has turned very blustery and a rain cell is approaching—again, amber. The sun is about to go down and although you have powerful hand-held torches, the lack of lighting could cause difficulties with the prop change—‘amber’.

Three ambers mean STOP. You now need to re-assess the situation. What options are there?

- When is the aircraft actually required back at base?
- Can you delay the task until the weather improves?
- Can the prop change wait until first light tomorrow?
- Is it possible to contact the on-site aero club to request the use of their hangar?

After you have reviewed the options, you have to decide how you will manage the risk. That answer depends on the context.

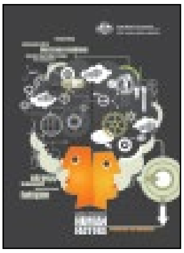
Your enquiries reveal that the spare aircraft can actually pick up tomorrow afternoon’s charter; and the president of the aero club has offered the aero club hangar for you to complete the prop change. Rather than just ‘getting on with it’, stopping, taking the time to find out more and review your options now substantially reduces the risk level associated with the task.

Strategies to reduce non-compliance	
Allocation of workload	High or inappropriate allocation of workload increases the likelihood of errors and violations occurring.
Allocation of time	Inappropriate time pressure to achieve a task increases the likelihood of all types of non-compliance occurring.
Safety culture	If personnel believe that the organisation wants them to 'bend the rules' to get the aircraft on line a culture of shortcuts and work-arounds will develop
Emergency stop procedures	If personnel can't follow the approved regulation/process/procedure or if they think there is a better way of doing the task they need a process. They should STOP and refer to the supervisor/manager. This ensures that the supervisor/manager is aware of the issue and allows for the appropriate review and approval process.
Appropriate supervision	Maintenance supervisors are the team leaders. Leadership involves the motivation of individuals within a team towards a stated goal. Supervisors must provide an example of professional behaviour and set the standard for personnel under their control.

Key points

- Safety culture is made up of the shared beliefs, values and practices which affect the safety of our environment
- An organisation with a good safety culture is one in which safe and professional behaviour is fully internalised as the way its people think and act.
- A good, positive and proactive safety culture can only grow when good safety behaviours are actively encouraged and poor safety behaviours are dealt with fairly and viewed as unprofessional.
- Although many are not even aware of them, each organisation or workplace has its own cultural norms, behaviours and practices. This organisational culture can have a significant effect—good or bad—on how we actually think and behave in the workplace.
- Organisational norms are the unwritten rules and workplace practices which are generally accepted as the way work is done within an organisation. These workplace norms may affect safety positively or negatively.
- Peer pressure is the pressure we feel to conform to what our group or peers expect of us.
- In a group, you are more likely to agree with the majority opinion, rather than disagree or rock the boat.
- Some feel that perceived pressure and actual pressure are different. For the individual, however, whether the pressure is actual or perceived does not matter, because they have the same result. The individual still feels they are under very significant and real pressure to achieve a specific outcome.
- Perceived pressure is a significant driver for both error and maintenance shortcuts/work-arounds. Make sure you allocate appropriate time to finish maintenance, including the associated administration and paperwork.
- An effective event and hazard reporting system requires an organisation to establish a culture in which people are happy to speak up when things go wrong.
- The fair-but-accountable reporting culture is an appropriate balance between punitive and non-punitive reporting cultures. The fair-but-accountable culture accepts that human error may occur, but it also requires people to perform their roles and duties professionally: all personnel are responsible for professional performance and are accountable for their intended actions.

- Major safety problems do not belong exclusively either the human or technical realms. Accident investigations, using a systems approach such as the Reason model, show that that safety breaks down because of often complex interactions between people, procedures, equipment, environment and the organisation where all these interactions take place.
- Maintenance risk management does not have to be complex. It can be as simple as getting your maintenance team together to discuss and identify the hazards, traps and risks inherent in the job you are about to start and how you can mitigate them.



When you are ready, please turn to page 63 of the *Workbook for Engineers* and complete the exercises.


leadership
communication
decision making
alcohol and other drugs
error management
stress
teamwork
fatigue
human performance

Chapter 13

‘Human factors is about people. It is about people in their working and living environments. It is about their relationship with machines and equipment, with procedures, and with the environment about them. And it is also about their relationship with other people.’

Frank Hawkins

Jargon busters—abbreviations, acronyms and definitions

Abbreviations

AC	Advisory circular
ADF	Australian Defence Force
AOD	Alcohol and other drugs
AOG	Aircraft on ground
AME	Aircraft maintenance engineer
AMM	Aircraft maintenance manual
AMO	Approved maintenance organisation
APU	Auxiliary power unit
ASRS	Aviation safety reporting system
ATC	Air traffic control
ATSB	Australian Transport Safety Bureau
BAC	Blood alcohol concentration
CAA	Civil Aviation Authority (of the UK)
CAAP	Civil Aviation Advisory Publication
CAO	Civil Aviation Order
CAR	*Civil Aviation Regulations 1988*
CAS	Circadian alertness simulator
CASA	Civil Aviation Safety Authority
CASR	*Civil Aviation Safety Regulation 1998*
CDU	Centre drive unit
CRM	Crew resource management
CRS	Certificate of release to service
DAMP	Drug and Alcohol Management Plan
DDG	Dispatch deviation guide
DOTARS	Department of Transport and Regional Services
EASA	European Aviation Safety Agency
ECAM	Electronic centralised aircraft activity monitoring
EFOB	Extra fuel on board
EGPWS	Enhanced ground proximity warning system
EGT	Exhaust gas temperature
ETOPS	Extended range twin-engine operations
FAA	Federal Aviation Administration (USA)

FAID	Fatigue audit InterDyne
FAIR	Flowchart analysis of investigation results
FAST	Fatigue avoidance scheduling tool
FEG	Force element group
FL	Flight level
FQI	Fuel quantity indicator
FMS	Flight management system
FOD	Foreign object damage
FRMS	Fatigue risk management system
GA	General aviation
GSE	Ground servicing equipment
HF	Human factors
ICAO	International Civil Aviation Organization
INOP	Inoperative
IPC	Illustrated parts catalogue
JAR	Joint Aviation Regulations
LAE	Licensed aircraft engineer
LAME	Licensed aircraft maintenance engineer
LTI	Lost time injury
MAN	Manual
MEL	Minimum equipment list
NASA	National Aeronautical and Space Administration
NDARC	National Drug and Alcohol Research Centre
NTSB	National Transport Safety Board (USA)
OFV	Out flow valve
OTC	Over-the-counter (used to refer to medicines)
PPE	Personal protective equipment
RON	Remain over night
SOP	Standard operating procedure
SMS	Safety management system
SRRS	Social readjustment rating scale
SSAA	Safety-sensitive aviation activities
TEM	Threat and error management
WOCL	Window of circadian low

Definitions

Arousal: being responsive to sensory stimulation, or excitability. Basically, it means being alert, mentally and physically.

Circadian rhythm: our body's 24-hour internal clock. Circadian is a Latin word meaning 'about a day'.

Communication: the creation of shared meaning by the effective transfer of information from one person to another.

Conformity: the natural human tendency to comply with social pressure to avoid rejection, or to gain social approval.

Defences: barriers or safeguards to guard against errors. They can range from engineered safety devices (i.e. seatbelts, electronic warning and detection systems) to defences such as standard operating procedures, or staff awareness via communication or training programs.

Episodic memory: remembering specific events, usually those that are significant to us.

Error: actions or inactions that lead to a deviation from intentions or expectations.

Error-producing conditions: conditions that increase the risk of error such as time pressure or fatigue.

Error tolerance: an approach designed to eliminate single points of failure so that errors not captured in the system do not lead to an accident.

Fatigue: the experience of physical and/or psychological weariness.

Followership: the ability to contribute to task and goal accomplishment, through supportive, technical, interpersonal, and cognitive skills.

Group think: the desire/pressure to reach unanimous agreement.

Hazard: something with the potential to cause harm.

Human error: those occasions in which a planned sequence of mental or physical activity fails to achieve its intended outcome.

Human factors: is a broad term referring to the study of people's performance in their work and non-work environments. It involves optimising the fit between people and the system in which they work.

Individual/team actions: the actual errors or violations committed by operators, which may lead directly to a safety incident.

Insomnia: an inability to get to sleep, or difficulty staying asleep. In many cases, insomnia is a symptom of another problem, such as medical conditions, side effects of medicines, or sleep disorders. Insomnia can also be caused by worry or emotional upsets.

Judgement: an opinion formed after analysis of relevant information.

Just culture: an organisational perspective that recognises that human error is normal, and thus discourages blaming individuals for honest mistakes. However, reckless behaviour is unacceptable, and brings sanctions. Also see 'safety reporting culture'.

Knowledge-based mistakes: these occur in situations where normal rules may not be working. In new situations, previous training may not provide sufficient procedures to adequately deal with an unusual situation.

Latent conditions: 'mouse traps' which may lie dormant within the work system, but have the potential to increase safety risk and create error-producing conditions in the workplace; for example, flaws in original design of aircraft components.

Long-term memory: a system that retains information more or less permanently.

Memory lapse: 'I forgot to …' When someone forgets to do something they intended to.

Mistake: the errors made where the plan for specific action is deficient or fundamentally flawed.

Manage(ment): To plan, resource, direct and control an operation or situation.

Near miss: a close call, which did not result in damage or injury.

No-blame culture: a flawed approach to safety that suggests as long as someone admits to an error they should not be disciplined or punished.

Non-technical skills: Specific human factors competencies, such as situational awareness, decision making, task management and team communication.

Norms: unwritten, informal rules/work practices members of the organisation follow—'It's the way we do things here'.

Periodic limb movements (PLM): Involuntary leg movements while asleep. They often disrupt sleep and may cause the person to wake up.

Person approach: tends to focus on an individual's errors and violations of individuals.

Restless legs syndrome (RLS): a disorder that causes a strong urge to move your legs. This urge to move often occurs with strange and unpleasant feelings such as creeping, tingling or burning. Moving your legs relieves the urge and the unpleasant feelings.

Risk: the chance of something happening that will have an impact on objectives. A risk is often specified in terms of an event or circumstance and any consequence that might flow from it. Risk is measured in terms of a combination of the consequences of an event, and its likelihood. Risk can have a positive or negative impact.

Rule-based mistakes: a type of error that involves the incorrect initiation of actions in response to existing behavioural routines. Frequently, rule-based mistakes involve an automatic response to a misdiagnosed problem, or the automatic misdiagnosis of a situation.

Safety: is the state in which the probability of harm to persons or of property damage is reduced to, and maintained at a level that is as low as reasonably practicable, through a continuing process of hazard identification and reduction.

Safety culture: an enduring set of beliefs, norms, attitudes and practices within an organisation concerned with minimising exposure of employees, managers, customers and members of the general public to dangerous or hazardous conditions. A positive safety culture is one which promotes concern for, commitment to, and accountability for, safety.

Safety reporting culture: acknowledges that error is a normal consequence of human activity. It is neither blame-free nor punitive. It ecourages open reporting of near misses and employee participation in safety issues.

Semantic memory: a type of memory that involves knowledge associated with data, skills, knowledge and things we are able to do for a purpose or meaning.

Sensory memory: a system that retains information for no more than a second or two.

Short-term memory: a system which holds a limited amount of information for approximately 30 seconds.

Situational awareness: the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future. Or simply, understanding 'what has happened, what is happening, and what might happen'.

Sleep apnoea: a disorder in which breathing pauses or becomes shallow during sleep.

Sleep inertia: a brief period of confusion, poor memory and grogginess experienced in the few minutes after waking up.

Slips: unintentional actions or active failures in the execution of a plan. 'I didn't mean to ...' An action is performed when there was no intention to perform it.

Standard operating procedure: any procedure included in an organisation's operations manual.

Stress: is the high level of emotional arousal typically associated with an overload of mental and/or physical activity.

Stressors: disturbing physical or psychological influences on human performance.

System approach: traces the causal factors back into the system as a whole.

Technical skills: the manipulative and knowledge skills an engineer employs when servicing an aircraft.

Task/environmental conditions: aspects of the task, equipment, environment or human limitations that increase the propensity for, or likelihood of, human error.

Violations: intended or deliberate deviations from rules, codes of practice, or procedures. Violations range from taking simple shortcuts, to one-off breaches of regulations, seemingly dictated by unusual circumstances (exceptional violation).

Exceptional violations: (often) well-intentioned, one-off departures from known procedures to get the job done—'we can't do this any other way'.

Further information

References and recommended reading

'AOD 12 Months On'. *Flight Safety Australia*. Issue #76 Sep-Oct, 2010

Australian Defence Force, (2009). ADF Maintenance Human Factors Foundation course (AL1) 26 Nov, Canberra.

Australian Transport Safety Bureau (ATSB), Aviation Research and Analysis Report – AR-2008-055, titled 'An Overview of Human Factors in Aviation Maintenance' by Alan Hobbs Ph.D, December 2008.

EASA. CAP 715. An Introduction to Aircraft Maintenance Engineering Human Factors for JAR 66 (EASA 66).

Endsley, M.R., & Robertson, M.M. (2000), 'Situation awareness in aircraft maintenance teams', *International Journal of Industrial Ergonomics*

FAA (2005). Operator's Manual. Human Factors in Aviation Maintenance. Available www.hf.faa.gov/opsmanual

FAA Federal Air Surgeon's Medical Bulletin, Vol. 48, No. 3 2010-3, *Aviation Safety Through Aerospace Medicine,* For FAA Aviation Medical Examiners, Office of Aerospace Medicine Personnel, Flight Standards Inspectors, and Other Aviation Professionals.

FAA Human factors in maintenance website: https://hfskyway.faa.gov

Hudson, P. (2001). Safety Management and Safety Culture. The Long and Winding Road. As presented to CASA, September 10, 2001, Canberra.

ICAO (1995). 'Human Factors in Aircraft Maintenance and Inspection'. *Human Factors Digest* No.12; ICAO (2003) 'Human Factors Guidelines for Aircraft Maintenance' (Contains a training syllabus for human factors in maintenance in appendix B, of Chapter 5).

Jurgen, A.G., van Avermaete, A.G., & Hakkeling-Mesland, M.Y. (2001). *Maintenance Human Factors from a European Research Perspective: Results from the ADAMS Project and Related Research Initiatives*. National Aerospace Laboratory NLR, Netherlands

Maurino, D.E., Reason, J., Johnston, N. & Lee, R. (2006). *Beyond Aviation Human Factors*. Ashgate.

McDonald N and others, Human-Centred Management Guide for Aircraft Maintenance Aircraft Dispatch and Maintenance Safety

Merritt, A.C., & Helmreich, R.L. (1996). 'Creating and sustaining a safety culture: Some practical strategies'. In B. Hayward & A. Lowe (Eds.), *Applied Aviation Psychology: Achievement, Change and Challenge*, Sydney: Avebury Aviation.

OTAC. Aircraft Maintenance Engineers, Personal Responsibility When Medically Unfit or Under the Influence of Drink or Drugs. 66-1, 145-9.

Reason, J. (1990). *Human Error.* Cambridge: Cambridge University Press.

Reason, J., Maurino, D. & and Helmreich, B. (2001). 'The brainy bunch'. *Flight Safety Australia*, Vol 5 No.1 Jan-Feb 2001, CASA.

Reason, J & Hobbs, A. (2003) *Managing maintenance error: A practical guide*. Ashgate: Aldershot.

Sellers, R, (2011). *Managing the risks of interruptions and distractions during safety critical maintenance*. Convergent Safety Systems.

Sellers, R, (2010), *A professional culture of safety*. Convergent Safety Systems.

UK CAA CAP 716 Aviation Maintenance Human Factors (EASA / JAR145 Approved Organisations) Guidance Material on the UK CAA Interpretation of Part-145 Human Factors and Error Management Requirements.

Available at http://www.caa.co.uk

U.K. CAA CAP 715

Chapter 3 – Social Psychology **www.caa.co.uk/docs/33/CAP715.pdf**

Chapter 4 – Factors Affecting Performance

U.K. CAA CAP 716

Chapter 4 – Factors Associated with the Individual

Chapter 8 – Planning, Preparation and Teamwork **www.caa.co.uk/docs/33/CAP716.pdf**

Chapter 9 – Professionalism and Integrity **www.caa.co.uk/docs/33/CAP716.pdf**

Recommended websites

Aviation Human Factors Industry News **www.decodinghumanfactors.com/current-newsletter**

CASA AOD website: **www.casa.gov.au/aod/**

Human Factors on Aviation Maintenance and Inspection (HFAMI) website
www.iasa.com.au/folders/Safety_Issues/others/maintsnafu.html

Royal Aeronautical Society Human Factors Group, **www.raes-hfg**

Neil Krey's CRM Developers Forum **www.crm-devel.org**

Fatigue modeling software can be found at the following websites:
Fatigue Audit InterDyne (FAID) **www.faidsafe.com**
Fatigue Avoidance Scheduling Tool (FAST) **www.fatiguescience.com**
Circadian Alertness Simulator (CAS) **www.circadian.com**

World's best practices on fatigue management in maintenance are summarized in a report entitled *'Fatigue Risk Management in Aviation Maintenance: Current Best Practices and Potential Future Countermeasures'* Available on the FAA fatigue website.

Federal Aviation Administration (FAA) **http://hfskyway.faa.gov**

Grounded, is an entertaining video about maintenance fatigue! As the DVD notes say: 'There is trouble on the home front and fires at work! Gregg is an airline manager who needs some rest. Can he get the aircraft back in the air and also correct his poor sleep habits? Or, will he go through life *Grounded?* This video is about sleep but is not a sleeper. Available free of charge at:
https://hfskyway.faa.gov/HFSkyway/FatigueEducation.aspx

International Civil Aviation Organization (ICAO) **www.icao.int**

European Aviation Safety Agency (EASA) **www.easa.eu.int**

Transport Canada **www.tc.gc.ca**

United Kingdom Civil Aviation Authority (CAA) **www.caa.co.uk**

United States Air Transport Association (ATA) **www.airlines.org**

Civil Aviation Safety Authority

GPO Box 2005 Canberra ACT 2601

Telephone 131 757 (local call)

Email humanfactors@casa.gov.au

Website www.casa.gov.au