Human Factors

for aviation maintenance technology

Complies with
EASA Part 66
Module 9
through level 3

performance and limitations, psychology,
factors affecting performance,
physical environment, tasks,
communication, human error, hazards

HATA
Hellenic Aviation Training Academy

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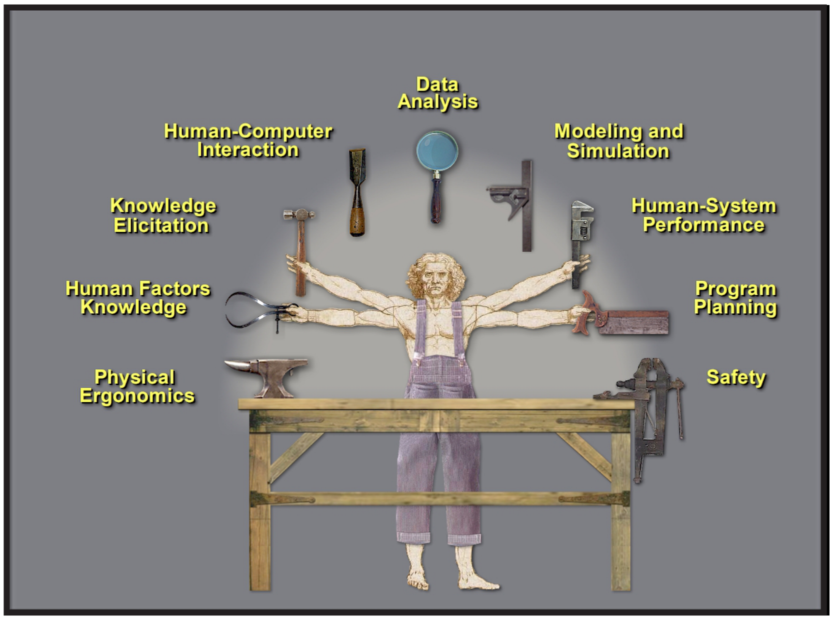

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Dear Student,

Human Factors is the study of how an aircraft mechanic interacts with the working environment. In the case of aircraft maintenance, it is the study of how a mechanic's performance is influenced by such issues as the design of aircraft systems, the physical and mental state of the mechanic, the effects of emotions, and the interaction and communication with the other colleagues of the aviation community, such as flight crew members and other personnel.

As an aircraft mechanic, it is important to stay aware of the mental and physical standards required for the type of maintenance work to be done. This module provides information on human factors related to aircraft maintenance activities.

The proper decision making is used by aircraft mechanics to consistently determine the best course of action in response to a given set of circumstances. The importance of learning effective decision making skills cannot be overemphasized. While progress is continually being made in the advancement of technical training methods, aircraft equipment and systems, and services for mechanics, human errors will be made and accidents will still occur. Despite all the changes in technology to improve flight safety, one factor remains the same: the human factor. It is estimated that approximately 80% of all aviation accidents are caused by human errors.

Historically, the term "human error" has been used to describe the causes of these accidents. Maintenance error means that an action or decision made by the mechanic was the cause, or a contributing factor that led to the accident. This definition also includes the mechanic's failure to make a decision or take action. From a broader perspective, the phrase "*human factors related*" more appropriately describes these accidents since it is usually not a single factor that leads to an accident, but a chain of events triggered by a number of factors.

The poor judgment chain, sometimes referred to as the "*error chain*," is a term used to describe this concept of contributing factors in a human factors - related accident.

Breaking one link in the chain normally is all that is necessary to change the outcome of the sequence of events.

And never forget:

YOU are the key for promoting safety, against the contributing factors that may affect your performance.

These factors are known as the "*DIRTY DOZEN*".

HATA Safety Management Team

April 2010

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Chapter 1. Introduction to Human Factors

1 General

This chapter introduces human factors and explains its importance to the aviation industry. It examines the relationship between human factors and incidents largely in terms of human error and "Murphy's Law" (i.e. if it can happen, one day it will).

1.1 The Need to Take Human Factors into Account

Greek mythology tells us that Daedalus and Icarus, father and son, were held as prisoners by King Minos on the island of Crete. Daedalus studied birds' flight and made for himself and his son pairs of wings. He used framework of wood covered with cloth, and with melted wax he attached feathers. Before the escape, Daedalus warned his son that if he flew too close to the sea, the spray would wet his feathers and make flying difficult; and Icarus was warned that if he climbed too high, the heat from the sun would melt the wax that held his feathers and flying would be impossible.

In their escape Icarus flew too close to the sea, got his feathers wet, and barely remained airborne. He then flew too high; the sun melted the wax, he lost his feathers, and fell to his death in the sea. This may have been the first forewarning of a need for procedural control over a process as well as a prophecy of a procedural noncompliance.

The aviation industry and the people within the industry have always been considered a little different than others. This may be attributable to the hundreds, or even thousands, of years attempting to do what many considered was impossible. Though this book is designed to provide an understanding of how the human factors principles combine to the requirements of the various aviation regulations for commercial aviation manufacturers, designated alteration stations, and repair stations, it is important that personnel working within this field understand the history of their industry. This also will provide some insight as to how and why regulation was implemented into the aviation industry. We cannot begin to focus on the future without understanding our past.

In the early days of powered flight, the design, construction and control of aircraft predominated. The main attributes of the first pilots were courage and the mastery of a whole new set of skills in the struggle to control the new flying machines.

As the technical aspects of flight were overcome bit by bit, the role of the people associated with aircraft began to come to the fore. Pilots were supported initially with mechanisms to help them stabilize the aircraft, and later with automated systems to assist the crew with tasks such as navigation and communication. With such interventions to complement the abilities of pilots, aviation human factors were born.

An understanding of the importance of human factors to aircraft maintenance engineering is essential to anyone considering a career as a licensed aircraft engineer. This is because human factors will impinge on everything they do in the course of their job in one way or another.

1.2 What is "Human Factors"?

The term **"human factors"** is used in many different ways in the aviation industry.

The term is, perhaps, best known in the context of aircraft cockpit design and Crew Resource Management (CRM). However, those activities constitute only a small percentage of aviation-related human factors, as broadly speaking it concerns any consideration of human involvement in aviation.

The use of the term "human factors" in the context of aviation maintenance engineering is relatively new. Aircraft accidents such as that to the Aloha aircraft in the USA in 1988 and the BAC 1-11 windscreen accident in the UK in June 1990 brought the need to address human factors issues in this environment into sharp focus. This does not imply that human factors issues were not present before these dates nor that human error did not contribute to other incidents; merely that it took an accident to draw attention to human factors problems and potential solutions.

Before discussing how these accidents were related to human factors, a definition of human factors is required. There are many definitions available. Some authors refer to the subject as 'human factors' and some as **'ergonomics'.** Some see "human factors" as a scientific discipline and others regard it as a more general part of the human contribution to system safety. Although there are simple definitions of human factors such as: "Fitting the man to the job and the job to the man", a good definition in the context of aviation maintenance would be:

"Human factors" refers to the study of human capabilities and limitations in the workplace. Human factors researchers study system performance. That is, they study the interaction of maintenance personnel, the equipment they use, the written and verbal procedures and rules they follow, and the environmental conditions of any system. The aim of human factors is to optimise the relationship between maintenance personnel and systems with a view to improving safety, efficiency and well-being".

Thus, human factors include such attributes as:

- ✈ human physiology (including perception, cognition, memory, social interaction, error)**;**
- ✈ work place design;
- ✈ environmental conditions;
- ✈ human-machine interface;
- ✈ anthropometrics (the scientific study of measurements of the human body).

1.3 The SHEL Model

Human factors concentrates on the interfaces between the human (the 'L' in the centre of the model) and the other elements of the SHEL model (see Figure 1-1 SHEL Model), and - from a safety viewpoint - where these elements can be deficient.

It can be helpful to use a model to aid in the understanding of human factors, or as a framework around which human factors issues can be structured. A model which is often used is the SHEL model, a name derived from the initial letters of its components:

Software misinterpretation of procedures, badly written manuals, poorly designed checklists, untested or difficult to use computer software (e.g. maintenance procedures, maintenance manuals, checklist layout, etc.);

Hardware lack of tools, inappropriate equipment, poor aircraft design for maintainability, test equipment, the physical structure of aircraft, design of flight decks, positioning and operating sense of controls and instruments, etc.);

Environment uncomfortable workplace, inadequate hangar space, extreme temperatures, excessive noise, poor lighting work environment such as work patterns, management structures, public perception of the industry, etc.;

Liveware relationships with other people, shortage of manpower, lack of supervision, lack of support from managers (i.e. the person or people at the centre of the model, including maintenance engineers, supervisors, planners, managers, etc.).

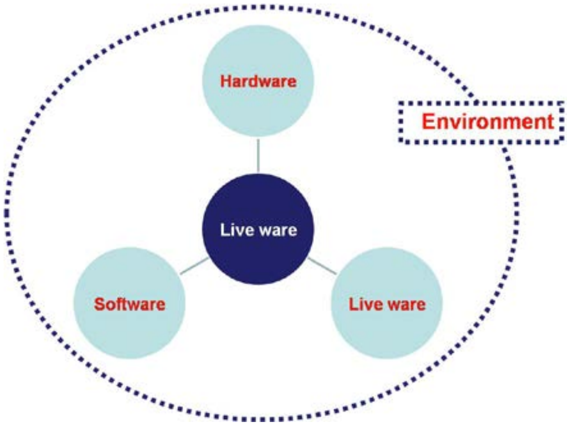


Figure 1-1 SHEL Model

As will be covered in this chapter, man, the "Liveware" - can perform a wide range of activities. Despite the fact that modern aircraft are now designed to embody the latest self-test and diagnostic routines that modern computing power can provide, one aspect of aviation maintenance has not changed: maintenance tasks are still being done by human beings. However, man has limitations. Since Liveware is at the centre of the model, all other aspects (Software, Hardware and Environment) must be designed or adapted to assist his performance and respect his limitations. If these two aspects are ignored, the human - in this case the maintenance engineer - will not perform to the best of his abilities, may make errors, and may jeopardize safety.

Thanks to modern design and manufacturing, aircraft are becoming more and more reliable. However, it is not possible to re-design the human being: we have to accept the fact that the human being is intrinsically unreliable. However, we can work around that unreliability by providing good training, procedures, tools, duplicate inspections, etc. We can also reduce the potential for error by improving aircraft design such that, for example, it is physically impossible to reconnect something the wrong way round.

1.4 Incidents and Accidents Attributable To Human Factors / Human Error

In 1940, it was calculated that approximately 70% of all aircraft accidents were attributable to man's performance, that is to say human error. When the International Air Transport Association (IATA) reviewed the situation 35 years later, they found that there had been no reduction in the human error component of accident statistics (Figure 1-2).

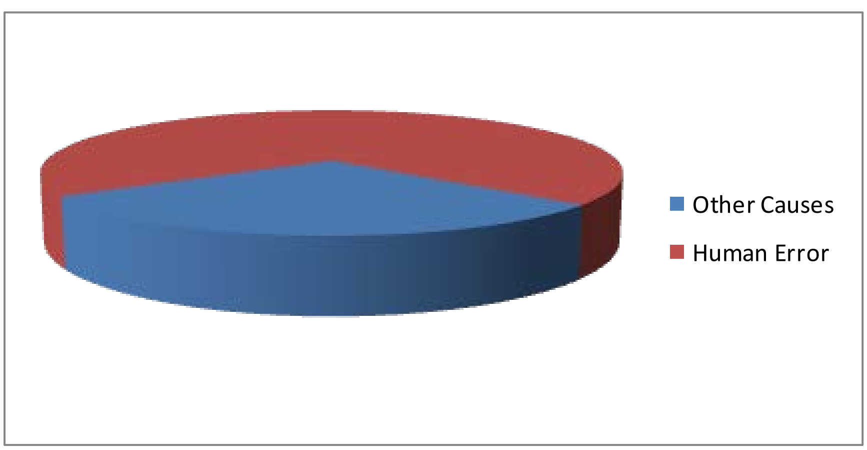


Figure 1-2 The dominant role played by human performance in civil aircraft accidents

A study was carried out in 1986, in the USA, looking at significant accident causes in 93 aircraft accidents. These were as follows:

Causes / major contributory factors	% of accidents in which this was a factor
Pilot deviated from basic operational procedures	33
Inadequate cross-check by second crew member	26
Design faults	13
Maintenance and inspection deficiencies	12
Absence of approach guidance	10
Captain ignored crew inputs	10
Air traffic control failures or errors	9
Improper crew response during abnormal conditions	9
Insufficient or incorrect weather information	8
Runways hazards	7
Air traffic control/crew communication deficiencies	6
Improper decision to land	6

As can be seen from the list, maintenance and inspection deficiencies are one of the major contributory factors to accidents.

The UK CAA carried out a similar exercise in 1998 looking at causes of 621 global fatal accidents between 1980 and 1996. Again, the area "*maintenance or repair oversight / error / inadequate*" featured as one of the top 10 primary causal factors.

It is clear from such studies that human factors problems in aircraft maintenance engineering are a significant issue, warranting serious consideration.

1.5 Examples of Incidents and Accidents

1.5.1 Aloha flight 243

The accident involving Aloha flight 243 in April 1988 involved 18 feet of the upper cabin structure suddenly being ripped away in flight due to structural failure. The Boeing 737 involved in this accident had been examined, as required by US regulations, by two of the engineering inspectors. One inspector had 22 years experience and the other, the chief inspector, had 33 years experience. Neither found any cracks in their inspection. Post-accident analysis determined there were over 240 cracks in the skin of this aircraft at the time of the inspection. The ensuing investigation identified many human-factors-related problems leading to the failed inspections.

As a result of the Aloha accident, the US instigated a programme of research looking into the problems associated with human factors and aircraft maintenance, with particular emphasis upon inspection.

1.5.2 British Airways flight 5390

On June 10th 1990 in the UK, a BAC1-11 (British Airways flight 5390) was climbing through 17,300 feet on departure from Birmingham International Airport when the left windscreen, which had been replaced prior to flight, was blown out under the effects of cabin pressure when it overcame the retention of the securing bolts, 84 of which, out of a total of 90, were smaller than the specified diameter. The commander was sucked halfway out of the windscreen aperture and was restrained by cabin crew whilst the co-pilot flew the aircraft to a safe landing at Southampton Airport.

The Shift Maintenance Manager, short-handed on a night shift, had decided to carry out the windscreen replacement himself. He consulted the Maintenance Manual (MM) and concluded that it was a straightforward job. He decided to replace the old bolts and, taking one of the bolts with him (a 7D), he looked for replacements. The storeman advised him that the job required 8Ds, but since there were not enough 8Ds, the SMM decided that 7Ds would do (since these had been in place previously). However, he used sight and touch to match the bolts and, erroneously, selected 8Cs instead, which were longer but thinner. He failed to notice that the countersink was lower than it should be, once the bolts were in position. He completed the job himself and signed it off, the procedures not requiring a pressure check or duplicated check.

There were several human factors issues contributing to this incident, including perceptual errors made by the SMM when identifying the replacement bolts, poor lighting in the stores area, failure to wear spectacles, circadian effects, working practices, and possible organizational and design factors.

1.5.3 Airbus A320, G-KMAM

An incident in the UK in August 1993 involved an Airbus 320 which, during its first flight after a flap change, exhibited an undemanded roll to the right after takeoff. The aircraft returned to Gatwick and landed safely. The investigation discovered that during maintenance, in order to replace the right outboard flap, the spoilers had been placed in maintenance mode and moved using an incomplete procedure; specifically the collars and flags were not fitted. The purpose of the collars and the way in which the spoilers functioned was not fully understood by the engineers. This misunderstanding was due, in part, to familiarity of the engineers with other aircraft (mainly 757) and contributed to a lack of adequate briefing on the status of the spoilers during the shift handover. The locked spoiler was not detected during standard pilot functional checks.

1.5.4 Boeing 737, G-OBMM

In the UK in February 1995,a Boeing 737-400 suffered a loss of oil pressure on both engines. The aircraft diverted and landed safely at Luton Airport. The investigation discovered that the aircraft had been subject to borescope inspections on both engines during the preceding night and the high pressure (HP) rotor drive covers had not been refitted, resulting in the loss of almost all the oil from both engines during flight. The line engineer was originally going to carry out the task, but for various reasons he swapped jobs with the base maintenance controller. The base maintenance controller did not have the appropriate paperwork with him. The base maintenance controller and a fitter carried out the task, despite many interruptions, but failed to refit the rotor drive covers. No ground idle engine runs (which would have revealed the oil leak) were carried out. The job was signed off as complete.

In all three of these UK incidents, the engineers involved were considered by their companies to be well qualified, competent and reliable employees. All of the incidents were characterized by the following:

- There were staff shortages;
- Time pressures existed;
- All the errors occurred at night;
- Shift or task handovers were involved;
- They all involved supervisors doing long hands-on tasks;
- There was an element of a "can-do " attitude;
- Interruptions occurred;
- There was some failure to use approved data or company procedures;
- Manuals were confusing;
- There was inadequate pre-planning, equipment or spares.

1.6 Incidents and Accidents - A Breakdown in Human Factors

In all of the examples above, the accident or incident was preventable and could have been avoided if any one of a number of things had been done differently. In some cases, a number of individuals were involved and the outcome could have been modified if any one of them had reacted or queried a particular action. In each situation however, the individuals failed to recognize or react to signs of potential hazards, did not react as expected of them, or allowed themselves to be diverted from giving their attention to the task in hand, leaving themselves open to the likelihood of committing an error.

As with many incidents and accidents, all the examples above involved a series of human factors problems which formed an error chain (see Figure 1-3).If any one of the links in this '*chain*' had been broken by building in measures which may have prevented a problem at one or more of these stages, these incidents may have been prevented.

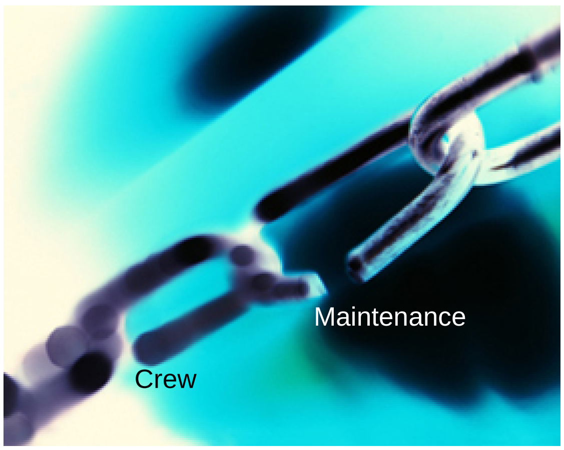


Figure 1-3 The Error Chain

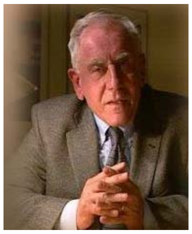
1.7 Murphy's Law

There is a tendency among human beings towards **complacency**. The belief that an accident will never happen to "me" or to "my Company" can be a major problem when attempting to convince individuals or organizations of the need to look at human factors issues, recognize risks and to implement improvements, rather than merely to play “hypocrisy” to human factors.

"Murphy's Law" can be regarded as the notion: "If something can go wrong, it will."

If everyone could be persuaded to acknowledge Murphy's Law, this might help overcome the "it will never happen to me" belief that many people hold. It is not true that accidents only happen to people who are irresponsible or 'sloppy'. The incidents and accidents described show that errors can be made by experienced, well-respected individuals and accidents can occur in organizations previously thought to be "safe".

1.8 Dr James Reason



James Reason is considered the leading authority on the study of human error until he retired. Many of the theories described in this manual were propounded by him.

James Reason was professor of psychology at the University of Manchester, United Kingdom. His primary research interest is human performance in hazardous systems. In 1999, Professor Reason was a member of the chief medical officer's expert group on 'learning from experience' and was also adviser to the Bristol Royal Infirmary Inquiry. In 1995, he received the Distinguished Foreign Colleague Award from the United States Human Factors and Ergonomics Society. From 1962 to 1977, Dr. Reason worked at the Royal Air Force Institute of Aviation Medicine, the United States Naval Aerospace Medical Institute and the University of Leicester. He has published books on motion sickness, transport human factors, absent-mindedness, human error, and on managing the risks of organizational accidents. He is a fellow of the British Psychological Society, the Aeronautical Society, and the British Academy. Professor Reason holds a Ph.D. in psychology and physiology from the University of Leicester, United Kingdom.

1.8.1 The Choice is Very Simple

"Either you manage human error or human error will manage you."

Another way of putting it is to say:

"If you're not part of the solution, then you're part of the problem."

1.8.2 There is bad news and good news:

The bad news

If some evil genius were given the job of designing a task guaranteed to produce an abundance of errors, he or she would come up with something like aircraft maintenance:

- frequent removal and replacement of many parts
- often in cramped and poorly lit spaces
- often with less than adequate tools
- often under severe time pressure.

Maintenance-related activities are so error-provoking that it is hard to believe that they have not been contrived by some malign mastermind.

Additional refinements

- People who write the manuals and procedures hardly ever do the job for real.
- People who start on a job are not necessarily the ones to finish it.
- Several groups work on same aircraft at same time and/or sequentially.

"Small wonder, then, that maintenance attracts more than its fair share of errors"

The good news

- Maintenance-related errors are not random events.

- ✈ They fall into recurrent patterns, shaped by situation and task factors characteristic of maintenance activities in general.
- ✈ Different people in different organisations keep on making the same blunders.
- ✈ Can focus limited resources to maximum remedial effect.

Many people regard errors as random occurrences, events that are so wayward and unpredictable as to be beyond effective control. But this is not the case. While it is true that chance factors play their part and that human fallibility will never be wholly eliminated, the large majority of slips, lapses and mistakes fall into systematic and recurrent patterns. Far from being entirely unpredictable happenings, maintenance mishaps fall mostly into well-defined clusters shaped largely by situation and task factors that are common to maintenance activities in general. That these errors are not committed by a few careless or incompetent individuals is evident from the way that different people in different kinds of maintenance organisations keep on making the same blunders.

One of the basic principles of error management is that the best people can make the worst mistakes.

So the good news boils down to this: the maintenance error problem can be managed in the same way that any well-defined business risk can be managed. And because most maintenance errors occur as recognisable and recurrent types, limited resources can be targeted to achieve maximum remedial effect. It should be stressed, however, that there is no one best way of limiting and containing human error. Effective error management requires a wide variety of counter-measures directed at different levels of the system: the individual, the team, the task, the workplace and the organisation as a whole.

Chapter 2. Human Performance and Limitations

2 Overview

The intention of this chapter is to provide an overview of those key physical and mental human performance characteristics which are likely to affect an aircraft maintenance engineer in his working environment, such as his vision, hearing, information processing, attention and perception, memory, judgment and decision making.

2.1 Human Performance as Part of the Maintenance Engineering System

Just as certain mechanical components used in aircraft maintenance engineering have limitations, engineers themselves have certain capabilities and limitations that must be considered when looking at the maintenance engineering 'system'. For instance, rivets used to attach aluminium skin to a fuselage can withstand forces that act to pull them apart. It is clear that that these rivets will eventually fail if enough force is applied to them. While the precise range of human capabilities and limitations might not be as well-defined as the performance range of mechanical or electrical components, the same principles apply in that human performance is likely to degrade and eventually 'fail' under certain conditions (e.g. stress).

Mechanical components in aircraft can, on occasion, suffer catastrophic failures. Man, can also fail to function properly in certain situations. Physically, humans become fatigued, are affected by the cold, can break bones in workplace accidents, etc. Mentally, humans can make errors, have limited perceptual powers, can exhibit poor judgment due to lack of skills and knowledge, etc. In addition, unlike mechanical components, human performance is also affected by social and emotional factors. Therefore failure by aircraft maintenance engineers can also be to the detriment of aircraft safety.

The aircraft engineer is the central part of the aircraft maintenance system. It is therefore very useful to have an understanding of how various parts of his body and mental processes function and how performance limitations can influence his effectiveness at work.

2.2 Vision

2.2.1 The Basic Function of the Eye

In order to understand vision, it is useful first to know a little about the anatomy of the eye (see Figure 2.1). The basic structure of the eye is similar to a simple camera with an aperture (the **iris**), a **lens**, and a light sensitive surface (the **retina**). Light enters the eye through the **cornea,** then passes through the iris and the lens and falls on the retina. Here the light stimulates the light-sensitive cells on the retina **(rods and cones)** and these pass small electrical impulses by way of the **optic nerve** to the **visual cortex** in the brain. Here, the electrical impulses are interpreted and an image is perceived.

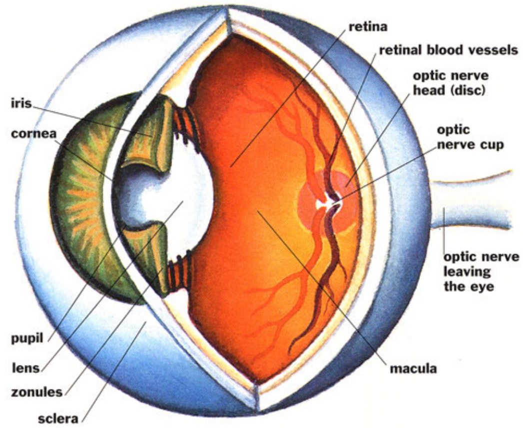


Figure 2-1 The human eye

2.2.2 Components of the Eye

The Cornea: The cornea is a clear 'window' at the very front of the eye. The cornea acts as a fixed focusing device. The focusing is achieved by the shape of the cornea bending the incoming light rays. The cornea is responsible for between 70% and 80% of the total focusing ability (refraction) of the eye.

The Iris and Pupil: The iris (the coloured part of the eye) controls the amount of light that is allowed to enter the eye. It does this by varying the size of the pupil (the dark area in the centre of the iris). The size of the pupil can be changed very rapidly to cater for changing light levels. The amount of light can be adjusted by a factor of 5:1.

The Lens: After passing through the pupil, the light passes through the lens. Its shape is changed by the muscles (cilliary muscles) surrounding it which results in the final focusing adjustment to place a sharp image onto the retina. The change of shape of the lens is called **accommodation.** In order to focus clearly on a near object, the lens is thickened. To focus on a distant point, the lens is flattened. The degree of accommodation can be affected by factors such as fatigue or the ageing process.

When a person is tired accommodation is reduced, resulting in less sharp vision (sharpness of vision is known as visual acuity).

The Retina: The retina is located on the rear wall of the eyeball. It is made up of a complex layer of nerve cells connected to the optic nerve. Two types of light sensitive cells are found in the retina **-rods** and **cones** The central area of the retina is known as the **fovea** and the receptors in this area are all cones. It is here that the visual image is typically focused. Moving outwards, the cones become less dense and are progressively replaced by rods, so that in the periphery of the retina, there are only rods.

Cones function in good light and are capable of detecting fine detail and are colour sensitive.

This means the human eye can distinguish about 1.000 different shades of colour.

Rods cannot detect colour. They are poor at distinguishing fine detail, but good at detecting movement in the edge of the visual field (peripheral vision). They are much more sensitive at lower light levels. As light decreases, the sensing task is passed from the cones to the rods. This means in poor light levels we see only in black and white and shades of grey.

At the point at which the optic nerve joins the back of the eye, a **'blind spot'** occurs. This is not evident when viewing things with both eyes (**binocular vision**)**,** since it is not possible for the image of an object to fall on the blind spots of both eyes at the same time. Even when viewing with one eye (**monocular vision**)**,** the constant rapid movement of the eye (saccades) means that the image will not fall on the blind spot all the time. It is only when viewing a stimulus that appears very fleetingly (e.g. a light flashing), that the blind spot may result in something not being seen. In maintenance engineering, tasks such as close visual inspection or crack detection should not cause such problems, as the eye or eyes move across and around the area of interest (**visual scanning**)**.**

2.2.3 Factors Affecting Clarity of Sight

The eye is very sensitive in the right conditions (e.g. clear air, good light, etc.). In fact, the eye has approximately 1.2 million nerve cells leading from the retinas to the area of the brain responsible for vision, while there are only about 50,000 from the inner ears -making the eye about 24 times more sensitive than the ear.

Before considering factors that can influence and limit the performance of the eye, it is necessary to describe visual acuity.

Visual acuity is the ability of the eye to discriminate sharp detail at varying distances.

An individual with an acuity of 20/20 vision should be able to see at 20 feet that which the so-called "normal" person is capable of seeing at this range. It may be expressed in metres as 6/6 vision. The figures 20/40 mean that the observer can read at 20 feet what a 'normal' person can read at 40 feet.

Various factors can affect and limit the visual acuity of the eye. These include physical factors such as:

- physical imperfections in one or both eyes (short sightedness, long sightedness),
- age.

The influence of ingested foreign substances such as:

- drugs,
- medication,
- alcohol,
- cigarettes.

Environmental factors such as:

- amount of light available,
- clarity of the air (e.g. dust, mist, rain, etc.).

Factors associated with object being viewed such as:

- size and contours of the object,
- contrast of the object with its surroundings,
- relative motion of the object,
- distance of the object from the viewer,
- the angle of the object from the viewer.

Each of these factors will now be examined in some detail.

2.2.3.1 Blind Spot

Occurs at the point where the optic nerve enters the retina (between the rods & cones). Facial features such as the nose also contribute to this problem.

Hold picture away. Close your left eye and focus on the cross with the right eye. Move the page slowly to the face and at some point the circle shall disappear...the blind spot.

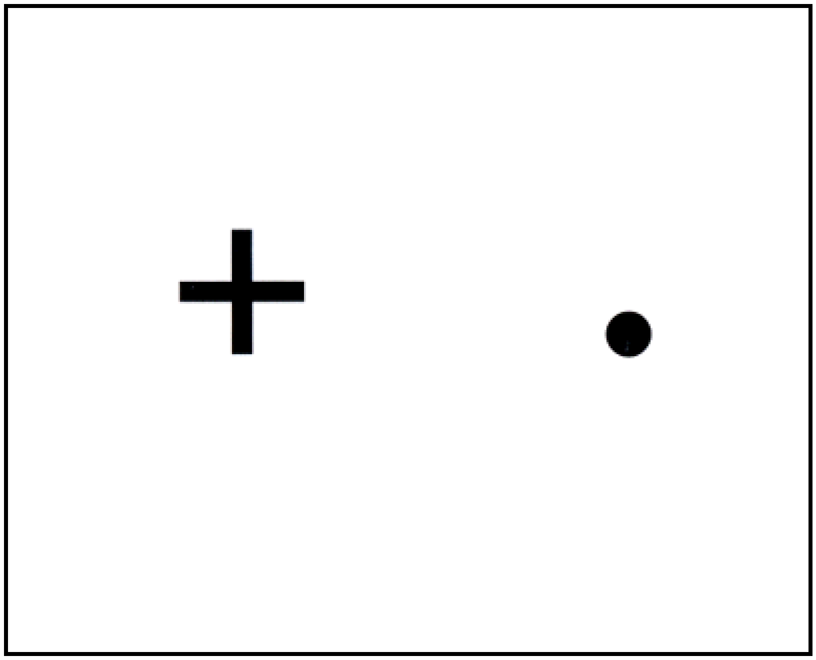


Figure 2-2 Standard test for the "blind spot"

2.2.3.2 Refractive Errors

Hyperopia (Farsightedness) also known as Hypermetropia - is caused by a shorter than normal eyeball which means that the image is formed behind the retina (Figure 2-3). If the cornea and the lens cannot use their combined focusing ability to compensate for this, blurred vision will result when looking at close objects.

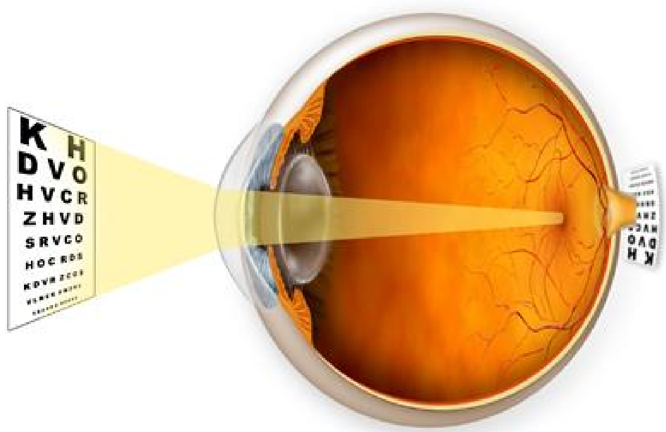


Figure 2-3 Farsighted focus

A convex lens overcomes long sightedness by bending light inwards before it reaches the cornea.

Short sight - known as **Myopia** - is where the eyeball is longer than normal, causing the image to be formed in front of the retina (Figure 2-4). If the accommodation of the lens cannot counteract this then distant objects are blurred.

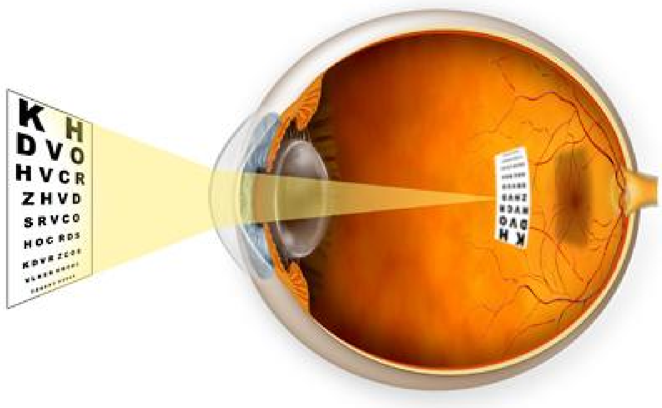


Figure 2-4 Nearsighted focus

A concave lens overcomes short sightedness by bending light outwards before it reaches the cornea.

Other visual problems include:

- cataracts - clouding of the lens usually associated with ageing;
- astigmatism - a misshapen cornea causing objects to appear irregularly shaped;
- glaucoma - a buildup in pressure of the fluid within the eye which can cause damage to the optic nerve and even blindness;
- migraine - severe headaches that can cause visual disturbances.

Finally as a person grows older, the lens becomes less flexible meaning that it is unable to accommodate sufficiently. This is known as **presbyopia** and is a form of long sightedness. Consequently, after the age of 40, spectacles may be required for near vision, especially in poor light conditions. Fatigue can also temporarily affect accommodation, causing blurred vision for close work.

Foreign Substances: Vision can be adversely affected by the use of certain drugs and medications, alcohol, and smoking cigarettes. With smoking, carbon monoxide which builds up in the bloodstream allows less oxygen to be carried in the blood to the eyes. This is known as hypoxia and can impair rapidly the sensitivity of the rods. Alcohol can have similar effects, even hours after the last drink.

2.2.3.3 Environmental Factors

Vision can be improved by increasing the lighting level, but only up to a point, as the law of diminishing returns operates. Also, increased illumination could result in increased glare. Older people are more affected by the glare of reflected light than younger people. Moving from an extremely bright environment to a dimmer one has the effect of vision being severely reduced until the eyes get used to less light being available. This is because the eyes have become **light adapted.** If an engineer works in a very dark environment for a long time, his eyes gradually become **dark adapted** allowing better visual acuity.

This can take about 7 minutes for the cones and 30 minutes for the rods

As a consequence, moving from a bright hangar (or the inside of a lighted aircraft cabin) to a dark apron area at night can mean that the maintenance engineer must wait for his eyes to adjust (adapt). In low light conditions, it is easier to focus if you look slightly to one side of an object. This allows the image to fall outside the fovea and onto the part of the retina that has many rods.

Any airborne particles such as dust, rain or mist can interfere with the transmission of light through the air, distorting what is seen. This can be even worse when spectacles are worn, as they are susceptible to getting dirty, wet, misted up or scratched. Engineers who wear contact lenses (especially hard or gas-permeable types) should take into account the advice from their optician associated with the maximum wear time -usually 8 to 12 hours - and consider the effects which extended wear may have on the eyes, such as drying out and irritation. This is particularly important if they are working in an environment which is excessively dry or dusty, as airborne particles may also affect contact lens wear. Goggles should be worn where necessary.

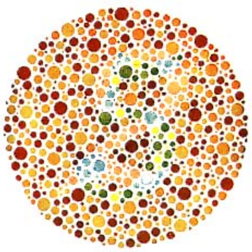
2.2.3.4 The Nature of the Object Being Viewed

Many factors associated with the object being viewed can also influence vision. We use information from the objects we are looking at to help distinguish what we are seeing. These are known as **visual cues.** Visual cues often refer to the comparison of objects of known size to unknown objects. An example of this is that we associate small objects with being further away. Similarly, if an object does not stand out well from its background (i.e. it has poor contrast with its surroundings), it is harder to distinguish its edges and hence its shape. Movement and relative motion of an object, as well as distance and angle of the object from the viewer, can all increase visual demands.

2.2.3.5 Colour Vision

Although not directly affecting visual acuity, inability to see particular colours can be a problem for the aircraft maintenance engineer. Amongst other things, good colour vision for maintenance engineers is important for:

- Recognizing components;
- Distinguishing between wires;
- Using various diagnostic tools;
- Recognizing various lights on the airfield (e.g. warning lights).



Colour defective vision is usually hereditary, although may also occur as a temporary condition after a serious illness.

Colour defective vision (normally referred to incorrectly as colour blindness, 'Daltonism') affects about 8% of men but only 0.5% of women. The most common type is difficulty in distinguishing between red and green. More rarely, it is possible to confuse blues and yellows.

There are degrees of colour defective vision, some people suffering more than others. Individuals may be able to distinguish between red and green in a well-lit situation but not in low light conditions. Colour defective people typically see the colours they have problems with, as shades of neutral grey.

Ageing also causes changes in colour vision. This is a result of progressive yellowing of the lens, resulting in a reduction in colour discrimination in the blue-yellow range. Colour defective vision and its implications can be a complex area and care should be taken not to stop an engineer from performing certain tasks merely because he suffers from some degree of colour deficient vision. It may be that the type and degree of colour deficiency is not relevant in their particular job. However, if absolutely accurate colour discrimination is critical for a job, it is important that appropriate testing and screening be put in place.

2.2.3.6 Colour Loss at Night

At night or in dim light central vision is poor under low illumination. Better results are obtained by looking slightly to one side of the object, rather than directly at them. This permits better use of the peripheral vision by using rods instead of the central cones. This effect can be demonstrated by counting a group of faint lights in the distance when looking directly at them. Then by looking some 10 deg to one side. It will be possible to see more lights.

A further point to bear in mind is that some people who have perfect day vision may be myopic (near sighted) at night. Night myopia is little recognized but can present a significant hazard, particularly because of the false confidence instilled from having good vision by day.

The reason for night myopia lies in the differing frequency of colours that prevail by night, and the varying ability of the eyes lens to focus them. Red and orange predominate by day and a lens whether natural or artificial, which is easily capable of focusing these wavelengths can be found wanting.

When it tries to focus the more violet colours that prevail at night. In dim conditions the lens has enough elasticity to focus the light from near objects (thus near sightedness) but cannot focus properly on objects further away.

2.2.3.7 Vision and the Aircraft Maintenance Engineer

It is important for an engineer, particularly one who is involved in inspection tasks, to have adequate vision to meet the task requirements. As discussed previously, age and problems developing in the eye itself can gradually affect vision. Without regular vision testing, aircraft maintenance engineers may not notice that their vision is deteriorating.

The UK CAA has produced guidance (CAAIP Leaflet 15-6, previously published as Airworthiness Notice 47) which states:

> *"A reasonable standard of eyesight is needed for any aircraft engineer to perform his duties to an acceptable degree. Many maintenance tasks require a combination of both distance and near vision. In particular, such consideration must be made where there is a need for the close visual inspection of structures or work related to small or miniature components. The use of glasses or contact lenses to correct any vision problems is perfectly acceptable and indeed they must be worn as prescribed. Frequent checks should be made to ensure the continued adequacy of any glasses or contact lenses. In addition, colour discrimination may be necessary for an individual to drive in areas where aircraft manoeuvre or where colour coding is used, e.g. in aircraft wiring.*
>
> *Organizations should identify any specific eyesight requirement and put in place suitable procedures to address these issues."*

Often, airline companies or airports will set the eyesight standards for reasons other than aircraft maintenance safety, e.g. for insurance purposes, or for driving on the airfield.

Ultimately, what is important is for the individual to recognize when his vision is adversely affected, either temporarily or permanently, and to consider carefully the possible consequences should they continue to work if the task requires good vision.

2.3 Hearing

2.3.1 The Basic Function of the Ear

The ear performs two quite different functions. It is used to detect sounds by receiving vibrations in the air, and secondly, it is responsible for balance and sensing acceleration. Of these two, the hearing aspect is more pertinent to the maintenance engineer, and thus it is necessary to have a basic appreciation of how the ear works.

As can be seen in Figure 2-5, the ear has three divisions: **outer ear, middle ear and inner ear.** These act to receive vibrations from the air and turn these signals into nerve impulses that the brain can recognize as sounds.

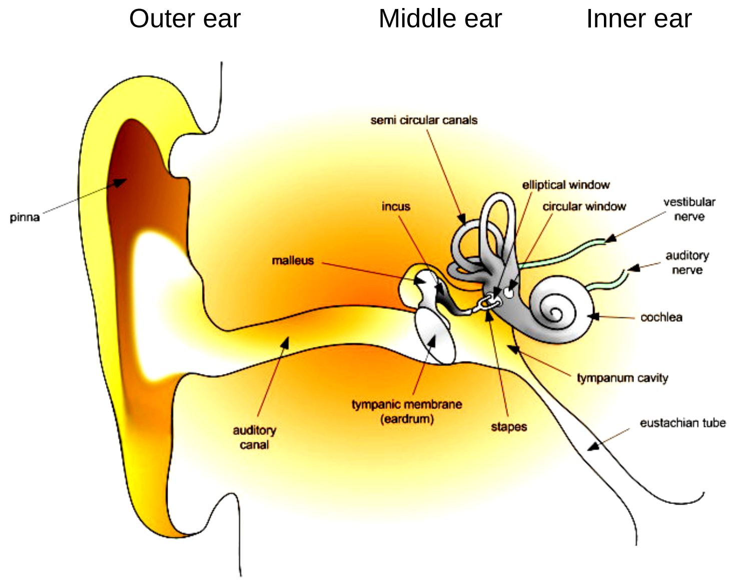


Figure 2-5 The human ear

Outer Ear: The outer part of the ear directs sounds down the auditory canal, and on to the eardrum The sound waves will cause the eardrum to vibrate.

Middle Ear: Beyond the eardrum is the middle ear which transmits vibrations from the eardrum by way of three small bones known as the **ossicles** , to the fluid of the inner ear. The middle ear also contains two muscles which help to protect the ear from sounds above 80 dB by means of the **acoustic or aural reflex,** reducing the noise level by up to 20 dB. However, this protection can only be provided for a maximum of about 15 minutes, and does not provide protection against sudden impulse noise such as gunfire. It does explain why a person is temporarily 'deafened' for a few seconds after a sudden loud noise. The middle ear is usually filled with air which is refreshed by way of the **eustachian tube** which connects this part of the ear with the back of the nose and mouth. However, this tube can allow mucus to travel to the middle ear which can build up, interfering with normal hearing.

Inner Ear: Unlike the middle ear, the inner ear is filled with fluid. The last of the ossicles in the middle ear is connected to the **cochlea** This contains a fine membrane (the **basilar membrane)** covered in hair-like cells which are sensitive to movement in the fluid. Any vibrations they detect cause neural impulses to be transmitted to the brain via the **auditory nerve.**

> The amount of vibration detected in the cochlea depends on the volume and pitch of the original sound

2.3.2 Performance and Limitations of the Ear

The performance of the ear is associated with the range of sounds that can be heard - both in terms of the pitch (frequency) and the volume of the sound.

> The audible frequency range that a young person can hear is typically between 20 and 20,000 cycles per second (or Hertz), with greatest sensitivity at about 3000 Hz.

Volume (or intensity) of sound is measured in decibels (dB). Table 2-1 shows intensity levels for various sounds and activities.

Activity	Approximate Intensity level (Decibels)
Rustling of leaves /Whisper	20
Conversation at 2m	50
Typewriter at 1 m	65
Carat 15m	70
Lorry at 15m	75
Power Mower at 2m	90
Propeller aircraft at 300m	100
Jet aircraft at 300m	110
Standing near a propeller aircraft	120
Threshold of pain	140
Immediate hearing damage results	150

Table 2-1 Typical sound levels for various activities

2.3.3 Impact of Noise on Performance

Noise can have various negative effects in the workplace. It can:

- be annoying (e.g. sudden sounds, constant loud sound, etc.);
- interfere with verbal communication between individuals in the workplace;
- cause accidents by masking warning signals or messages;
- be fatiguing and affect concentration, decision making, etc.;
- damage workers' hearing (either temporarily or permanently).

Intermittent and sudden noise is generally considered to be more disruptive than continuous noise at the same level. In addition, high frequency noise generally has a more adverse affect on performance than lower frequency. Noise tends to increase errors and variability, rather than directly affect work rate.

2.3.4 Hearing Impairment

Hearing loss can result from exposure to even relatively short duration noise. The degree of impairment is influenced mainly by the intensity of the noise. Such damage is known as **Noise Induced Hearing Loss (NIHL)**. The hearing loss can be temporary -lasting from a few seconds to a few days -or permanent. Temporary hearing loss may be caused by relatively short exposure to very loud sound, as the hair-like cells on the basilar membrane take time to 'recover'. With additional exposure, the amount or recovery gradually decreases and hearing loss becomes permanent. Thus, regular exposure to high levels of noise over a long period may permanently damage the hair-like cells in the cochlea, leading to irreversible hearing impairment.

In UK 'Noise at Work' regulations stipulate three levels of noise at which an employer must act:

- 85 decibels (if normal speech cannot be heard clearly at 2 metres), employer must;
  - assess the risk to employees ' hearing,,
  - tell the employees about the risks and what precautions are proposed,
  - provide their employees with personal ear protectors and explain their use.
- 90 decibels (if normal speech cannot be heard clearly at 1 metre), employer must;
  - do all that is possible to reduce exposure to the noise by means other than by providing hearing protection,

- mark zones where noise reaches the second level and provide recognized signs to restrict entry.

✈ 140 decibels (noise causes pain).

The combination of duration and intensity of noise can be described as **noise dose.**

Exposure to any sound over 80 dB constitutes a noise dose, and can be measured over the day

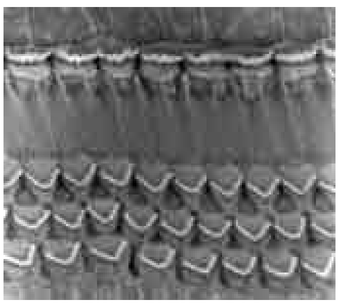
as an 8 hour Time Weighted Average sound level (TWA).

For example, a person subjected to 95 dB for 3.5 hours, then 105 dB for 0.5 hours, then 85 dB for 4 hours, results in a TWA of 93.5 which exceed the recommended maximum TWA of 90 dB.

Permanent hearing loss may occur if the TWA is above the recommended maximum.

It is normally accepted that a TWA noise level exceeding 85 dB for 8 hours is hazardous and potentially damaging to the inner ear. Exposure to noise in excess of 115 decibels without ear protection, even for a short duration, is not recommended.

2.3.5 High and Low Tone Deafness



The normal human ear is sensitive to frequencies between about 20 Hz and 20,000 Hz, being particularly sensitive in eth range 1000 Hz to 4000 Hz and progressively less sensitive at higher and lower frequencies.

This is very important when measuring noise since two sounds of equal intensity, but of different frequency, may appear subjectively to be of different loudness.

In the cochlea there are 23,000 nerve cells and each has about 100 sensory hairs. These hairs sense the vibration of the ossicles.

There are two sizes of hair; long; which detect low frequencies, and short; which detect high frequencies. Deterioration of the sensory hairs occurs with over exposure to high levels of noise.

2.3.6 Hearing Protection

Hearing protection is available, to a certain extent, by using ear plugs or ear defenders.

Noise levels can be reduced (attenuated) by up to 20 dB using ear plugs and 40 dB using ear muffs. However, using ear protection will tend to adversely interfere with verbal communication. Despite this, it must be used consistently and as instructed to be effective.

It is good practice to reduce noise levels at source, or move noise away from workers.

Often this is not a practical option in the aviation maintenance environment. Hearing protection should always be used for noise, of any duration, above 115 dB. Referring again to Table 2-1, this means that the aviation maintenance engineer will almost always need to use some form of hearing protection when in reasonably close proximity (about 200-300m) to aircraft whose engines are running.

2.3.7 Presbycusis

Hearing deteriorates naturally as one grows older. This is known as **presbycusis.** This affects ability to hear high pitch sounds first, and may occur gradually from the 30's onwards. When this natural decline is exacerbated by Noise Induced Hearing Loss, it can obviously occur rather sooner.

2.3.8 Hearing and the Aircraft Maintenance Engineer

The UK CAA makes the following recommendations (Leaflet 15-6, previously published as Airworthiness Notice 47) regarding hearing:

> *"The ability to hear an average conversational voice in a quiet room at a distance of 2 metres (6 feet) from the examiner is recommended as a routine test. Failure of this test would require an audiogram to be carried out to provide an objective assessment. If necessary, a hearing aid may be worn but consideration should be given to the practicalities of wearing the aid during routine tasks demanded of the individual."*

It is very important that the aircraft maintenance engineer understands the limited ability of the ears to protect themselves from damage due to excessive noise. Even though engineers should be given appropriate hearing protection and trained in its use, it is up to individuals to ensure that they actually put this to good use. It is a misconception that the ears get used to constant noise. If this noise is too loud, it will damage the ears gradually and insidiously.

2.4 Information Processing

The previous sections have described the basic functions and limitations of two of the senses used by aircraft maintenance engineers in the course of their work. This section examines the way the information gathered by the senses is processed by the brain. The limitations of the human information processing system are also considered.

> Information processing is the process of receiving information through the senses, analysing it and making it meaningful.

2.4.1 An Information Processing Model

Information processing can be represented as a **model.** This captures the main elements of the process, from receipt of information via the senses, to outputs such as decision making and actions. One such model is shown in Figure 2-6 A functional model of human information processing.

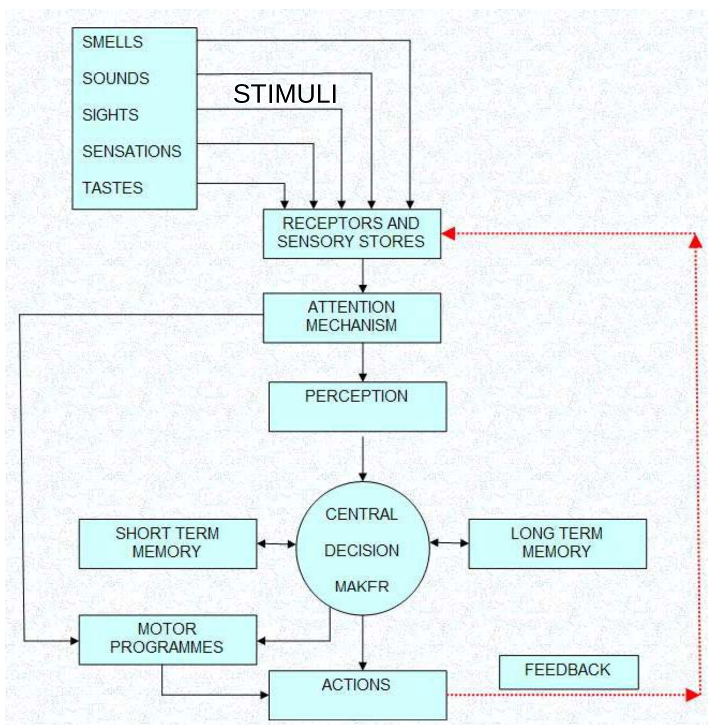


Figure 2-6 A functional model of human information processing

2.4.2 Sensory Receptors and Sensory Stores

Physical stimuli are received via the **sensory receptors** (eyes, ears, etc.) and stored for a very brief period of time in **sensory stores** (sensory memory). Visual information is stored for up to half a second in **iconic memory** and sounds are stored for slightly longer (up to 2 seconds) in **echoic memory.** This enables us to remember a sentence as a sentence, rather than merely as an unconnected string of isolated words, or a film as a film, rather than as a series of disjointed images.

2.4.2.1 Attention and Perception

Having detected information, our mental resources are concentrated on specific elements - this is **attention.**

> Attention can be thought of as the concentration of mental effort on sensory or mental events.

Although attention can move very quickly from one item to another, it can only deal with one item at a time. Attention can take the form of:

- **selective attention**, occurs when a person is monitoring several sources of input, with greater attention being given to one or more sources which appear more important. A person can be consciously attending to one source whilst still sampling other sources in the background. Psychologists refer to this as the **'cocktail party effect**' whereby you can be engrossed in a conversation with one person but your attention is temporarily diverted if you overhear your name being mentioned at the other side of the room, even though you were not aware of listening in to other people's conversations. Distraction is the negative side of selective attention.
- **divided attention**, is common in most work situations, where people are required to do more than one thing at the same time. Usually, one task suffers at the expense of the other, more so if they are similar in nature. This type of situation is also sometimes referred to as time sharing.
- **focused attention**, is merely the skill of focusing one's attention upon a single source and avoiding distraction.
- **sustained attention**, as its name implies, refers to the ability to maintain attention and remain alert over long periods of time, often on one task. Most of the research has been carried out in connection with monitoring radar displays, but there is also associated research which has concentrated upon inspection tasks.

Attention is influenced by arousal level and stress. This can improve attention or damage it depending on the circumstances.

Perception involves the organisation and interpretation of sensory data in order to make it meaningful, discarding non-relevant data, i.e. transforming data into information. Perception is a highly sophisticated mechanism and requires existing knowledge and experience to know what data to keep and what to discard, and how to associate the data in a meaningful manner.

> Perception can be defined as the process of assembling sensations into a useable mental representation of the world. Perception creates faces, melodies, works of art, illusions, etc. out of the raw material of sensation.

Examples of the perceptual process:

1. the image formed on the retina is inverted and two dimensional, yet we see the world the right way up and in three dimensions;
2. if the head is turned, the eyes detect a constantly changing pattern of images, yet we perceive things around us to have a set location, rather than move chaotically.

2.4.2.2 Decision Making

Having recognized coherent information from the stimuli reaching our senses, a course of action has to be decided upon. In other words **decision making** occurs.

> Decision making is the generation of alternative courses of action based on available information, knowledge, prior experience, expectation, context, goals, etc. and selecting one preferred option. It is also described as thinking, problem solving and judgment.

This may range from deciding to do nothing, to deciding to act immediately in a very specific manner. A fire alarm bell, for instance, may trigger a well-trained sequence of actions without further thought (i.e. evacuate); alternatively, an unfamiliar siren may require further information to be gathered before an appropriate course of action can be initiated.

We are not usually fully aware of the processes and information which we use to make a decision. Tools can be used to assist the process of making a decision. For instance, in aircraft maintenance engineering, many documents (e.g. maintenance manuals, fault diagnosis manuals), and procedures are available to supplement the basic decision making skills of the individual. Thus, good decisions are based on knowledge supplemented by written information and procedures, analysis of observed symptoms, performance indications, etc. It can be dangerous to believe that existing knowledge and prior experience will always be sufficient in every situation as will be shown in the section entitled 'Information Processing Limitations'.

Finally, once a decision has been made, an appropriate action can be carried out. Our senses receive feedback of this and its result. This helps to improve knowledge and refine future judgment by learning from experience.

2.4.3 Memory

Memory is critical to our ability to act consistently and to learn new things. Without memory, we could not capture a 'stream' of information reaching our senses, or draw on past experience and apply this knowledge when making decisions.

> Memory can be considered to be the storage and retention of information, experiences and knowledge, as well as the ability to retrieve this information.

Memory depends on three processes:

- **registration** - the input of information into memory;
- **storage** - the retention of information;
- **retrieval** - the recovery of stored information.

It is possible to distinguish between three forms of memory:

- **ultra short-term** (or sensory storage), has already been described when examining the role **of sensory stores**. It has a duration of up to 2 seconds (depending on the sense) and is used as a buffer, giving us time to attend to sensory input.
- **short term** (often referred to as working memory), receives a proportion of the information received into sensory stores, and allows us to store information long enough to use it (hence the idea of 'working memory'). It can store only a relatively small amount of information at one time, i.e. 5 to 9 (often referred to as 7 ±2) items of information, for a short duration, typically 10 to 20 seconds. As the following example shows, capacity of short term memory can be enhanced by splitting information in to 'chunks' (a group of related items).

  A telephone number, e.g. 01222555234, can be stored as 11 discrete digits, in which case it is unlikely to be remembered. Alternatively, it can be stored in chunks of related information, e.g. in the UK, 01222 may be stored as one chunk, 555 as another, and 234 as another, using only 3 chunks and therefore, more likely to be remembered. In mainland Europe, the same telephone number would probably be *stored as 01 22 25 55 23 4, using 6 chunks. The size of the chunk will be determined by the individual's familiarity with the information (based on prior experience and context), thus in this example, a person from the UK might recognize 0208 as the code for London, but a person from mainland Europe might not.*

The duration of short term memory can be extended through **rehearsal** (mental repetition of the information) or **encoding** the information in some meaningful manner (e.g. associating it with something as in the example above).

- ✈ **long term**. The capacity of **long-term memory** appears to be unlimited. It is used to store information that is not currently being used, including:
  - o knowledge of the physical world and objects within it and how these behave;
  - o personal experiences;
  - o beliefs about people, social norms, values, etc.;
  - o motor programmes, problem solving skills and plans for achieving various activities;
  - o abilities, such as language comprehension.

Information in long-term memory can be divided into two types:

- o **Semantic memory** refers to our store of general, factual knowledge about the world, such as concepts, rules, one's own language, etc. It is information that is not tied to where and when the knowledge was originally acquired.
- o **Episodic memory** refers to memory of specific events, such as our past experiences (including people, events and objects). We can usually place these things within a certain context. It is believed that episodic memory is heavily influenced by a person's expectations of what should have happened, thus two people 's recollection of the same event can differ.

2.5 Summary

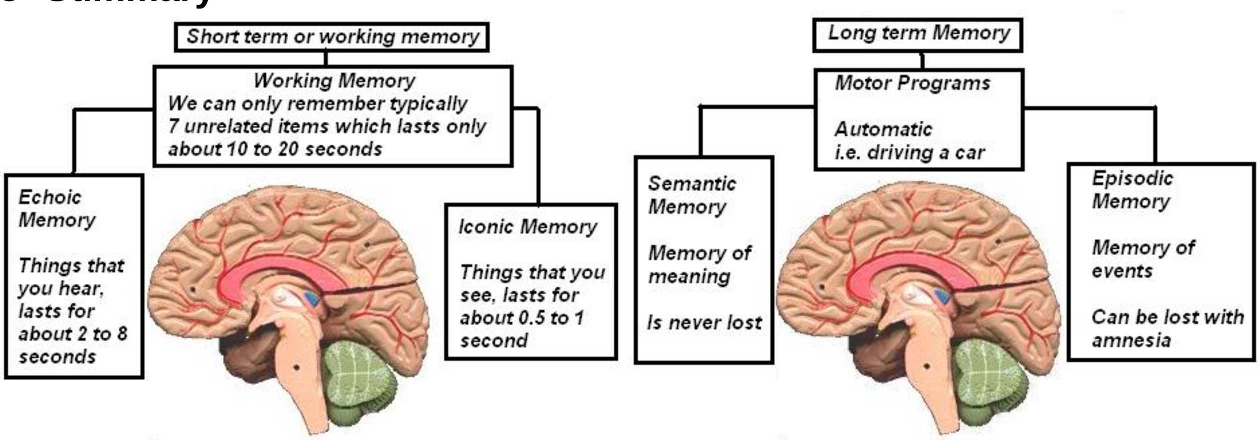


Figure 2-7 Sections of the memory

2.6 Motor Programs

If a task is performed often enough, it may eventually become automatic and the required skills and actions are stored in long term memory. These are known as **motor programmes** and are ingrained routines that have been established through practice. The use of a motor programme reduces the load on the central decision maker. An often quoted example is that of driving a car: at first, each individual action such as gear changing is demanding, but eventually the separate actions are combined into a motor programme and can be performed with little or no awareness.

These motor programmes allow us to carry out simultaneous activities, such as having a conversation whilst driving.

2.6.1 Situation Awareness

Although not shown explicitly in Figure 8, the process of attention, perception and judgment should result in awareness of the current situation.

> Situation awareness is the synthesis of an accurate and up-to-date 'mental model' of one's environment and state, and the ability to use this to make predictions of possible future states.

Situation awareness has traditionally been used in the context of the flight deck to describe the pilot's awareness of what is going on around him, e.g. where he is geographically, his orientation in space, what mode the aircraft is in, etc. In the maintenance engineering context, it refers to:

- **the perception** of important elements, e.g. seeing loose bolts or missing parts, hearing information passed verbally;
- **the comprehension** of their meaning, e.g. why is it like this? Is this how it should be?
- **the projection** of their status into the future, e.g. future effects on safety, schedule, airworthiness.

> An example is an engineer seeing (or perceiving) blue streaks on the fuselage. His comprehension may be that the lavatory fill cap could be missing or the drain line leaking. If his situation awareness is good, he may appreciate that such a leak could allow blue water to freeze, leading to airframe or engine damage.

As with decision making, feedback improves situation awareness by informing us of the accuracy of our **mental models** and their predictive power. The ability to project system status backward, to determine what events may have led to an observed system state, is also very important in aircraft maintenance engineering, as it allows effective fault finding and diagnostic behaviour.

Situation awareness for the aircraft maintenance engineer can be summarized as:

- the status of the system the engineer is working on;
- the relationship between the reported defect and the intended rectification;
- the possible effect on this work on other systems;
- the effect of this work on that being done by others and the effect of their work on this work.

This suggests that in aircraft maintenance engineering, the entire team needs to have situation awareness - not just of what they are doing individually, but of their colleagues' activities as well.

2.6.2 Information Processing Limitations

The basic elements of human information processing have now been explored. It is important to appreciate that these elements have limitations. As a consequence, the aircraft engineer, like other skilled professionals, requires support such as reference to written material (e.g. manuals).

2.6.3 Attention and Perception

A proportion of 'sensed' data may be lost without being 'perceived'. An example with which most people are familiar is that of failing to perceive something which someone has said to you, when you are concentrating on something else, even though the words would have been received at the ear without any problem. The other side of the coin is the ability of the information processing system to perceive something (such as a picture, sentence, concept, etc.) even though some of the data may be missing. The danger, however, is that people can fill in the gaps with information from their own store of knowledge or experience, and this may lead to the wrong conclusion being drawn.

Once we have formed a mental model of a situation, we often seek information which will confirm this model and, not consciously, reject information which suggests that this model is

There are many well-known visual 'illusions' which illustrate the limits of human perception. Figure 2-8 shows how the perceptual system can be misled into believing that one line is longer than the other, even though a ruler will confirm that they are exactly the same.

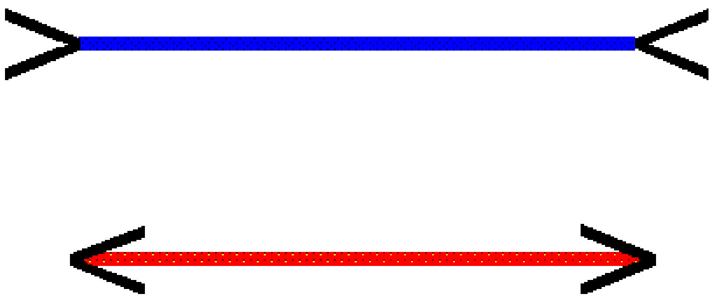


Figure 2-8 The Muller-Lyer Illusion

Figure 2-9 illustrates that we can perceive the same thing quite differently (i.e. the letter "B" or the number "13"). This shows the influence **of context** on our information processing.

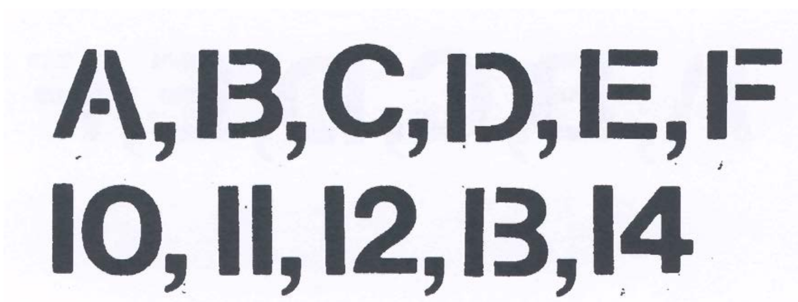


Figure 2-9 The importance of context.

In aviation maintenance it is often necessary to consult documents with which the engineer can become very familiar. It is possible that an engineer can scan a document and fail to notice that subtle changes have been made. He sees only what he expects to see **(expectation).** To illustrate how our eyes can deceive us when quickly scanning a sentence, read quickly the sentence below in Figure 2-10.

Figure 2-10 The effects of expectation

At first, most people tend to notice nothing wrong with the sentence. Our perceptual system sub-consciously rejects the additional "A".

As an illustration of how expectation, can affect our judgment, the same video of a car accident was shown to two groups of subjects. One group was told in advance that they were to be shown a video of a car crash; the other was told that the car had been involved in a 'bump'. Both groups were asked to judge the speed at which the vehicles had collided. The first group assessed the speed as significantly higher than the second group.

Expectation can also affect our memory of events. The study outlined above was extended such that subjects were asked, a week later, whether they recalled seeing glass on the road after the collision. (There was no glass). The group who had been told that they would see a crash, recalled seeing glass; the other group recalled seeing no glass.

2.6.4 Decision Making, Memory, and Motor Programmes

Attention and perception shortcomings can clearly impinge on decision making. Perceiving something incorrectly may mean that an incorrect decision is made, resulting in an inappropriate action. Figure 8 also shows the dependence on memory to make decisions. It was explained earlier that sensory and short-term memories have limited capacity, both in terms of capacity and duration. It is also important to bear in mind that human memory is fallible, so that information:

- may not be stored;
- may be stored incorrectly;
- may be difficult to retrieve.

All these may be referred to as **forgetting,** which occurs when information is unavailable (not stored in the first place) or inaccessible (cannot be retrieved). Information in short-term memory is particularly susceptible to interference, an example of which would be trying to remember a part number whilst trying to recall a telephone number.

It is generally better to use manuals and **temporary aides-memoires** rather than to rely upon memory, even in circumstances where the information to be remembered or recalled is relatively simple. For instance, an aircraft maintenance engineer may think that he will remember a torque setting without writing it down, but between consulting the manual and walking to the aircraft (possibly stopping to talk to someone on the way), he may forget the setting or confuse it (possibly with a different torque setting appropriate to a similar task with which he is more familiar). Additionally, if unsure of the accuracy of memorized information, an aircraft maintenance engineer should seek to check it, even if this means going elsewhere to do so. Noting something down temporarily can avoid the risk of forgetting or confusing information. However, the use of a personal note book to capture such information on a permanent basis can be dangerous, as the information in it may become out-of-date.

In the B737 double engine oil loss incident, the AAIB report stated:

"Once the Controller and fitter had got to T2 and found that this supportive material [Task Cards and AMM extracts] was not available in the workpack, they would have had to return to Base Engineering or to have gone over to the Line Maintenance office to get it. It would be, in some measure, understandable for them to have a reluctance to re-cross the exposed apron area on a winter's night to obtain a description of what they were fairly confident they knew anyway. However, during the course of the night, both of them had occasion to return to the Base Maintenance hangar a number of times before the task had been completed. Either could, therefore, have referred to or even drawn the task descriptive papers before the job was signed off. The question that should be addressed, therefore, is whether there might be any factors other than overconfidence in their memories, bad judgment or idleness which would dispose them to pass up these opportunities to refresh their memories on the proper and complete procedures."

2.7 Summary

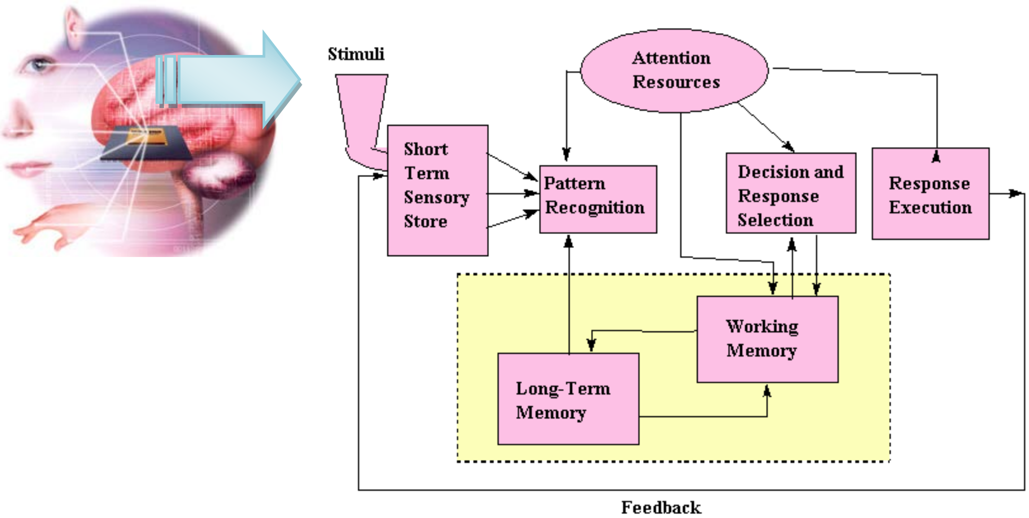


Figure 2-11 Summary of information processing

2.8 Claustrophobia, Physical Access and Fear of Heights

Although not peculiar to aircraft maintenance engineering, working in restricted space and at heights is a feature of this trade. Problems associated with physical access are not uncommon. Maintenance engineers and technicians often have to access, and work in, very small spaces (e.g. in fuel tanks), cramped conditions (such as beneath flight instrument panels, around rudder pedals), elevated locations (on cherry-pickers or staging), sometimes in uncomfortable climatic or environmental conditions (heat, cold, wind, rain, noise).This can be aggravated by aspects such as poor lighting or having to wear breathing apparatus. The physical environments associated with these problems are examined further in Chapter 5.

2.8.1 Physical Access and Claustrophobia

There are many circumstances where people may experience various levels of physical or psychological discomfort when in an enclosed or small space, which is generally considered to be quite normal. When this discomfort becomes extreme, it is known as **claustrophobia.**

Claustrophobia can be defined as abnormal fear of being in an enclosed space.

It is quite possible that susceptibility to claustrophobia is not apparent at the start of employment. It may come about for the first time because of an incident when working within a confined space, e.g. panic if unable to extricate oneself from a fuel tank. If an engineer suffers an attack of claustrophobia, they should make their colleagues and supervisors aware so that if tasks likely to generate claustrophobia cannot be avoided, at least colleagues may be able to assist in extricating the engineer from the confined space quickly, and sympathetically. Engineers should work in a team and assist one another if necessary, making allowances for the fact that people come in all shapes and sizes and that it may be easier for one person to access a space, than another. However, this should not be used as an excuse for an engineer who has put on weight, to excuse himself from jobs which he would previously have been able to do with greater ease!

2.8.2 Fear of Heights

Working at significant heights can also be a problem for some aircraft maintenance engineers, especially when doing 'crown' inspections (top of fuselage, etc.).Some engineers may be quite at ease in situations like these whereas others may be so uncomfortable that they are far more concerned about the height, and holding on to the access equipment, than they are about the job in hand. In such situations, it is very important that appropriate use is made of harnesses and safety ropes. These will not necessarily remove the fear of heights, but will certainly help to reassure the engineer and allow him to concentrate on the task in hand. The FAA's hfskyway website provides practical guidance to access equipment when working at height. Ultimately, if an engineer finds working high up brings on phobic symptoms (such as severe anxiety and panic), they should avoid such situations for safety's sake. However, as with claustrophobia, support from team members can be helpful.

Shortly before the Aloha accident, during maintenance, the inspector needed ropes attached to the rafters of the hangar to prevent falling from the aircraft when it was necessary to inspect rivet lines on top of the fuselage. Although unavoidable, this would not have been conducive to ensuring that the inspection was carried out meticulously (nor was it, as the subsequent accident investigation revealed). The NTSB investigation report stated:

> "Inspection of the rivets required inspectors to climb on scaffolding and move along the upper fuselage carrying a bright light with them; in the case of an eddy current inspection, the inspectors needed a probe, a meter, and a light. At times, the inspector needed ropes attached to the rafters of the hangar to prevent falling from the airplane when it was necessary to inspect rivet lines on top of the fuselage. Even if the temperatures were comfortable and the lighting was good, the task of examining the area around one rivet after another for signs of minute cracks while standing on scaffolding or on top of the fuselage is very tedious. After examining more and more rivets and finding no cracks, it is natural to begin to expect that cracks will not be found."

Managers and supervisors should attempt to make the job as comfortable and secure as reasonably possible (e.g. providing knee pad rests, ensuring that staging does not wobble, providing ventilation in enclosed spaces, etc.) and allow for frequent breaks if practicable.

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Chapter 3. Social Psychology

3 Social Psychology

The previous chapter considered the abilities and limitations of the individual. This chapter draws together issues relating to the social context in which the aircraft maintenance engineer works. This includes the organisation in which he works and how responsibilities may be delegated, motivation, and aspects of team working, supervision and leadership.

3.1 The Social Environment

Aircraft maintenance engineers work within a **'system'.** As indicated in Figure 3-1, there are various factors within this system that impinge on the aircraft maintenance engineer, ranging from his knowledge, skills and abilities (discussed in the previous chapter),the environment in which he works (dealt with in Chapter 5), to the culture of the organisation for which he works. Even beyond the actual company he works for, the regulatory requirements laid down for his trade clearly impact on his behaviour. As will be seen in Chapter 8 on Human Error, all aspects of this system may contribute towards errors that the engineer might make.

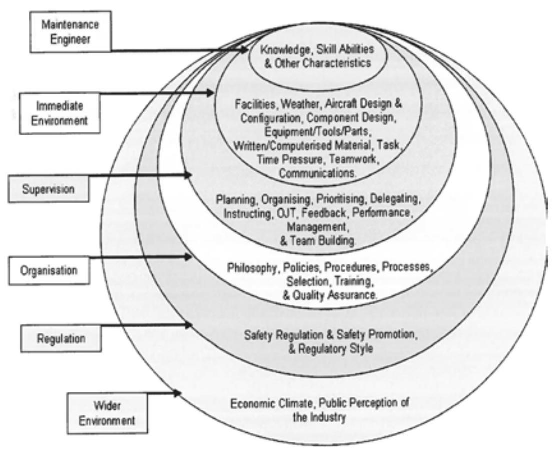


Figure 3-1 The maintenance system. Source: Boeing

The vast majority of aircraft maintenance engineers work for a company, either directly, or as contract staff. It is important to understand how the organisation in which the engineer works might influence him. Every organisation or company employing aircraft maintenance engineers will have different "ways of doing things".

This is called the organizational culture**.** They will have their own company philosophy, policies, procedures, selection and training criteria, and quality assurance methods. Culture will be discussed further in a separate section in this chapter.

The impact of the organisation may be positive or negative. Organizations may encourage their employees (both financially and with career incentives), and take notice of problems that their engineers encounter, attempting to learn from these and make changes where necessary or possible. On the negative side, the organization may exert pressure on its engineers to get work done within certain timescales and within certain budgets. At times, individuals may feel that these conflict with their ability to sustain the quality of their work. These organizational stresses may lead to problems of poor industrial relations, high turnover of staff, increased absenteeism, and most importantly for the aviation industry, more incidents and accidents due to human error.

3.2 Responsibility: Individual and Group

Being an aircraft maintenance engineer is a responsible job. Clearly, the engineer plays a part in the safe and efficient passage of the travelling public when they use aircraft.

> If someone is considered responsible, they are liable to be called to account as being in charge or control of, or answerable for something.

Within aircraft maintenance, responsibility should be spread across all those who play a part in the activity. This ranges from the accountable manager who formulates policy, through management that set procedures, to supervisors, teams of engineers and individuals within those teams. Flight crew also play a part as they are responsible for carrying out preflight checks and walkarounds and highlighting aircraft faults to maintenance personnel.

3.2.1 Working as an Individual or as a Group

Traditionally, in the maintenance engineering environment, responsibility has been considered in terms of the individual rather than the group or team. This is historical, and has much to do with the manner in which engineers are licensed and the way in which work is certified. This has both advantages and disadvantages. The main advantage to individual responsibility is that an engineer understands clearly that one or more tasks have been assigned to him and it is his job to do them (it can also be a strong incentive to an engineer to do the work correctly knowing that he will be the one held responsible if something goes wrong). The main disadvantage of any emphasis upon personal responsibility is that this may overlook the importance of working together as a cohesive team or group to achieve goals.

In practice, aircraft maintenance engineers are often assigned to groups or teams in the workplace. These may be shift teams, or smaller groups within a shift. A team may be made up of various engineering trades, or be structured around aircraft types or place of work (e.g. a particular hangar). Although distinct tasks may be assigned to individuals within a team, the responsibility for fulfilling overall goals would fall on the entire team.

3.2.2 Individual Responsibility

All aircraft maintenance engineers are skilled individuals having undertaken considerable training. They work in a highly professional environment and generally have considerable pride in their work and its contribution to air safety.

All individuals, regardless of their role, grade or qualifications should work in a responsible manner. This includes not only Licensed Aircraft Engineers (LAE's), but non-licensed staff.

"The certifying engineer shall be responsible for ensuring that work is performed and recorded in a satisfactory manner..."

Likewise, non-certifying technicians also have a responsibility in the maintenance process. An organisation approved in accordance with EASA Part-145 must establish the competence of every person, whether directly involved in hands-on maintenance or not. The CAA's have previously ruled that an organisation can make provision on maintenance records or work sheets for the mechanic(s) involved to sign for the work. Whilst this is not the legally required certification under the requirements of EASA Part-145.50, it provides the traceability to those who were involved in the job. The LAE is then responsible for any adjustment or functional test and the required maintenance records are satisfied before making the legal certification.

3.2.3 Group or Team Responsibility

Group responsibility has its advantages and disadvantages. The advantages are that each member of the group ought to feel responsible for the output of that group, not just their own output as an individual, and ought to work towards ensuring that the whole 'product' is safe. This may involve cross-checking others' work (even when not strictly required), politely challenging others if you think that something is not quite right, etc.

The disadvantage of group responsibility is that it can potentially act against safety, with responsibility being devolved to such an extent that no-one feels personally responsible for safety (referred to as **diffusion of responsibility).** Here, an individual, on his own, may take action but, once placed within a group situation, he may not act if none of the other group members do so, each member of the group or team assuming that 'someone else will do it'. This is expanded upon further in the section on peer pressure later in this chapter.

> Social psychologists have carried out experiments whereby a situation was contrived in which someone was apparently in distress, and noted who came to help. If a person was on their own, they were far more likely to help than if they were in a pair or group. In the group situation, each person felt that it was not solely his responsibility to act and assumed that someone else would do so.

Other recognized phenomena associated with group or team working and responsibility for decisions and actions which aircraft maintenance engineers should be aware of are:

- **Intergroup Conflict** in which situations evolve where a small group may act cohesively as a team, but rivalries may arise between this team and others (e.g. between engineers and planners, between shifts, between teams at different sites, etc). This may have implications in terms of responsibility, with teams failing to share responsibility between them. This is particularly pertinent to change of responsibility at shift handovers, where members of the outgoing shift may feel no 'moral' responsibility for waiting for the incoming shift members to arrive and giving a verbal handover in support of the written information on the workcards or task sheets, whereas they might feel such responsibility when handing overtasks to others within their own shift.
- **Group Polarisation** is the tendency for groups to make decisions that are more extreme than the individual members' initial positions. At times, group polarization results in more cautious decisions. Alternatively, in other situations, a group may arrive at a course of action that is riskier than that which any individual member might pursue. This is known as risky shift. Another example of group polarisation is groupthink in which the desire of the group to reach unanimous agreement overrides any individual impulse to adopt proper, rational (and responsible) decision making procedures.
- **Social Loafing** has been coined to reflect the tendency for some individuals to work less hard on a task when they believe others are working on it. In other words, they consider that their own efforts will be pooled with that of other group members and not seen in isolation.

Responsibility is an important issue in aircraft maintenance engineering, and ought to be addressed not only by licensing, regulations and procedures, but also by education and training, attempting to engender a culture of shared, but not diffused, responsibility.

Social Loafing
Tendency for some individuals to work less hard on a task when they believe others are working on it.
In other words, they consider that their own efforts will be pooled with that of other group members and not seen in isolation.

Figure 3-2 Social Loafing

3.3 Motivation and De-motivation

3.3.1 Introduction

Motivated behaviour is goal-directed, purposeful behaviour, and no human behaviour occurs without some kind of motivation underpinning it. In aircraft maintenance, engineers are trained to carry out the tasks within their remit. However, it is largely their motivation which determines what they *actually do* in any given situation. Thus, "motivation reflects the difference between what a person can do and what he will do".

> Motivation can be thought of as a basic human drive that arouses, directs and sustains all human behaviour. Generally we say a person is motivated if he is taking action to achieve something.

Motivation is usually considered to be a positive rather than a negative force in that it stimulates one to achieve various things. However just because someone is motivated, this does not mean to say that they are doing the right thing. Many criminals are highly motivated for instance. Motivation is difficult to measure and predict. We are all motivated by different things, for example, an artist might strive over many months to complete a painting that he may never sell, whereas a businessman may forfeit all family life in pursuit of financial success.

With respect to aviation safety, being appropriately motivated is vital. Ideally, aircraft maintenance engineers ought to be motivated to work in a safe and efficient manner. However, many factors may cause conflicting motivations to override this ideal. For instance, the motivation of some financial bonus, or de-motivation of working outdoors in extreme cold weather might lead to less consideration of safety and increase the likelihood of risk taking, corner cutting, violating procedures and so on. Aircraft maintenance engineers should be aware of conflicting motivations that impinge on their actions and attempt to examine their motivations for working in a certain way.

3.3.2 External and Internal Motivation

- ***External:*** System rewards & punishments.
- ***Internal:*** Do it because we want to.
- ***What people want from work:***
    - To feel valued and competent
    - To feel in control (to a degree)
- External sticks and carrots far less effective than internal motivation.

Intrinsic motivation (doing things because you want to rather than because someone else has told you to) is far more effective than extrinsic sticks and carrots. Punishing (or even rewarding inappropriately) people who are intrinsically motivated can be counter-productive.

3.3.3 Reward and Punishment: Effects on Behaviour

Figure 3-3 summarises what psychologists know about the effects of reward and punishment in the workplace. Rewards are the most powerful means of changing behaviour, but they are only effective if delivered close in time and place to the behaviour that is desired. Delayed punishments have negative effects: they don't lead to improved behaviour and they make people resentful.

	Immediate	Delayed
Reward	Positive effects	Doubtful effects
Punishment	Doubtful effects	Negative effects

Figure 3-3 Punishment and reward

The cells labelled 'doubtful effects' mean that, in each case, there are opposing forces at work. Hence, the results are uncertain.

3.3.4 Maslow's Hierarchy of Needs

Possibly one of the most well known theories which attempts to describe human motivation is Maslow's hierarchy of needs. Maslow considered that humans are driven by two different sets of motivational forces:

- those that ensure survival by satisfying basic physical and psychological needs;
- those that help us to realize our full potential in life known as self-actualization needs (fulfilling ambitions, etc.).

Figure 3-4 shows the hypothetical hierarchical nature of the needs we are motivated to satisfy. The theory is that the needs lower down the hierarchy are more primitive or basic and must be satisfied before we can be motivated by the higher needs. For instance, you will probably find it harder to concentrate on the information in this document if you are very hungry (as the lower level physiological need to eat predominates over the higher level cognitive need to gain knowledge). There are always exceptions to this, such as the mountain climber who risks his life in the name of adventure. The higher up the hierarchy one goes, the more difficult it becomes to achieve the need. High level needs are often long-term goals that have to be accomplished in a series of steps.

Figure 3-4 Maslow's hierarchy of needs.

An aircraft maintenance engineer will fulfil lower level needs by earning money to buy food, pay for a home and support a family. They may well be motivated by middle level needs in their work context (e.g. social groups at work, gaining status and recognition). It is noteworthy that for shift workers, tiredness may be a more powerful motivator than a higher order need (such as personal satisfaction to get the job done in time or accurately).

An interesting experiment on motivation was carried out in 1924 at the Hawthorne Works of the Western Electric Company in Chicago. Here, the management altered various factors such as rest periods, lighting levels, working hours, etc. and each time they did so, performance improved, even when the apparent improvements were taken away! This suggested that it was not the improvements themselves which were causing the increased production rates, but rather the fact that the staff felt that management were taking notice of them and were concerned for their welfare. This phenomenon is known as the Hawthorne effect.

3.3.5 De-motivation

Highly motivated people tend to show the following characteristics:

- high performance and results being consistently achieved;
- the energy, enthusiasm and determination to succeed;
- unstinting co-operation in overcoming problems;
- willingness to accept responsibility;
- willingness to accommodate change.

People who are de-motivated lack motivation, either intrinsically or through a failure of their management to motivate the staff who work for them. De-motivated people tend to demonstrate the following characteristics:

- apathy and indifference to the job, including reduced regard for safety whilst working;
- a poor record of time keeping and high absenteeism;
- an exaggeration of the effects/difficulties encountered in problems, disputes and grievances;
- a lack of co-operation in dealing with problems or difficulties;
- unjustified resistance to change.

However, care should be taken when associating these characteristics with lack of motivation, since some could also be signs of stress.

There is much debate as to the extent to which financial reward is a motivator. There is a school of thought which suggests that whilst lack of financial reward is a demotivator, the reverse is not necessarily true. The attraction of the extra pay offered to work a 'back to back shift' can be a strong motivator for an individual to ignore the dangers associated with working when tired.

The motivating effects of job security and the de-motivating impact of lack of job security is also an area that causes much debate. The 'hire and fire' attitude of some companies can, potentially, be a major influence upon safety, with real or perceived pressure upon individuals affecting their performance and actions. It is important that maintenance engineers are motivated by a desire to ensure safety (Maslow's 'self esteem/self respect'), rather than by a fear of being punished and losing their job (Maslow's 'security'). It is possible that the "can do" culture, which is evident in some areas of the industry, may be generated by the expectancy that if individuals do not 'deliver', they will be punished (or even dismissed) and, conversely, those who do 'deliver' (whether strictly by the book or not, finding ways around lack of time, spares or equipment) are rewarded and promoted. This is not motivation in the true sense but it has its roots in a complex series of pressures and drives and is one of the major influences upon human performance and human error in maintenance engineering.

3.4 Peer Pressure

In the working environment of aircraft maintenance, there are many pressures brought to bear on the individual engineer. We have already discussed the influence of the organisation, of responsibility and motivational drives. In addition to these, there is the possibility that the aircraft maintenance engineer will receive pressure at work from those that work with him. This is known as peer pressure.

> Peer pressure is the actual or perceived pressure which an individual may feel, to conform to what he believes that his peers or colleagues expect.

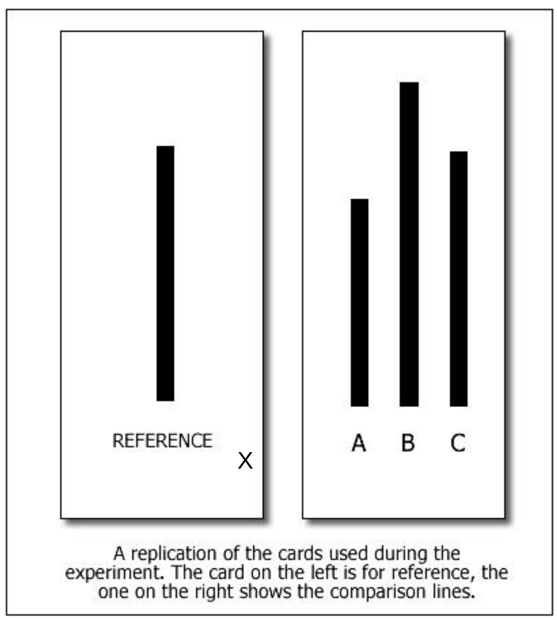
For example, an individual engineer may feel that there is pressure to cut corners in order to get an aircraft out by a certain time, in the belief that this is what his colleagues would do under similar circumstances. There may be no actual pressure from management to cut corners, but subtle pressure from peers, e.g. taking the form of comments such as "You don't want to bother checking the manual for that. You do it like this..." would constitute peer pressure.

Peer pressure thus falls within the area of conformity**.** Conformity is the tendency to allow one's opinions, attitudes, actions and even perceptions to be affected by prevailing opinions, attitudes, actions and perceptions.

3.4.1 Experiments in Conformity

Solomon Asch carried out several experiments investigating the nature of conformity, in which he asked people to judge which of lines A, B & C was the same length as line X. (see Figure 3-5). He asked this question under different conditions:

- where the individual was asked to make the judgment on his own;
- where the individual carried out the task after a group of 7-9 confederates of Asch had all judged that line A was the correct choice. Of course, the real participant did not know the others were "stooges"



B is the same length as X

Figure 3-5 Experiment to illustrate conformity (S. Asch 1951)

In the first condition, very few mistakes were made (as would be expected of such a simple task with an obvious answer). In the latter condition, on average, participants gave wrong answers on one third of the trials by agreeing with the confederate majority. Clearly, participants yielded to group pressure and agreed with the incorrect 'group' finding (however, it is worth mentioning that there were considerable individual differences: some participants never conformed, and some conformed all the time).

Further research indicated that conformity does not occur with only one confederate (as then it is a case of 'my word against yours'). However, it is necessary to have only three confederates to one real participant to attain the results that Asch found with 7- 9 confederates.

The degree to which an individual's view is likely to be affected by conformity or peer pressure, depends on many factors, including:

- culture (people from country 'x' tend to conform more than those from country 'y');
- gender (men tend to conform less than women);
- self-esteem (a person with low self-esteem is likely to conform more);
- familiarity of the individual with the subject matter (a person is more likely to conform to the majority view if he feels that he knows less about the subject matter than they do);
- the expertise of the group members (if the individual respects the group or perceives them to be very knowledgeable he will be more likely to conform to their views);
- the relationship between the individual and group members (conformity increases if the individual knows the other members of the group, i.e. it is a group of peers).

3.5 Countering Peer Pressure and Conformity

The influence of peer pressure and conformity on an individual's views can be reduced considerably if the individual airs their views publicly from the outset. However, this can be very difficult: after Asch's experiments, when asked, many participants said they agreed with the majority as they did not want to appear different or to look foolish.

Conformity is closely linked with 'culture' (described in the next section). It is highly relevant in the aircraft maintenance environment where it can work for or against a safety culture, depending on the attitudes of the existing staff and their influence over newcomers. In other words, it is important for an organisation to engender a positive approach to safety throughout their workforce, so that peer pressure and conformity perpetuates this. In this instance, peer pressure is clearly a good thing. Too often, however, it works in reverse, with safety standards gradually deteriorating as shift members develop practices which might appear to them to be more efficient, but which erode safety. These place pressure, albeit possibly unwittingly, upon new engineers joining the shift, to do likewise.

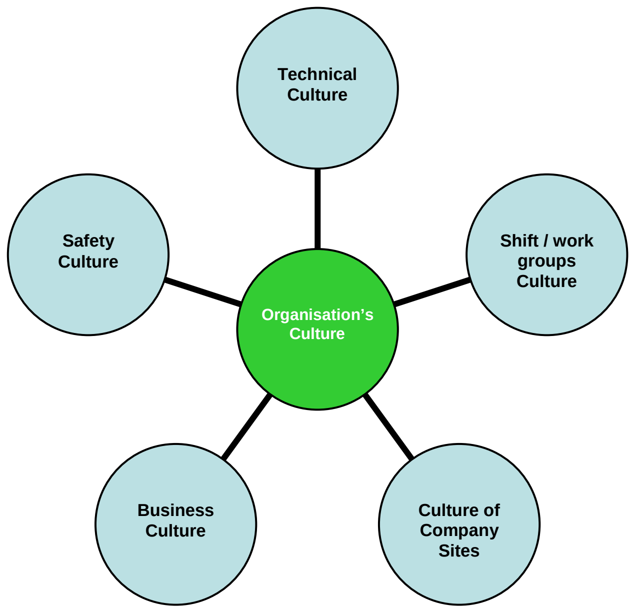
3.6 Culture Issues

There can be a degree of mistrust of anything new in the workplace, (e.g. an individual joining a company whose expertise has not yet been proven, or contracting out maintenance to another company, etc.). There may be a tendency for groups within organisation and the organisation itself to think that their own methods are the best and that others are not as good. This viewpoint is known as the group's or organization's culture.

> The culture of an organisation can be described as 'the way we do things here'. It is a group or company norm.

Figure 3-6 indicates that there can be an overall organizational culture, and a number of different 'sub-cultures', such as safety culture, professional/technical culture, etc.

It is possible for cultural differences to exist between sites or even between shifts within the same organisation. The prevailing culture of the industry as a whole also influences individual organizations.



Culture of the Aircraft Maintenance Engineering Industry as a Whole
Figure 3-6 The influences on an organization's culture.

Culture is not necessarily always generated or driven from the top of an organization (as one might think), but this is the best point from which to influence the culture.

3.7 Safety Culture

The ICAO Human factors Digest No. 10, "Human Factors, Management and Organisation" (Circular 247), discusses corporate culture and the differences between safe and unsafe corporate cultures.

> ICAO HF Digest 10 describes a safety culture as "a set of beliefs, norms, attitudes, roles and social and technical practices concerned with minimizing exposure of employees, managers, customers and members of the general public to conditions considered dangerous or hazardous"

Gary Eiff from Purdue University discusses safety culture in his paper "Organizational Culture and its Effect on Safety". He suggests that "A safety culture exists only within an organisation where each individual employee, regardless of their position, assumes an active role in error prevention", stressing that "Safety cultures do not ...spring to life simply at the declaration of corporate leaders".

The culture of an organisation can best be judged by what is done rather than by what is said. Organizations may have grand 'mission statements' concerning safety but this does not indicate that they have a good safety culture unless the policies preached at the top are actually put into practise at the lower levels. It may be difficult to determine the safety culture of an organisation by auditing the procedures and paperwork; a better method is to find out what the majority of the staff actually believe and do in practice.

> A method for measuring attitudes to safety has been developed by the Health and Safety Executive utilising a questionnaire approach. Examples of the statements which employees are asked the extent to which they agree are:

1. It is necessary to bend some rules to achieve a target;
2. Short cuts are acceptable when they involve little or no risk;
3. I often come across situations with which I am unfamiliar;

4 I sometimes fail to understand which rules apply;

5 I am not given regular break periods when I do repetitive and boring jobs;

6 There are financial rewards to be gained from breaking the rules.

> The results are scored and analyzed to give an indication of the safety culture of the organisation, broken down according to safety commitment, supervision, work conditions, logistic support, etc. In theory, this enables one organisation to be objectively compared with another.

Professor James Reason describes the key components of a safety culture, summarized as follows:

- The 'engine' that continues to propel the system towards the goal of maximum safety health, regardless of the leadership's personality or current commercial concerns;
- Not forgetting to be afraid;
- Creating a safety information system that collects, analyses and disseminates information from incidents and near-misses as well as from regular proactive checks on the system's vital signs;
- A good reporting culture, where staff are willing to report near-misses;
- A just culture - an atmosphere of trust, where people are encouraged, even rewarded, for providing essential safety related information - but in which they are clear about where the line must be drawn between acceptable and unacceptable behaviour;
- A flexible culture;
- Respect for the skills, experience and abilities of the workforce and first line supervisors;
- Training investment;
- A learning culture - the willingness and the competence to draw the right conclusions from its safety information system, and the will to implement major reforms when their need is indicated.

3.8 Social Culture

The influence of social culture (an individual's background or heritage) can be important in determining how an individual integrates into an organizational culture. The way an individual behaves outside an organisation is likely to have a bearing on how they behave within it. Internal pressures and conflicts within groups at work can be driven by underlying social cultural differences (e.g. different nationalities, different political views, different religious beliefs, etc.). This is an extremely complex subject, however, and in-depth discussion is beyond the scope of this text.

> Whilst safety culture has been discussed from the organizational perspective, the responsibility of the individual should not be overlooked. Ultimately, safety culture is an amalgamation of the attitude, beliefs and actions of all the individuals working for the organisation and each person should take responsibility for their own contribution towards this culture, ensuring that it is a positive contribution rather than a negative one.

3.9 Engineering a Just Culture (Dr. Reason)

In complex, well-defended systems, like aircraft maintenance organisations, culture is crucial because it reaches into all parts of the system. It is probably the only single factor that can influence the quality of the defences for good or ill, because they too are scattered widely throughout the system.

An effective safety culture is an informed culture, one that knows where the 'edge' is without having to fall over it. But incidents and accidents are still relatively rare. They are not enough to steer by. To achieve that, we need people to report their errors and near misses. But they won't do that unless they trust the system and its bosses. And they certainly won't confess their errors if they get disciplined for it. So, an effective reporting culture depends upon having a just culture. That is, an organisation in which people clearly understand where the line must be drawn between acceptable and unacceptable actions. In short, a just culture lies at the heart of a safe culture.

- ✈ **Culture: A workable definition**: Shared values (what is important) and beliefs (how things work) that interact with an organization's structure and control systems to produce behavioural norms (the way we do things around here).
- ✈ **The significance of culture**:
  - o Defences, barriers and safeguards take many different forms and are widely distributed throughout the system.
  - o Perhaps the only factor that can have a systematic and far-reaching effect upon defences (for good or ill) is the organisational culture.
- ✈ **Culture: Two aspects**:
  - o Something an organisation **is**: shared values and beliefs.
  - o Something an organisation **has**: structures, practices, systems.
  - o Changing practices is much easier than changing values and beliefs.

There can be no doubt that it is extremely difficult to change adult attitudes directly. Think how long it has taken to reduce the number of smokers to a relatively small group. It has taken around 30 years to achieve this. Smokers have known throughout all of this time that smoking could kill them. But this knowledge alone did not significantly change their behaviour. Now, most buildings have outlawed smoking. To satisfy their need, smokers have to indulge outside the front door or in dark dirty rooms set aside for the purpose. This practice has greatly reduced their desire to smoke. They are also tired of being treated as pariahs. In short, changing practices has changed attitudes.

3.9.1 Engineering a safety culture

Figure 3-7 spells out in diagrammatic form the message of getting people to change the way they do things (by changing organisational practices) eventually changes the way they think and believe.

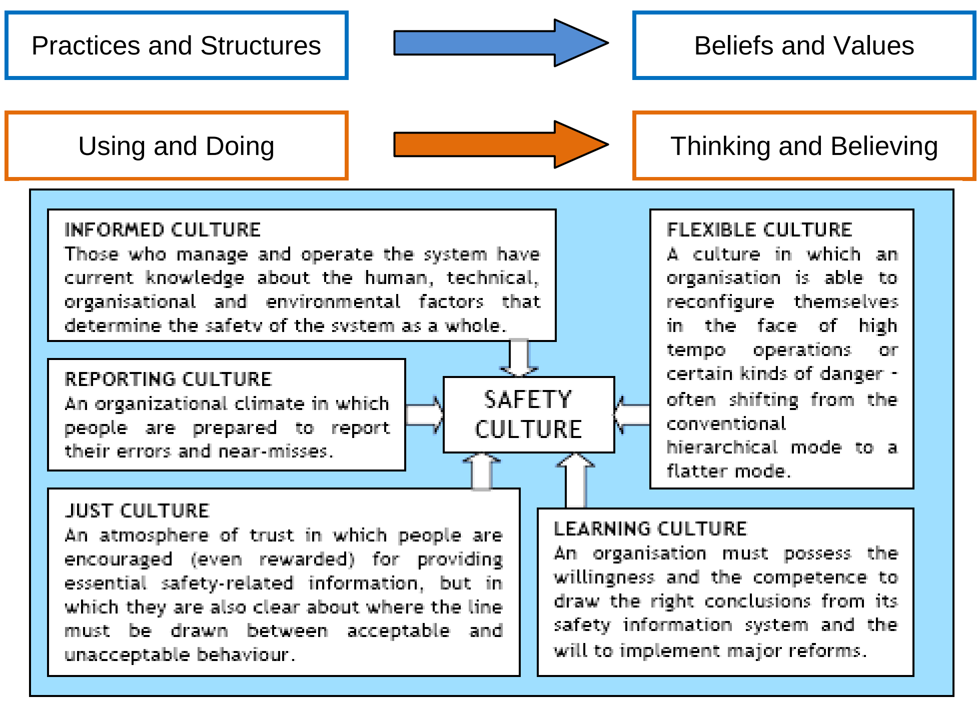


Figure 3-7 Getting people to change

3.9.2 Safety culture = Informed culture

- An informed culture means not forgetting to be afraid in the absence of bad accidents.
- An informed culture means collecting data about incidents and near misses.
- An informed culture is one in which those who manage the system know where the 'edge' is without falling over it.

Above all else, a safe culture is one that does not forget to be afraid. In order to keep up the proper level of intelligent wariness, we need to understand the hazards and risks that beset our operation. In short, we need to know where the 'edge' is. Many organisations do not discover this until they fall over it. It is better to know in advance. But how do we find out? Aviation does not have that many accidents, and, in aviation engineering, only the more dramatic incidents tend to get reported. We need people to tell us about their errors, near misses and free lessons. In short, we need to operate a reporting culture. NASA's Aviation Safety Reporting System (ASRS) has achieved this through clever social engineering-much of which has to do with the issue of sanctions and immunity. Around the world, there are many other, confidential Human Factors reporting schemes with similar objectives.

3.9.3 But an informed culture can only grow from a just culture

- An adequate reporting system depends on people reporting near misses, errors and incidents.
- But they won't do that if they don't trust the system.
- And they certainly won't do it if they are disciplined because of what they report.

3.10 The Blame Cycle

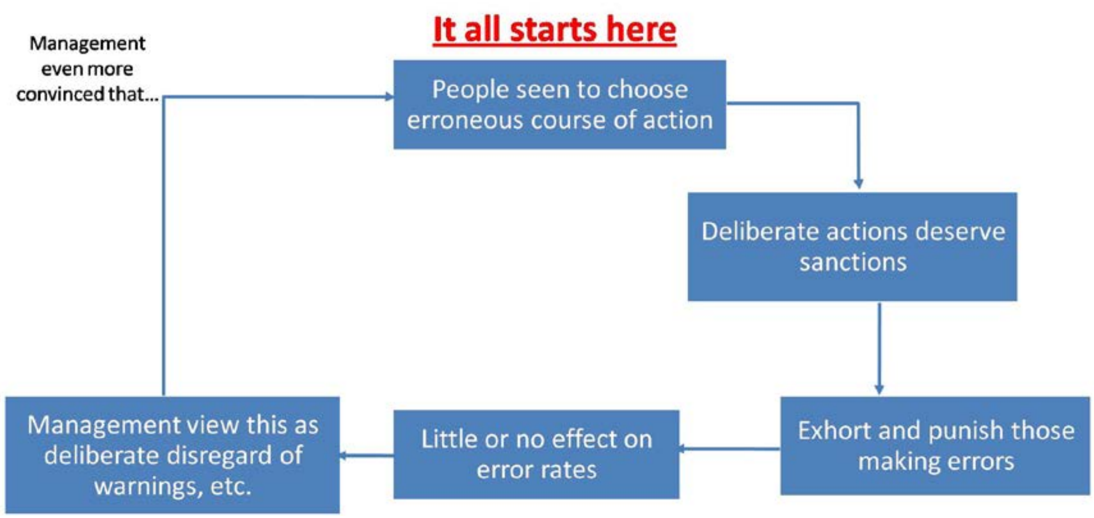


Figure 3-8 The blame cycle

Why are we so inclined to blame people rather than situations? The answer comes in two parts:

- The first of these is what psychologists call the 'fundamental attribution error'. When we see or hear of someone performing less than adequately, we tend to attribute this to the person's character or ability. We say he or she was silly, careless, stupid, incompetent, reckless or thoughtless. But if we were to ask the person why they did it, they would almost certainly tell you how the circumstances forced them to act that way. The truth, of course, lies somewhere in between.
- The second part of the answer relates to the 'illusion of free will'. It is this that makes the attribution error so fundamental to human nature. People, especially in western cultures, place great value in the belief that they are free agents, the masters of their own fate. They can become mentally ill when they are

deprived of this sense of personal freedom by illness, old age or enforced confinement. Feeling ourselves to be capable of free choice naturally leads us to assume that other people are the same. They are also seen as free agents, able to choose between right and wrong, and between correct and erroneous courses of action. People are assumed to be the least constrained factor causing an accident. Their actions are seen as more avoidable than situational conditions. It is this, together with the illusion of free will, that drives the fruitless Blame Cycle.

3.10.1 Avoiding the Blame Cycle

- ✈ Recognise that human actions are almost always affected by factors outside a person's control.
- ✈ Recognise that people cannot easily avoid those actions they did not intend in the first place.
- ✈ Recognise that errors are ***consequences*** rather than ***causes.*** The beginning of search rather than end.
- ✈ Recognise that in a well-trained and well-motivated workforce, situations are easier to fix than people.

Of course, people can behave carelessly and stupidly. We all do so at some time or another. But a stupid or careless act does not necessarily make a stupid or careless person. Everyone is capable of a wide range of actions, sometimes inspired and sometimes silly, but mostly somewhere in between.

An important point to emphasise here is the third bullet about errors being consequences rather than causes. Many investigations stop as soon as they have identified human errors. These are then called the causes of the incident or accident. But the errors, just as much as their bad outcomes, are consequences rather than causes. They are a chapter in a long history of prior error-provoking factors. Finding errors, therefore, should mark the beginning rather than the end of the search for causal factors.

Common sense would suggest that people are easier to fix than circumstances. People, after all, are capable of wide variability. They can be retrained, punished, advised or warned (it is believed) in ways that will make them behave more appropriately in the future. But, in this regard, common sense is wrong. Yes, we can change individual behaviour up to a point, but we cannot change human nature. And it is human nature to go wrong occasionally. Situations and even organisations are actually easier to change than human nature. And that is where the main focus of error management must lie: in changing the conditions that provoke errors rather than trying to change humankind.

3.11 Engineering a just culture

- ✈ A 'no blame' culture is neither feasible nor desirable.
- ✈ Some unsafe acts deserve sanctions.
- ✈ A 'just' culture depends on:
    - o the trust of the workforce
    - o knowing the difference between acceptable and unacceptable behaviour.

Decades ago, most maintenance organisations were punitive cultures: people got punished if they caused damage to the aircraft without regard to the nature of the actions involved. In the 1980s, the phrase 'blame-free' culture came along. But that is equally inappropriate. Some actions deserve punishment. The important thing that everyone must understand is where the line should be drawn between acceptable and unacceptable actions, between blameworthy and blameless behaviour.

3.12 Can the law help?

- **Negligence:** involves bringing about a bad consequence that a 'reasonable and prudent person' would have foreseen and avoided. Actions do not need to be intended. Mainly an issue for civil law.
- **Recklessness:** involves taking a deliberate and unjustifiable risk. Mainly an issue for criminal law.

The law identifies two kinds of actions:

- those that are merely negligent and
- those that are reckless.

The latter clearly deserve some kind of sanction, even dismissal.

3.13 Errors Vs violations?

- Should all unintended actions (errors) be exempt from disciplinary action?
- Should all deliberate violations be punished?
- Unfortunately, it's not as simple as that.

How do we draw a line between innocent negligence and deliberate recklessness? It is not easy.

3.14 The underlying conduct

- We can't assume that all errors are 'blame free', nor that all procedural violations are blameworthy.
- It all depends on what the person was doing when the error or violation was committed.
- Consider the following two scenarios.

3.15 David Marx Scenarios

David Marx, a former Boeing engineer who has taken a law degree, now spends a good deal of his time helping aircraft maintenance organisations to establish fair and just disciplinary systems. He argues that the important thing to determine is the nature of the underlying conduct. What was the person doing when he/she made the error? What was his/her motivation? Marx created the next two scenarios to help clarify the important issues.

3.15.1 Scenario 1

A maintainer is assigned to inspect for cracks in an aircraft's wings.

- In accordance with procedures, he/she gets the appropriate workstand and lights then carries out a close inspection
- Despite this, he/she misses a crack that could have seriously endangered the aircraft.

Here a maintainer did everything he/she should have done to carry out a proper inspection. Yet he/she still missed a dangerous crack.

3.15.2 Scenario 2

As before, a maintainer is assigned to check for cracks in a wing.

- This time, however, he/she doesn't bother to fetch the stand and lights.
- He/she merely walks beneath the aircraft using a hand-held flashlight.
- Once again, a dangerous crack is missed.

In this case, the underlying conduct is quite different. The maintainer deliberately failed to comply with established and appropriate procedures. He/she did so because he/she couldn't be bothered to do the job properly. In so doing, he/she also misses a dangerous crack.

3.15.3 Who is most to blame?

- Both maintainers committed the same unintended error: missing the crack.
- But, in scenario 2, the maintainer's actions made this error far more likely.
- He/she deliberately engaged in behaviour that significantly and unjustifiably increased the risk of error (recklessness).

On the face of it, the difference between the two scenarios is clear. The first person followed procedures, the second person deliberately failed to comply. In so doing, he/she greatly increased the chances of missing a crack.

3.15.4 Compliance versus non-compliance?

- It could be that the main difference was that one person complied with procedures and the other did not.
- In other words, the issue of blame could hinge on compliance or non-compliance said.
- But even that is too simple. Consider Scenario 3.

3.15.5 Scenario 3

- The situation is basically as before.
- But this time the maintainer discovers that the proper workstand is broken.
- Pressed for time, the maintainer does a walk-under inspection using a flashlight.
- As before, a dangerous crack is missed.

This situational violation (or necessary violation) shows how important it is not to assume that all violations are down to human weakness. Many are created by the system, and it is the system that must be corrected.

3.15.6 Differences between Scenarios 2 and 3

- In Scenario 2, the maintainer deliberately decides to short-cut the appropriate procedures re: workstand.
- In Scenario 3, the maintainer is forced to commit a situational violation because the appropriate equipment is either unserviceable or missing.

Again, this reiterates the distinction between deliberate short cuts and system-induced violations. Many necessary violations happen because a person feels that some action is better than none, even though it does not comply with procedures.

3.16 Where the line should be drawn?

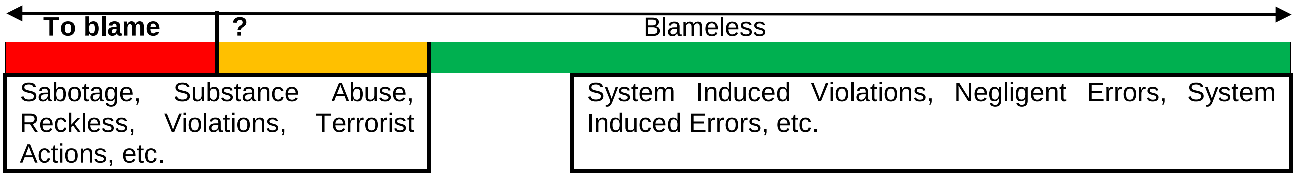


Figure 3-9 Drawing the line

Figure 3-9 poses the question again: Where should we draw the line? David Marx's research has shown that, in general, only about 10% of unsafe acts fall clearly into the culpable category. The vast majority are blameless, and so could be safely reported-if the reporters really trusted the system.

3.17 The Substitution Test

Question to peers:

'Given the circumstances, could you be sure that you would not have made the same or a similar error?'

- ✈ If answer is 'no', then blame probably inappropriate.
- ✈ The best people can make the worst mistakes.

Neil Johnston, an Aer Lingus captain, has come up with this very useful substitution test. After an unsafe act has been committed, the perpetrator's peers are asked whether or not it could have happened to them. We all recognise human fallibility. We all know that we have made mistakes in the past. If the peers say it could have happened to them, then the act is probably blameless.

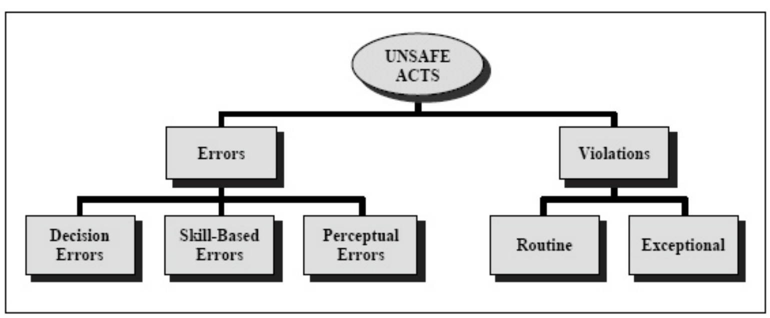


Figure 3-10: Categories of unsafe acts committed by mechanics.

The history of maintenance-related accidents shows us very clearly that well-trained, well-intentioned and experienced people with blameless records can sometimes make the worst mistakes. This means that maintenance errors are not just created by a few incompetent or reckless people. Blaming individuals rarely leads to effective remedial action - except, of course, when blaming and then dismissing someone removes a dangerous 'cowboy' from the work force.

3.18 The Blame Scale

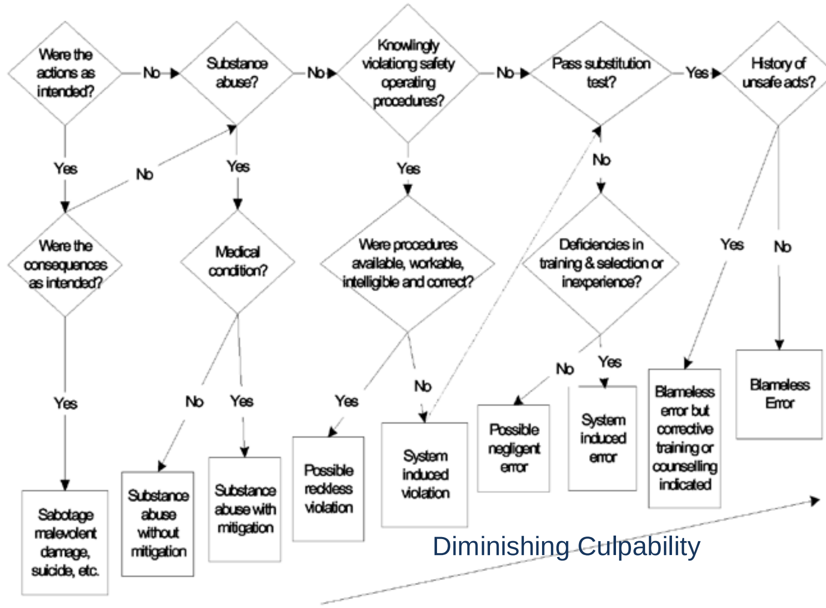


Figure 3-11: A decision tree for determining the culpability of unsafe acts. Reason, 1997.

3.19 Summary

- A safety culture is an informed culture: one that knows where the 'edge[1] is without falling over it.
- An informed culture depends on trust. The workforce will not report errors and near misses if they are punished for it.
- Thus a safety culture depends critically upon 'engineering' a just culture.

By now, you should have a clear idea of the importance of disciplinary proceedings in shaping a safe culture. The issue of justice (or apparent injustice) lies at the heart of aviation engineering human factors. There are no black and white answers. Each organisation has to work out the solutions for itself. But this is not an issue that can be either dodged or fudged.

This module is rich in discussion material. How do these issues apply to your organisation? Experience has shown that people are happy to argue about these matters for many hours.

3.20 Personality Types

3.20.1 Five Factor Model

The Big Five factors and their constituent traits can be summarized as follows:

- **Openness** - appreciation for art, emotion, adventure, unusual ideas, curiosity, and variety of experience.
- **Conscientiousness** - a tendency to show self-discipline, act dutifully, and aim for achievement; planned rather than spontaneous behaviour.
- **Extraversion** - energy, positive emotions, and the tendency to seek stimulation and the company of others.
- **Agreeableness** - a tendency to be compassionate and cooperative rather than suspicious and antagonistic towards others.

- ✈ **Neuroticism** - a tendency to experience unpleasant emotions easily, such as anger, anxiety, depression, or vulnerability; sometimes called emotional instability.

When scored for individual feedback, these traits are frequently presented as percentile scores. For example, a Conscientiousness rating in the 80th percentile indicates a relatively strong sense of responsibility and orderliness, whereas an Extraversion rating in the 5th percentile indicates an exceptional need for solitude and quiet.

Although these trait clusters are statistical aggregates, exceptions may exist on individual personality profiles. On average, people who register high in Openness are intellectually curious, open to emotion, interested in art, and willing to try new things. A particular individual, however, may have a high overall Openness score and be interested in learning and exploring new cultures. Yet he or she might have no great interest in art or poetry. Situational influences also exist, as even extraverts may occasionally need time away from people.

3.20.2 "Accident Prone"

Personality can be described along two personality dimensions lying at right angles to one another. The traits listed in each cell show the characteristics associated with various combinations of the two main personality dimensions.

Accident proneness is associated with unstable extraverts.

Accident - prone?

	Introverts	Extraverts
Unstable	Moody Anxious Pessimistic Unsociable Quiet	Touchy Restless Optimistic Aggressive Active
Stable	Passive Careful Thoughtful Controlled Reliable	Sociable Outgoing Lively Carefree Leadership

Figure 3-12 "Accident prone" personality

3.21 Team Working

3.21.1 The Concept of a Team

A lot has been written on the concept of a team, and it is beyond the scope of this document to give anything but a flavour of this.

> Whereas individualism encourages independence, teams are associated with interdependence and working together in some way to achieve one or more goals.

Teams may comprise a number of individuals working together towards one shared goal. Alternatively, they may consist of a number of individuals working in parallel to achieve one common goal. Teams generally have a recognized leader and one or more follower(s). Teams need to be built up and their identity as a team needs to be maintained in some way.

A team could be a group of engineers working on a specific task or the same aircraft, a group working together on the same shift, or a group working in the same location or site. There are natural teams within the aircraft maintenance environment. The most obvious is the supervisor and the engineers working under his supervision. A team could also be a Licensed Aircraft Engineer (LAE) and unlicensed engineers working subject to his scrutiny. A team may well comprise engineers of different technical specialities (e.g. sheet/metal structures, electrical/electronics/avionics, hydraulics, etc.).

There has been a great deal of work carried out on teamwork, in particular "Crew Resource Management (CRM)" in the cockpit context and, more recently, "Maintenance Resource Management (MRM)" in the maintenance context. The ICAO Human Factors Digest No. 12 "Human Factors in Aircraft Maintenance and Inspection" (ICAO Circular 253), includes a Chapter on team working, to which the reader is directed for further information. MRM is addressed separately (section 8) since it covers more than just teamwork.

3.21.2 Some Advantages and Disadvantages of Team Working

The discussion on motivation suggests that individuals need to feel part of a social group. In this respect, team working is advantageous. However, the work on conformity suggests that they feel some pressure to adhere to a group's views, which may be seen as a potential disadvantage.

Working as part of a team has a number of potential benefits which include:

- individuals can share resources (knowledge, tools, etc.);
- they can discuss problems and arrive at shared solutions;
- they can check each others' work (either "officially" or "unofficially").

Teams can be encouraged to take ownership of tasks at the working level. This gives a team greater responsibility over a package of work, rather than having to keep referring to other management for authorization, support or direction. However, groups left to their own devices need proper leadership. Healthy competition and rivalry between teams can create a strong team identity and encourage pride in the product of a team. Team identity also has the advantage that a group of engineers know one another's capabilities (and weaknesses).

If work has to be handed over to another group or team (e.g. shift handover), this can cause problems if it is not handled correctly. If one team of engineers consider that their diligence (i.e. taking the trouble to do something properly and carefully) is a waste of time because an incoming team's poor performance will detract from it, then it is likely that diligence will become more and rarer over time.

3.21.3 Important Elements of Team Working

For teams to function cohesively and productively, team members need to have or build up certain interpersonal and social skills. These include communication, co-operation, co-ordination and mutual support.

- **Communication**: Communication is essential for exchanging work-related information within the team. For example, a team leader must ensure that a team member has not just heard an instruction, but understood what is meant by it. A team member must highlight problems to his colleagues and/or team leader. Furthermore, it is important to listen to what others say. This is covered in greater depth in Chapter 7.
- **Co-operation**: 'Pulling together' is inherent in the smooth running of a team. Fairness and openness within the team encourage cohesiveness and mutual respect. Disagreements must be handled sensitively by the team leader.
- **Co-ordination**: Co-ordination is required within the team to ensure that the team leader knows what his group members are doing. This includes delegation of tasks so that all the resources within the team are utilised. Delegated tasks should be supervised and monitored as required. The team leader must ensure that no individual is assigned a task beyond his capabilities. Further important aspects of co-ordination are agreement of responsibilities (i.e. who should accomplish which tasks and within what timescale), and prioritization of tasks.
- **Mutual Support**:

  1 Mutual support is at the heart of the team's identity. The team leader must engender this in his team. For instance, if mistakes are made, these should be discussed and corrected constructively.

2 It is worth noting that in many companies, line engineers tend to work as individuals whereas base engineers tend to work in teams. This may be of significance when an engineer who normally works in a hangar, finds himself working on the line, or vice versa. This was the case in the Boeing 737 incident involving double engine oil pressure loss, where the Base Controller took over a job from the Line Maintenance engineer, along with the line maintenance paperwork. The line maintenance paperwork is not designed for recording work with a view to a handover, and this was a factor when the job was handed over from the Line engineer to the Base Controller.

3.22 Management, Supervision and Leadership

The previous section made frequent reference to the team leader. Management, supervision and leadership are all skills that a team leader requires. Of course, management is also a function within an organisation (i.e. those managers responsible for policy, business decisions, etc.), as is the supervisor (i.e. in an official role overseeing a team).

> Managers and supervisors have a key role to play in ensuring that work is carried out safely. It is no good instilling the engineers and technicians with 'good safety practice' concepts, if these are not supported by their supervisors and managers.

3.22.1 The Management Role

Line Managers, particularly those working as an integral part of the 'front line' operation, may be placed in a situation where they may have to compromise between commercial drivers and 'ideal' safety practices (both of which are passed down from 'top management' in the organisation). For example, if there is a temporary staff shortage, he must decide whether maintenance tasks can be safely carried out with reduced manpower, or he must decide whether an engineer volunteering to work a "back to back shift," to make up the numbers will be able to perform adequately. The adoption of Safety Management Principles may help by providing Managers with techniques whereby they can carry out a more objective assessment of risk.

3.22.2 The Supervisory Role

Supervision may be a formal role or post (i.e. a Supervisor), or an informal arrangement in which a more experienced engineer 'keeps an eye on' less experienced staff. The Supervisor is in a position not only to watch out for errors which might be made by engineers and technicians, but will also have a good appreciation of individual engineer's strengths and weaknesses, together with an appreciation of the norms and safety culture of the group which he supervises. It is mainly his job to prevent unsafe norms from developing, and to ensure that good safety practices are maintained. There can be a risk however, that the Supervisor becomes drawn down the same cultural path as his team without realizing. It is good practice for a Supervisor to step back from the day-to-day work on occasion and to try to look at his charges' performance objectively.

It can be difficult for supervisory and management staff to strike the right balance between carrying out their supervisory duties and maintaining their engineering skills and knowledge (and appropriate authorizations), and they may get out of practice. In the UK Air Accidents Investigation Branch (AAIB) investigation reports of the BAC 1-11, A320 and B737 incidents, a common factor was:

> "Supervisors tackling long duration, hands-on involved tasks". In the B737 incident, the borescope inspection was carried out by the Base Controller, who needed to do the task in order to retain his borescope authorization.

Also, there is unlikely to be anyone monitoring or checking the Supervisor, because:

- of his seniority;
- he is generally authorized to sign for his own work (except, of course, in the case where a duplicate inspection is required);

- he may often have to step in when there are staff shortages and, therefore, no spare staff to monitor or check the tasks;
- he may be 'closer' (i.e. more sensitive to) to any commercial pressures which may exist, or may perceive that pressure to a greater extent than other engineers.

It is not the intention to suggest that supervisors are more vulnerable to error; rather that the circumstances which require supervisors to step in and assist tend to be those where several of the 'defences' (see Chapter 8 - Error) have already failed and which may result in a situation which is more vulnerable to error.

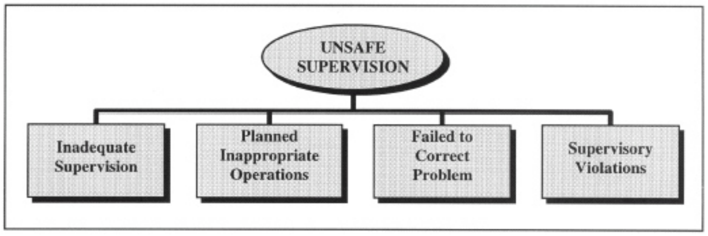


Figure 3-13 Categories of unsafe supervision

3.22.3 Characteristics of a Leader

There are potentially two types of leader in aircraft maintenance: the person officially assigned the team leader role (possibly called the Supervisor), an individual within a group that the rest of the group tend to follow or defer to (possibly due to a dominant personality, etc.). Ideally of course, the official team leader should also be the person the rest of the group defer to.

> A leader in a given situation is a person whose ideas and actions influence the thought and the behaviour of others.

A good leader in the maintenance engineering environment needs to possess a number of qualities:

- **Motivating the Team**: Just as the captain of a football team motivates his fellow players, the leader of a maintenance team must do likewise. This can be done by ensuring that the goals or targets of the work which need to be achieved are clearly communicated and manageable. For instance, the team leader would describe the work required on an aircraft within a shift. He must be honest and open, highlighting any potential problems and where appropriate encouraging team solutions.
- **Reinforcing Good Attitudes and Behaviour**: When team members work well (i.e. safely and efficiently), this must be recognized by the team leader and reinforced. This might be by offering a word of thanks for hard work, or making a favourable report to senior management on an individual. A good leader will also make sure that bad habits are eliminated and inappropriate actions are constructively criticized.
- **Demonstrating by Example**: A key skill for a team leader is to lead by example. This does not necessarily mean that a leader must demonstrate that he is adept at a task as his team (it has already been noted that a Supervisor may not have as much opportunity to practise using their skills). Rather, he must demonstrate a personal understanding of the activities and goals of the team so that the team members respect his authority. It is particularly important that the team leader establishes a good safety culture within a team through his attitude and actions in this respect.
- **Maintaining the Group**: Individuals do not always work together as good teams. It is part of the leader's role to be sensitive to the structure of the team and the relationships within it. He must engender a 'team spirit' where the team members support each other and feel responsible for the work of the team. He must also recognize and resolve disputes within the team and encourage co-operation amongst its members.
- **Fulfilling a Management Role**: The team leader must not be afraid to lead (and diplomatically making it clear when necessary that there cannot be more than one leader in a team). The team leader is the link

between higher levels of management within the organisation and the team members who actually work on the aircraft. He is responsible for coordinating the activities of the team on a day-to-day basis, which includes allocation of tasks and delegation of duties. There can be a tendency for team members to transfer some of their own responsibilities to the team leader, and he must be careful to resist this.

Skilled management, supervision and leadership play a significant part in the attainment of safety and high quality human performance in aircraft maintenance engineering.

In terms of the relationship between managers, supervisors and engineers, a 'them and us' attitude is not particularly conducive to improving the safety culture of an organisation. It is important that managers, supervisors, engineers and technicians all work together, rather than against one another, to ensure that aircraft maintenance improves airworthiness.

3.23 Maintenance Resource Management (MRM)

Although not part of the EASA Part-66 Module 9 syllabus, Maintenance Resource Management (MRM) is nevertheless included as a specific topic because it is implicit in many of the areas covered in this chapter, such as team working, communication, responsibility, shift handovers. The discussion of MRM in this text is intended only as an introduction to the basic concepts. For in-depth information concerning MRM, the reader is referred to the "Maintenance Resource Management Handbook" produced on behalf of the FAA.

MRM is not about addressing the individual human factors of the engineer or his manager; rather, it looks at the larger system of human factors concerns involving engineers, managers and others, working together to promote safety.

3.23.1 CRM and MRM

The term 'Maintenance Resource Management' became better known after the Aloha accident in 1988, when researchers took Crew Resource Management (CRM) concepts and applied them to the aircraft maintenance environment. CRM concerns the process of managing all resources in and out of the cockpit to promote safe flying operations. These resources not only include the human element, but also mechanical, computer and other supporting systems. MRM has many similarities to CRM, although the cockpit environment and team is somewhat different from that found in aircraft maintenance. The FAA MRM handbook highlights the main differences between CRM and MRM, and these are summarized in Table 3-1.

CRM	MRM
Human error	
Errors tend to be 'active' in that their consequences follow on immediately after the error.	The consequences of an engineer's error are often not immediately apparent, and this has implications for training for error avoidance.
Communication	
Much of flight operations are characterized by synchronous, "face-to-face" communications, or immediate voice communications (e.g. with ATC) over the radio.	Maintenance operations tend to be characterized by "asynchronous" communications such as technical manuals, memos, Advisory Circulars, Airworthiness Directives, workcards and other non-immediate formats. Much of the information transfer tends to be of a non-verbal nature.
"Team" composition	
Flight crews are mostly homogenous by nature, in that they are similar in education level and experience, relative to their maintenance counterparts.	Maintenance staff are diverse in their range of experiences and education and this needs to be taken into account in a MRM programme.
Teamwork	
Flight deck crew team size is small - two or three members; although the wider team is obviously larger (i.e. flight deck crew + cabin crew, flight crew + ATC, ground crew, etc.)	Maintenance operations are characterized by large teams working on disjointed tasks, spread out over a hangar. In addition, a maintenance task may require multiple teams (hangar, planning department, technical library, management) each with their own responsibilities. Therefore MRM places equal emphasis on inter-team teamwork skills.
Situation awareness	
The flight environment is quickly changing, setting the stage for the creation of active failures. Situation awareness in CRM is tailored to avoid these errors; Line Oriented Flight Training (LOFT) simulations provide flight crews with real-time, simulations to improve future situation awareness.	The maintenance environment, thought hectic, changes slowly relative to flight operations. In terms of situation awareness, engineers must have the ability to extrapolate the consequences of their errors over hours, days or even weeks. To do this, the situation awareness cues that are taught must be tailored to fit the maintenance environment using MRM-specific simulations.
Leadership	
Similar to teamwork issues, leadership skills in CRM often focus mainly on intra-team behaviours or 'how to lead the team', as well as followership skills. Inter-team interaction is somewhat limited during flight.	Because supervisors or team leaders routinely serve as intermediaries among many points of the organisation, engineer leaders must be skilled not only in intra-team behaviours, but in handling team '*outsiders*' (personnel from other shifts, managers outside the immediate workgroup, etc.) during any phase of the maintenance problem. These outsiders also vary widely in experience, mannerisms, etc. A good MRM programme should take these into account.

Table 3-1 Examples of the Differences Between CRM and MRM from the FAA MRM Handbook.

3.24 The Dirty Dozen

One of the early HF training programmes was developed by Gordon Dupont for Transport Canada. It introduced "The Dirty Dozen", which are 12 areas of potential problems in human factors. A series of posters has been produced, one for each of these headings, giving a few examples of good practices or "safety nets" which ought to be adopted. These are summarized in Table 3-2 and addressed in most maintenance human factors programmes.

Problem Example	Potential Solutions
Lack of communication	Use logbooks, worksheets, etc. to communicate and remove doubt. Discuss work to be done or what has been completed. Never assume anything.
Complacency	Train yourself to expect to find a fault. Never sign for anything you didn't do (or see done).
Lack of knowledge	Get training on type. Use up-to-date manuals. Ask a technical representative or someone who knows.
Distraction	Always finish the job or unfasten the connection. Mark the uncompleted work. Lockwire where possible or use torque-seal. Double inspect by another or self. When you return to the job, always go back three steps. Use a detailed check sheet.
Lack of teamwork	Discuss what, who and how a job is to be done. Be sure that everyone understands and agrees.
Fatigue	Be aware of the symptoms and look for them in yourself and others. Plan to avoid complex tasks at the bottom of your circadian rhythm. Sleep and exercise regularly. Ask others to check your work.
Lack of parts	Check suspect areas at the beginning of the inspection and AOG the required parts. Order and stock anticipated parts before they are required. Know all available parts sources and arrange for pooling or loaning. Maintain a standard and if in doubt ground the aircraft.
Pressure	Be sure the pressure isn't self-induced. Communicate your concerns. Ask for extra help. Just say 'No'.
Lack of assertiveness	If it's not critical, record it in the journey log book and only sign for what is serviceable. Refuse to compromise your standards.
Stress	Be aware of how stress can affect your work. Stop and look rationally at the problem. Determine a rational course of action and follow it. Take time off or at least have a short break. Discuss it with someone. Ask fellow workers to monitor your work. Exercise your body.
Lack of awareness	Think of what may occur in the event of an accident. Check to see if your work will conflict with an existing modification or repair. Ask others if they can see any problem with the work done.
Norms	Always work as per the instructions or have the instruction changed. Be aware the "norms" don't make it right.

Table 3-2 Examples of Potential Human Factors Problems from the "Dirty Dozen"

The UK Human Factors Combined Action Group (UK-HFCAG) has suggested a generic MRM syllabus which organizations may wish to adopt. MRM training programmes have been implemented by several airlines and many claim that such training is extremely successful. There has been work carried out to evaluate the success of MRM and the reader is directed in particular at research by Taylor, which looks at the success of MRM programmes in various US airlines.

Chapter 4. Physical Performance

4 Factors Affecting Performance

The performance abilities and limitations of aircraft maintenance engineers have been described in Chapter 2. . Other factors may also impinge on the engineer, potentially rendering him less able to carry out his work and attain the levels of safety required. These include fitness and health, stress, time pressures, workload, fatigue and the effects of medication, alcohol and drugs. These subjects are discussed in this chapter.

4.1 Fitness and Health

The job of an aircraft maintenance engineer can be physically demanding. In addition, his work may have to be carried out in widely varying physical environments, including cramped spaces, extremes of temperature, etc. (as discussed in the next chapter). There are at present no defined requirements for physical or mental fitness for engineers or maintenance staff.

Some references include:

- ✈ **ICAO Annex 11 states**: *"An applicant shall, before being issued with any licence or rating (for personnel other than flight crew members), meet such requirements in respect of age, knowledge, experience and, where appropriate, medical fitness and skill, as specified for that licence or rating."*
- ✈ In the UK, the ICAO requirements are enforced through **the provision of Article 13 (paragraph 7) of the Air Navigation Order (ANO)**. This states: *"The holder of an aircraft maintenance engineer's licence shall not exercise the privileges of such a licence if he knows or suspects that his physical or mental condition renders him unfit to exercise such privileges."*

There are two aspects to fitness and health: the disposition of the engineer prior to taking on employment and the day-to-day well being of the engineer once employed.

4.2 Pre-employment Disposition

Some employers may require a medical upon commencement of employment. This allows them to judge the fitness and health of an applicant (and this may also satisfy some pension or insurance related need). There is an obvious effect upon an engineer's ability to perform maintenance or carry out inspections if through poor physical fitness or health he is constrained in some way (such as his freedom of movement, or his sight). In addition, an airworthiness authority, when considering issuing a licence, will consider these factors and may judge the condition to be of such significance that a licence could not be issued. This would not, however, affect the individual's possibility of obtaining employment in an alternative post within the industry where fitness and health requirements are less stringent.

4.3 Day-to-Day Fitness and Health

Fitness and health can have a significant effect upon job performance (both physical and cognitive). Day-to-day fitness and health can be reduced through illness (physical or mental) or injury.

> EASA Part-66.50 imposes a requirement that "certifying staff must not exercise the privileges of their certification authorisation if they know or suspect that their physical or mental condition renders them unfit".

Responsibility falls upon the individual aircraft maintenance engineer to determine whether he is not well enough to work on a particular day. Alternatively, his colleagues or supervisor may persuade or advise him to absent himself until he feels better. In fact, as the CAA's CAAIPs Leaflet 15-6 (previously published as

Airworthiness Notice 47) points out, it is a legal requirement for aircraft maintenance engineers to make sure they are fit for work:

"Fitness: In most professions there is a duty of care by the individual to assess his or her own fitness to carry out professional duties. This has been a legal requirement for some time for doctors, flight crew members and air traffic controllers. Licensed aircraft maintenance engineers are also now required by law to take a similar professional attitude. Cases of subtle physical or mental illness may not always be apparent to the individual but as engineers often work as a member of a team any substandard performance or unusual behaviour should be quickly noticed by colleagues or supervisors who should notify management so that appropriate support and counseling action can be taken."

Many conditions can impact on the health and fitness of an engineer and there is not space here to offer a complete list. However, such a list would include:

- Minor physical illness (such as colds, 'flu, etc.);
- More major physical illness (such as HIV, malaria, etc.);
- Mental illness (such as depression, etc.);
- Minor injury (such as a sprained wrist, etc.);
- Major injury (such as a broken arm, etc.);
- Ongoing deterioration in physical condition, possibly associated with the ageing process (such as hearing loss, visual defects, obesity, heart problems, etc.);
- Affects of toxins and other foreign substances (such as carbon monoxide poisoning, alcohol, illicit drugs, etc.).

This document does not attempt to give hard and fast guidelines as to what constitutes 'unfit for work'; this is a complex issue dependent upon the nature of the illness or condition, its effect upon the individual, the type of work to be done, environmental conditions, etc. Instead, it is important that the engineer is aware that his performance, and consequently the safety of aircraft he works on, might be affected adversely by illness or lack of fitness.

An engineer may consider that he is letting down his colleagues by not going to work through illness, especially if there are ongoing manpower shortages. However, he should remind himself that, in theory, management should generally allow for contingency for illness. Hence the burden should not be placed upon an individual to turn up to work when unfit if no such contingency is available. Also, if the individual has a contagious illness (e.g. 'flu), he may pass this on to his colleagues if he does not absent himself from work and worsen the manpower problem in the long run. There can be a particular problem with some contract staff due to loss of earnings or even loss of contract if absent from work due to illness. They may be tempted to disguise their illness, or may not wish to admit to themselves or others that they are ill. This is of course irresponsible, as the illness may well adversely affect the contractor's standard of work.

4.4 Positive Measures

Aircraft maintenance engineers can take common sense steps to maintain their fitness and health. These include:

- Eating regular meals and a well-balanced diet;
- Taking regular exercise (exercise sufficient to double the resting pulse rate for 20 minutes, three times a week is often recommended);
- Stopping smoking;
- Sensible alcohol intake (for men, this is no more than 3-4 units a day or 28 per week, where a unit is equivalent to half a pint of beer or a glass of wine or spirit);

- Finally, day-to-day health and fitness can be influenced by the use of medication, alcohol and illicit drugs. These are covered later.

4.5 Stress

Stress is an unavoidable part of life for all of us.

Stress can be defined as any force, that when applied to a system, causes some significant modification of its form, where forces can be physical, psychological or due to social pressures.

From a human viewpoint, stress results from the imposition of any demand or set of demands which require us to react, adapt or behave in a particular manner in order to cope with or satisfy them. Up to a point, such demands are stimulating and useful, but if the demands are beyond our personal capacity to deal with them, the resulting stress is a problem.

4.6 Causes and Symptoms

Stress is usually something experienced due to the presence of some form of stressor, which might be a one-off stimulus (such as a challenging problem or a punch on the nose), or an ongoing factor (such as an extremely hot hangar or an acrimonious divorce). From these, we get acute stress (typically intense but of short duration) and chronic stress (frequent recurrence or of long duration) respectively.

Different Stressors affect different people to varying extents. Stressors may be:

- **Physical** - such as heat, cold, noise, vibration, presence of something damaging to health (e.g. carbon monoxide);
- **Psychological** - such as emotional upset (e.g. due to death, domestic problems, etc.), worries about real or imagined problems (e.g. due to financial problems, ill health, etc.);
- **Reactive** - such as events occurring in everyday life (e.g. working under time pressure, encountering unexpected situations, etc.).

4.6.1 Types of Stressors

- ***Physical:*** heat, noise, vibration, etc.
- ***Social:*** anxiety, incentives, group pressures.
- ***Drugs:*** alcohol, nicotine, medication, etc.
- ***Work:*** boredom, fatigue, lack of sleep, too much to do in too little time.
- ***Body clock:*** shift changes, jet lag.
- ***Personal:*** domestic worries, aches and pains, feeling under the weather, etc.

CAAIPs Leaflet 15-6 (previously published as Airworthiness Notice 47) points out that:

"A stress problem can manifest itself by signs of irritability, forgetfulness, sickness absence, mistakes, or alcohol or drug abuse. Management has a duty to identify individuals who may be suffering from stress and to minimise workplace stresses. Individual cases can be helped by sympathetic and skilful counseling which allows a return to effective work and licensed duties."

In brief, the possible signs of stress can include:

- Physiological symptoms - such as sweating, dryness of the mouth, etc.;
- Health effects - such as nausea, headaches, sleep problems, diarrhea, ulcers, etc.;

- Behavioural symptoms - such as restlessness, shaking, nervous laughter, taking longer overtasks, changes to appetite, excessive drinking, etc.;
- Cognitive effects - such as poor concentration, indecision, forgetfulness, etc.;
- Subjective effects - such as anxiety, irritability, depression, moodiness, aggression, etc.

It should be noted that individuals respond to stressful situations in very different ways. Generally speaking though, people tend to regard situations with negative consequences as being more stressful than when the outcome of the stress will be positive (e.g. the difference between being made redundant from work and being present at the birth of a son or daughter).

4.6.2 Domestic Stress

When aircraft maintenance engineers go to work, they cannot leave stresses associated with home behind. Pre-occupation with a source of domestic stress can play on one's mind during the working day, distracting from the working task. Inability to concentrate fully may impact on the engineer's task performance and ability to pay due attention to safety.

Domestic stress typically results from major life changes at home, such as marriage, birth of a child, a son or daughter leaving home, bereavement of a close family member or friend, marital problems, or divorce.

4.6.3 Work Related Stress

Aircraft maintenance engineers can experience stress for two reasons at work: because of the task or job they are undertaking at that moment, or because of the general organisational environment. Stress can be felt when carrying out certain tasks that are particularly challenging or difficult. This stress can be increased by lack of guidance in this situation, or time pressures to complete the task or job (covered later in this chapter). This type of stress can be reduced by careful management, good training, etc.

Within the organisation, the social and managerial aspects of work can be stressful.

Chapter 3 discussed the impact on the individual of peer pressure, organizational culture and management, all of which can be Stressors. In the commercial world that aircraft maintenance engineers work in, shift patterns, lack of control over own workload, company reorganisation and job uncertainty can also be sources of stress.

4.6.4 Stress Management

Once we become aware of stress, we generally respond to it by using one of two strategies: **defence or coping**.

Defence strategies involve alleviation of the symptoms (taking medication, alcohol, etc.) or reducing the anxiety (e.g. denying to yourself that there is a problem (denial), or blaming someone else).

Coping strategies involve dealing with the source of the stress rather than just the symptoms (e.g. delegating workload, prioritizing tasks, sorting out the problem, etc.).

Coping is the process whereby the individual either adjusts to the perceived demands of the situation or changes the situation itself.

Unfortunately, it is not always possible to deal with the problem if this is outside the control of the individual (such as during an emergency), but there are well-published techniques for helping individuals to cope with stress. Good stress management techniques include:

- Relaxation techniques;
- Careful regulation of sleep and diet;
- A regime of regular physical exercise;

- Counselling - ranging from talking to a supportive friend or colleague to seeking professional advice.

There is no magic formula to cure stress and anxiety, merely common sense and practical advice.

Stress is part of our lifestyle. It is inevitable but manageable. Management of stress is relatively easy once learnt. But we each have to learn a way that best suits us. We need to find the particular technique that tickles our own fancy. The objective is not to confront stress head on. Like a kite it will climb against the wind and become even more challenging. The idea is to defuse it, to divide it into bite-size chunks, and remind yourself that it is temporary. It will pass and there is a future. Alcohol does not defuse stress, it defers it and then it is added to the next day's lot.

- **Exercise /sports** Physical demand takes your mind of mental problems and is good for you. Physical demand that also demands mental concentration is even better i.e. golf, or sailing, is more diverting than jogging.
- **Fresh air** The wide world around us keeps everything in perspective and reinforces our hope and realisation that we are both small, and large in the scheme of things;
- **Diversions/hobbies** Mental and manipulative occupation is a marvellous relaxant something that requires total concentration.
- **Relaxation therapy and meditation** These use the same technique of mental occupation and diversion so that the build-up of stress is deflated by inattention. It is not the same as lying in the sun and snoozing as the brain dwells on the problem. They are effective and easy-to-learn techniques for focusing the single-channel processor of the conscious mind on a trivial routine symbol.

4.7 Summary: Fatigue and stress

- Upsets timing of skilled performance.
- Causes tired person to do more work to achieve same results (involves more effort).
- Tired people tend to focus on one out of many sources of information.
- Tired people do not always notice these changes and assume that their performance is as good as ever.

This outlines how skilled performance breaks down as the result of fatigue or stress. As indicated previously, the direction of this breakdown process is in the opposite direction to skill acquisition.

4.8 Time Pressure and Deadlines

There is probably no industry in the commercial environment that does not impose some form of deadline, and consequently time pressure, on its employees. Aircraft maintenance is no exception. It was highlighted in the previous section that one of the potential Stressors in maintenance is time pressure. This might be actual pressure where clearly specified deadlines are imposed by an external source (e.g. management or supervisors) and passed on to engineers, or perceived where engineers feel that there are time pressures when carrying out tasks, even when no definitive deadlines have been set in stone. In addition, time pressure may be self-imposed, in which case engineers set themselves deadlines to complete work (e.g. completing a task before a break or before the end of a shift).

Management has contractual pressures associated with ensuring an aircraft is released to service within the time frame specified by their customers. Striving for higher aircraft utilisation means that more maintenance must be accomplished in fewer hours, with these hours frequently being at night. Failure to do so can impact on flight punctuality and passenger satisfaction. Thus, aircraft maintenance engineers have two driving forces: the deadlines handed down to them and their responsibilities to carry out a safe job. The potential conflict between these two driving pressures can cause problems.

4.9 The Effects of Time Pressure and Deadlines

As with stress, it is generally thought that some time pressure is stimulating and may actually improve task performance. However, it is almost certainly true that excessive time pressure (either actual or perceived, external or self-imposed), is likely to mean that due care and attention when carrying out tasks diminishes and more errors will be made. Ultimately, these errors can lead to aircraft incidents and accidents.

It is possible that perceived time pressure would appear to have been a contributory factor in the BAC 1-11 accident described in Chapter 1. Although the aircraft was not required the following morning for operational use, it was booked for a wash. The wash team had been booked the previous week and an aircraft had not been ready. This would have happened again, due to short-staffing, so the Shift Manager decided to carry out the windscreen replacement task himself so that the aircraft would be ready in time.

An extract from the NTSB report on the Aloha accident refers to time pressure as a possible contributory factor in the accident: "*The majority of Aloha's maintenance was normally conducted only during the night. It was considered important that the airplanes be available again for the next day's flying schedule. Such aircraft utilization tends to drive the scheduling, and indeed, the completion of required maintenance work. Mechanics and inspectors are forced to perform under time pressure. Further, the intense effort to keep the airplanes flying may have been so strong that the maintenance personnel were reluctant to keep airplanes in the hangar any longer than absolutely necessary.*"

4.10 Managing Time Pressure and Deadlines

One potential method of managing time pressures exerted on engineers is through regulation. For example, FAA research has highlighted the need to isolate aircraft maintenance engineers from commercial pressures. They consider this would help to ensure that airworthiness issues will always take precedence over commercial and time pressures. Time pressures can make 'corner-cutting' a cultural norm in an organisation. Sometimes, only an incident or accident reveals such norms (the extract from the Aloha accident above exemplifies this).

Those responsible for setting deadlines and allocating tasks should consider:

- ✈ Prioritising various pieces of work that need to be done;
- ✈ The actual time available to carry out work (considering breaks, shift handovers, etc.);
- ✈ The personnel available throughout the whole job (allowing a contingency for illness);
- ✈ The most appropriate utilisation of staff (considering an engineer's specialisation, and strengths and limitations);
- ✈ Availability of parts and spares.

It is important that engineering staff at all levels are not afraid to voice concerns over inappropriate deadlines, and if necessary, cite the need to do a safe job to support this. As highlighted in Chapter 3, within aircraft maintenance, responsibility should be spread across all those who play a part. Thus, the aircraft maintenance engineer should not feel that the 'buck stops here'.

4.11 Workload - Overload and Underload

The preceding sections on stress and time pressure have both indicated that a certain amount of stimulation is beneficial to an aircraft maintenance engineer, but that too much stimulation can lead to stress or over-commitment in terms of time. It is noteworthy that too little stimulation can also be a problem.

Before going on to discuss workload, it is important to consider this optimum level of stimulation or arousal.

4.11.1 Arousal

Arousal in its most general sense, refers to readiness of a person for performing work. To achieve an optimum level of task performance, it is necessary to have a certain level of stimulation or arousal. This level of stimulation or arousal varies from person to person. There are people who are overloaded by having to do more than one task at a time; on the other hand there are people who appear to thrive on stress, being happy to take on more and more work or challenges. Figure 4.1 shows the general relationship between arousal and task performance.

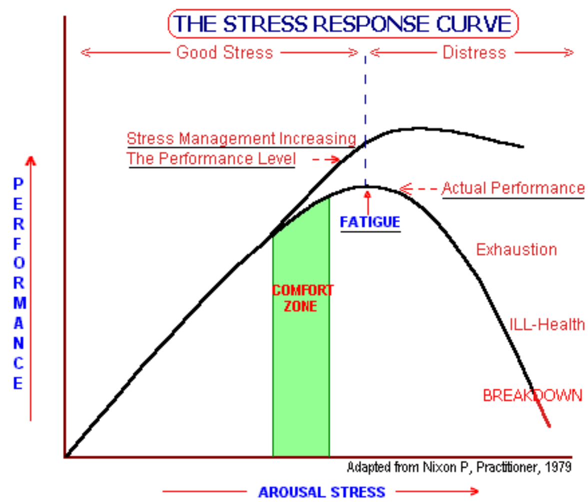


Figure 4-1: Optimum arousal leads to best task performance

At low levels of arousal, our attention mechanisms will not be particularly active and our performance capability will be low (complacency and boredom can result). At the other end of the curve, performance deteriorates when arousal becomes too high. To a certain extent, this is because we are forced to shed tasks and focus on key information only (called narrowing of attention). Best task performance occurs somewhere in the middle.

In the work place, arousal is mainly influenced by stimulation due to work tasks.

However, surrounding environmental factors such as noise may also influence the level of arousal.

4.12 Summary

Level of arousal has an important influence upon performance. The best performance is associated with an intermediate level of arousal. This is sometimes called the inverted U-curve; reflecting how performance varies with arousal level.

- Arousal is the body's reaction to stresses, drives and motivation.
- Sleep (low arousal) - Panic (high arousal)
- Too little or too much arousal causes poor performance.
- Low arousal: focus on task-irrelevant cues.
- High arousal: neglect task relevant cues.

4.13 Factors Determining Workload

An individual aircraft maintenance engineer can usually identify what work he has to do quite easily. It is more difficult to assess how that work translates into workload.

> The degree of stimulation exerted on an individual caused by a task is generally referred to as workload, and can be separated into physical workload and mental workload.

As noted in the section on information processing in Chapter 2, humans have limited mental capacity to deal with information. We are also limited physically, in terms of visual acuity, strength, dexterity and so on. Thus, workload reflects the degree to which the demands of the work we have to do eats into our mental and physical capacities. Workload is subjective (i.e. experienced differently by different people) and is affected by:

- The nature of the task, such as the:
    - physical demands it requires (e.g. strength required, etc.);
    - mental demands it requires (e.g. complexity of decisions to be made, etc.).
- The circumstances under which the task is performed, such as the:
    - standard of performance required (i.e. degree of accuracy);
    - time available to accomplish the task (and thus the speed at which the task must be carried out);
    - requirement to carry out the task at the same time as doing something else;
    - perceived control of the task (i.e. is it imposed by others or under your control, etc.);
    - environmental factors existing at time (e.g. extremes of temperature, etc.).
- The person and his state, such as his:
    - skills (both physical and mental);
    - his experience (particularly familiarity with the task in question);
    - his current health and fitness levels;
    - his emotional state (e.g. stress level, mood, etc.).

As the workload of the engineer may vary, he may experience periods of overload and underload. This is a particular feature of some areas of the industry such as line maintenance.

4.14 Overload

Overload occurs at very high levels of workload (when the engineer becomes over aroused). As highlighted previously, performance deteriorates when arousal becomes too high and we are forced to shed tasks and focus on key information. Error rates may also increase. Overload can occur for a wide range of reasons based on the factors highlighted above. It may happen suddenly (e.g. if asked to remember one further piece of information whilst already trying to remember a large amount of data), or gradually. Although EASA Part-145 states that "*The Part-145 approved maintenance organisation must employ sufficient personnel to plan, perform, supervise and inspect the work in accordance with the approval*", and "*the Part-145 organisation should have a production man hours plan showing that it has sufficient man hours for the work that is intended to be carried out*", this does not prevent individuals from becoming overloaded. As noted earlier in this section, it can be difficult to determine how work translates into workload, both for the individual concerned, and for those allocating tasks.

4.14.1 How we cope with overload

These are the ways in which we shed informational overloads. Each of the bullet points on the following list shows a progression of steps for coping with overload, starting by ignoring selected inputs and ending by abandoning the task altogether. Unlike machines that tend to break down suddenly, human performance degrades gracefully under conditions of overload.

- Ignore selected inputs.
- Trade-off accuracy for speed.
- Postpone things until quieter times.
- Reduce level of discrimination
- Redistribute the work if possible
- Abandon the task altogether

4.15 Underload

Underload occurs at low levels of workload (when the engineer becomes under aroused). It can be just as problematic to an engineer as overload, as it too causes deterioration in performance and an increase in errors, such as missed information. Underload can result from a task an engineer finds boring, very easy, or indeed a lack of tasks. The nature of the aircraft maintenance industry means that available work fluctuates, depending on time of day, maintenance schedules, and so forth. Hence, unless stimulating 'housekeeping' tasks can be found, underload can be difficult to avoid at times.

4.16 Workload Management

Unfortunately, in a commercial environment, it is seldom possible to make large amendments to maintenance schedules, nor eliminate time pressures. The essence of workload management in aircraft maintenance should include:

- ensuring that staff have the skills needed to do the tasks they have been asked to do and the proficiency and experience to do the tasks within the timescales they have been asked to work within;
- making sure that staff have the tools and spares they need to do the tasks;
- allocating tasks to teams or individual engineers that are accomplishable (without cutting corners) in the time available;
- providing human factors training to those responsible for planning so that the performance and limitations of their staff are taken into account;
- encouraging individual engineers, supervisors and managers to recognise when an overload situation is building up.

If an overload situation is developing, methods to help relieve this include:

- seeking a simpler method of carrying out the work (that is just as effective and still legitimate);
- delegating certain activities to others to avoid an individual engineer becoming overloaded;
- securing further time in order to carry out the work safely;
- postponing, delaying tasks/deadlines and refusing additional work.

Thus, although workload varies in aircraft maintenance engineering, the workload of engineers can be moderated. Much of this can be done by careful forward planning of tasks, manpower, spares, tools and training of staff.

4.17 Sleep, Fatigue and Shift Work

4.17.1 What Is Sleep?

Man, like all living creatures has to have sleep. Despite a great deal of research, the purpose of sleep is not fully understood.

> Sleep is a natural state of reduced consciousness involving changes in body and brain physiology which is necessary to man to restore and replenish the body and brain.

Sleep can be resisted for a short time, but various parts of the brain ensure that sooner or later, sleep occurs. When it does, it is characterised by five stages of sleep:

- **Stage 1**: This is a transitional phase between waking and sleeping. The heart rate slows and muscles relax. It is easy to wake someone up.
- **Stage 2**: This is a deeper level of sleep, but it is still fairly easy to wake someone.
- **Stage 3**: Sleep is even deeper and the sleeper is now quite unresponsive to external stimuli and so is difficult to wake. Heart rate, blood pressure and body temperature continue to drop.
- **Stage 4**: This is the deepest stage of sleep and it is very difficult to wake someone up.
- **Rapid Eye Movement or REM Sleep**: Even though this stage is characterised by brain activity similar to a person who is awake, the person is even more difficult to awaken than stage 4. It is therefore also known as paradoxical sleep. Muscles become totally relaxed and the eyes rapidly dart back and forth under the eyelids. It is thought that dreaming occurs during REM sleep.

Stages 1 to 4 are collectively known as non-REM (NREM) sleep. Stages 2-4 are categorised as slow-wave sleep and appear to relate to body restoration, whereas REM sleep seems to aid the strengthening and organisation of memories. Sleep deprivation experiments suggest that if a person is deprived of stage 1-4 sleep or REM sleep he will show rebound effects. This means that in subsequent sleep, he will make up the deficit in that particular type of sleep. This shows the importance of both types of sleep.

As can be seen from Figure 4.2, sleep occurs in cycles. Typically, the first REM sleep will occur about 90 minutes after the onset of sleep. The cycle of stage 1 to 4 sleep and REM sleep repeats during the night about every 90 minutes. Most deep sleep occurs earlier in the night and REM sleep becomes greater as the night goes on.

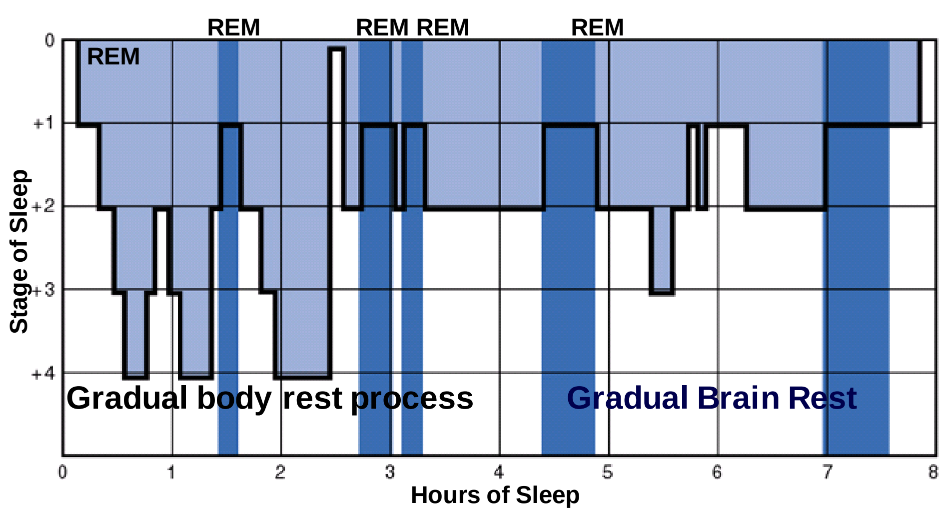


Figure 4-2: Typical cycle of REM sleep in the course of a night.

4.17.2 Circadian Rhythms

Apart from the alternation between wakefulness and sleep, man has other internal cycles, such as body temperature and hunger/eating. These are known as circadian rhythms as they are related to the length of the day.

Circadian rhythms are physiological and behavioural functions and processes in the body that have a regular cycle of approximately a day (actually about 25 hours in man).

Although, circadian rhythms are controlled by the brain, they are influenced and synchronised by external (environmental) factors such as light.

An example of disrupting circadian rhythms would be taking a flight that crosses time zones. This will interfere with the normal synchronisation with the light and dark (day/night). This throws out the natural link between daylight and the body's internal clock, causing jet lag, resulting in sleepiness during the day, etc. Eventually however, the circadian rhythm readjusts to the revised environmental cues.

Figure 4.3 shows the circadian rhythm for body temperature. This pattern is very robust, meaning that even if the normal pattern of wakefulness and sleep is disrupted (by shift work for example), the temperature cycle remains unchanged. Hence, it can be seen that if you are awake at 4-6 o'clock in the morning, your body temperature is in a trough and it is at this time that is hardest to stay awake. Research has shown that this drop in body temperature appears to be linked to a drop in alertness and performance in man.

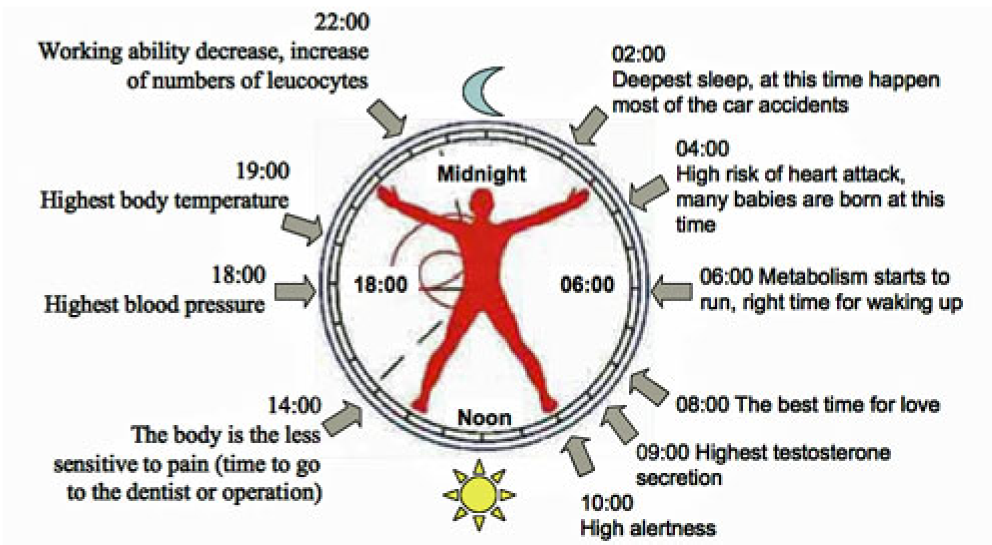


Figure 4-3: The Circadian Rhythm for Internal Body Temperature

Although there are many contributory factors, it is noteworthy that a number of major incidents and accidents involving human error have either occurred or were initiated in the pre-dawn hours, when body temperature and performance capability are both at their lowest. These include Three Mile Island, Chernobyl, and Bhopal, as well as the BAC1-11, A320, and B737 incidents summarised in Chapter 1.

The engineer's performance at this 'low point' will be improved if he is well rested, feeling well, highly motivated and well practised in the skills being used at that point.

4.18 Fatigue

Fatigue is a loss of alertness and a feeling of tiredness that can be caused by a lack of sleep, a change in your work schedule due to working overtime or working second shift, or trying to fit too many things in a 24-hour period.

The National Transportation Safety Board (NTSB) has found fatigue to be a causal or contributory factor in accidents in every mode of transportation and has issued almost 80 fatigue-related safety recommendations since 1972. The National Aeronautics and Space Administration (NASA) Ames Fatigue Countermeasures program has addressed fatigue in aviation through research and other activities since 1980.

4.18.1 A look at the causes

Our internal clock or circadian clock controls immune function, digestion, performance, alertness, and mood. The lowest point occurs around 3 to 5 a.m. each day making this time period one of the lowest levels of performance activity, although sometimes it can be anywhere from midnight to 6 a.m. A second period of sleepiness occurs around 3 to 5 p.m. These low circadian levels are associated with decreased performance and alertness. And these time periods can become more relevant if there is an accident and a follow-up investigation.

Fatigue is most often associated with being extra tired and the usual cause and effect scenario leads one to consider sleep (or sleeplessness). Eight hours of sleep is considered the norm for the average person, although it can vary by the individual and range from six to ten hours. Sleep loss can be acute, the amount of sleep loss in a 24-hour period, and cumulative, sleep loss over several days. Recovery from cumulative sleep loss requires more deep sleep and not an hour-for-hour exchange.

How long an individual remains awake is a factor that can affect performance and alertness. Studies have examined the lengths of shifts and the results on performance. NTSB data has shown an increased risk beyond 12 hours. And at 16 hours of work, a national occupation-injury database revealed an accident/injury rate three times greater than a nine-hour shift. Seventeen hours or longer of prolonged wakefulness can be similar to changes experienced with alcohol consumption.

Research has shown that the effects of fatigue are similar to moderate alcohol consumption. On-the-job performance loss for every hour of wakefulness between 10 and 26 hours is equivalent to a 0.004 percent rise in blood alcohol concentration. Eighteen hours of wakefulness are usually considered to be equivalent to a blood alcohol concentration of 0.05 percent. A person who has been awake for this length of time will act and perform as if he or she has consumed one glass of beer. The result is significantly delayed response and reaction times, impaired reasoning, reduced vigilance, and impaired hand-eye coordination.

Tied in with the study of circadian rhythms is the effect of light. The National Lighting Bureau (NLB) reveals that research shows that lighting supports more than visual needs, it affects health. The amount of light needed to influence health tends to be about 10 times greater than for vision, according to John Bachner of the NLB. Studies have shown that a lack of light can cause certain forms of cancer. And having greater amounts of light can reduce the risk of colon and prostate cancer; prevent myopia; counteract airborne disease transmission; and cure psoriasis, seasonal affective disorder, and sleep disorders.

Other factors that influence fatigue include stress, drugs, medications, illness, large temperature variations, noise, boredom, vibration, and dehydration (See sidebar on page 85).

Sources of fatigue can be very easy to underestimate. Who reads the packages of cold and sinus medication? Caution: This drug may cause drowsiness and impair the ability to drive or operate machinery. So even a runny nose could affect your job performance.

4.18.2 Effect on performance

Some of the most common effects due to fatigue are feeling lethargic, becoming withdrawn, having difficulty concentrating, and a reduced attention span. Other effects include short-term memory loss (what was I working on?); complacency (it doesn't matter); lack of awareness affected by hearing and eyesight; loss of coordination; lack of good judgment and decision making; and lengthened reaction time. All of these conditions increase the possibility of reduced safety and increased risk.

4.18.3 Solutions

So what can you do? The best solution is to be aware of your performance level. If you think there is a problem take a break; a short walk, a glass of water, or a snack might give you the burst of energy you need. Talk to your co-workers; it will increase your awareness of things around you. Research has shown that a short nap can also improve alertness and performance. Other solutions concern your lifestyle. Try and get adequate sleep, exercise regularly, eat a balanced diet, and drink at least eight glasses of water a day.

The typical cup of coffee can improve alertness but only for a limited time. Coffee is a stimulant and causes a temporarily increased level of alertness, but fatigue is a symptom of its withdrawal. And it's a diuretic, which causes the body to discharge more fluid than it is taking in, resulting in dehydration, which can also cause fatigue.

If your schedule is too hectic to eat a balanced diet, you can always take vitamins and supplements to fight fatigue. To make up for deficiencies in your diet consider vitamins A, B complex, C, E, zinc, iron, potassium, and calcium. Use carefully and check with a physician about use and possible side effects.

Work conditions and practices also need to be considered. A culture that supports safety and conducts human factors training so you are more aware of factors that influence performance is one that will help prevent fatigue or injuries from occurring.

Management should have adequate staff to handle tasks, this includes having the right experience levels as well as the manpower. And when designing and planning work schedules, circadian rhythms should be taken into consideration.

Other management practices should include additional inspections, rotating shifts, and longer rest periods following night shifts. If possible more critical tasks should be allocated for day shifts. Procedures should be documented so that there is a record of what has been done. This will ensure tasks are completed or indicate where someone left off in case someone else has to follow up to complete maintenance procedures.

Know your own limits and adjust your behaviour in areas that you can, such as hours of sleep, proper diet, and exercise. And if work affects your energy level, see what steps you can take or recommend to make work procedures safe and productive.

4.19 Shift work

Most aircraft movements occur between 6 a.m. and 10 p.m. to fit in with the requirements of passengers. Aircraft maintenance engineers are required whenever aircraft are on the ground, such as during turn-arounds. However, this scheduling means that aircraft are often available for more significant maintenance during the night. Thus, aircraft maintenance engineering is clearly a 24 hour business and it is inevitable that, to fulfil commercial obligations, aircraft maintenance engineers usually work shifts. Some engineers permanently work the same shift, but the majority cycle through different shifts. These typically comprise either an 'early shift', a 'late shift' and a 'night shift', or a 'day shift' and a 'night shift' depending on the maintenance organisation.

4.19.1 Advantages and Disadvantages of Shift Work

There are pros and cons to working shifts. Some people welcome the variety of working different times associated with regular shift work patterns.

Advantages may include more days off and avoiding peak traffic times when travelling to work. The disadvantages of shift working are mainly associated with:

- working 'unsociable hours', meaning that time available with friends, family, etc. will be disrupted;
- working when human performance is known to be poorer (i.e. between 4 am and 6 a.m.);
- problems associated with general desynchronisation and disturbance of the body's various rhythms (principally sleeping patterns).

4.19.2 Working At Night

Shift work means that engineers will usually have to work at night, either permanently or as part of a rolling shift pattern. As discussed earlier in this chapter, this introduces the inherent possibility of increased human errors. Working nights can also lead to problems sleeping during the day, due to the interference of daylight and environmental noise. Blackout curtains and use of ear plugs can help, as well as avoidance of caffeine before sleep.

In the B737 double engine oil loss incident, the error occurred during the night shift. The accident investigation report commented that: "It is under these circumstances that the fragility of the self monitoring system is most exposed because the safety system can be jeopardised by poor judgment on the part of one person and it is also the time at which people are most likely to suffer impaired judgment".

4.19.3 Rolling Shift Patterns

When an engineer works rolling shifts and changes from one shift to another (e.g. 'day shift' to 'night shift'), the body's internal clock is not immediately reset. It continues on its old wake-sleep cycle for several days, even though it is no longer possible for the person to sleep when the body thinks it is appropriate, and is only gradually resynchronised. However, by this time, the engineer may have moved onto the next shift. Generally, it is now accepted that shift rotation should be to later shifts (i.e. early shift ⇨ late shift ⇨ night shift or day shift ⇨ night shift) instead of rotation towards earlier shifts (night shift ⇨ late shift ⇨ early shift).

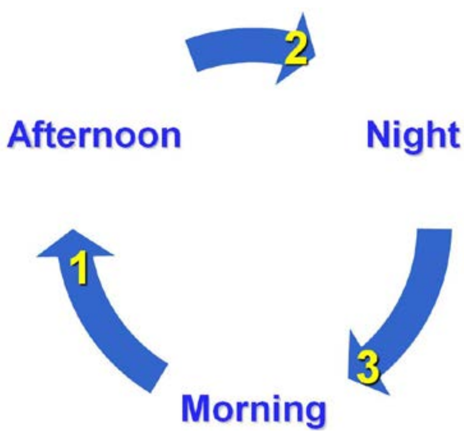


Figure 4-4: The proper shift rotation

4.19.4 Sleep, Fatigue, Shift Work and the Aircraft Maintenance Engineer

Most individuals need approximately 8 hours sleep in a 24 hour period, although this varies between individuals, some needing more and some happy with less than this to be fully refreshed. They can usually perform adequately with less that this for a few days, building up a temporary sleep 'deficit'. However, any sleep deficit will need to be made up, otherwise performance will start to suffer.

A good rule of thumb is that one hour of high-quality sleep is good for two hours of activity.

As previously noted, fatigue is best tackled by ensuring adequate rest and good quality sleep are obtained. The use of blackout curtains if having to sleep during daylight has already been mentioned. It is also best not to eat a large meal shortly before trying to sleep, but on the other hand, the engineer should avoid going to bed hungry. As fatigue is also influenced by illness, alcohol, etc., it is very important to get more sleep if feeling a little unwell and drink only in moderation between duties (discussed further in the next section). Taking over-the-counter drugs to help sleep should only be used as a last resort.

When rotating shifts are worked, it is important that the engineer is disciplined with his eating and sleeping times. Moreover, out of work activities have to be carefully planned. For example, it is obvious that an individual who has been out night-clubbing until the early hours of the morning will not be adequately rested if rostered on an early shift.

Shift working patterns encountered by aircraft maintenance engineers may include three or four days off after the last night shift. It can be tempting to work additional hours, taking voluntary overtime, or another job, in one or more of these days off. This is especially the case when first starting a career in aircraft maintenance engineering when financial pressures may be higher. Engineers should be aware that their vulnerability to error is likely to be increased if they are tired or fatigued, and they should try to ensure that any extra hours worked are kept within reason.

> It is always sensible to monitor ones performance, especially when working additional hours. Performance decrements can be gradual, and first signs of chronic fatigue may be moodiness, headaches or finding that familiar tasks (such as programming the video recorder) seem more complicated than usual.

Finally, it is worth noting that, although most engineers adapt to shift working, it becomes harder to work rotating shifts as one gets older.

4.19.5 Sleep Disorders

- **Narcolepsy**.
  - An inability to stop falling asleep even when in sleep credit.
  - Specialists believe that this is associated with the Inability of the brain to distinguish between wakefulness and REM sleep.
- **Apnoea**.
  - A cessation of breathing whilst asleep.
  - A common condition and the subject will normally either wake up or restart breathing after a short time.
  - It becomes a more serious problem when the breathing stoppage lasts for up to a minute and the frequency of stoppages increases.
  - The frequent awakenings will disturb the normal sleep pattern and the individual may experience excessive daytime sleepiness.
- **Sleepwalking** (Somnambulism).
  - This condition, as well as talking in one's sleep, Is more common in childhood, but does occur later in life.
  - It may happen more frequently in those operating irregular hours or those under some stress.
  - The condition should not cause difficulty in healthy adults unless the sleep walker is involved in an accident whilst away from his bed.
- **Insomnia**.
  - This is simply the term for difficulty in sleeping.
  - Clinical insomnia - a person has difficulty in sleeping under normal, regular conditions in phase with the body rhythms (an inability to sleep when the body's systems are calling for sleep).
    - Clinical Insomnia is rarely a disorder within itself, it is normally a symptom of another disorder.
    - For this reason the common and symptomatic treatment with sleeping drugs or tranquillisers is inappropriate unless treatment for the underlying cause is also undertaken.
  - Situational insomnia - an inability to sleep due to disrupted work/rest patterns, or arcadian disrhythmia.
    - This often occurs when one is required to sleep but the brain and body are not in the sleeping phase.
    - This condition is the one most frequently reported by aircrew.

4.20 Alcohol, Medication and Drug Abuse

It should come as no surprise to the aircraft maintenance engineer that his performance will be affected by alcohol, medication or illicit drugs. Under EASA legislation it is an offence for safety critical personnel to carry out their duties whilst under the influence of alcohol or drugs.

Article 18 of the UK ANO, states:

"*The holder of an aircraft maintenance engineer's licence shall not, when exercising the privileges of such a licence, be under the influence of drink or a drug to such an extent as to impair his capacity to exercise such privileges.*"

The current law which does not prescribe a blood / alcohol limit, is soon to change. There will be new legislation permitting police to test for drink or drugs where there is reasonable cause, and the introduction of a blood/alcohol limit of 20 milligrams of alcohol per 100 millilitres of blood for anyone performing a safety critical role in UK civil aviation (which includes aircraft maintenance engineers).

4.20.1 Alcohol

Alcohol acts as a depressant on the central nervous system, dulling the senses and increasing mental and physical reaction times. It is known that even a small amount of alcohol leads to a decline in an individual's performance and may cause his judgment (i.e. ability to gauge his performance) to be hindered.

Alcohol is removed from the blood at a fixed rate and this cannot be speeded up in any way (e.g. by drinking strong coffee). In fact, sleeping after drinking alcohol can slow down the removal process, as the body's metabolic systems are slower.

CAAIP Leaflet 15-6 (previously Airworthiness Notice 47) provides the following advice concerning alcohol:

"Alcohol has similar effects to tranquillisers and sleeping tablets and may remain circulating in the blood for a considerable time, especially if taken with food. It may be borne in mind that a person may not be fit to go on duty even 8 hours after drinking large amounts of alcohol. Individuals should therefore anticipate such effects upon their next duty period. Special note should be taken of the fact that combinations of alcohol and sleeping tablets, or anti-histamines, can form a highly dangerous and even lethal combination."

> As a general rule, aircraft maintenance engineers should not work for at least eight hours after drinking even small quantities of alcohol and increase this time if more has been drunk.

The affects of alcohol can be made considerably worse if the individual is fatigued, ill or using medication.

Even small quantities of alcohol in the blood can impair one's performance, with the added danger of relieving anxiety so that the person thinks he is performing marvellously. Alcohol severely affects a person's judgment and abilities; high altitudes, where there is less oxygen, worsens the effect. Alcohol is a depressant. It lowers the body's natural sensitivities, cautions and fears (showing as over-confidence) and, at the same time, it lowers capabilities; a deadly combination as we know by the road accident statistics. It also represses social mores and allows emotions, that would otherwise be controlled, to run free. Hence loudness, aggression, anger, passion, violence, showing-off and risk-taking. In some personalities it actually causes depression and low self-esteem. The World Health Organisation defines an alcoholic as someone whose excessive drinking repeatedly damages their physical, mental or social life. (I would add their professional life also.) It takes time for the body to remove alcohol. After heavy drinking, alcohol may still be in the blood 24 hours later. Having coffee, soup or water between drinks only helps if they are taken instead of an alcoholic beverage. Otherwise, the body receives the same total amount of alcohol in the same time; it takes the same time for it to be discarded and for its effects to be removed. Also of concern are the long-term effects of alcohol consumption, such as dependency and damage to kidneys, liver and brain. Studies suggest that females who drink 14-21 standard drinks per week, or less, and males who drink 21-28 per week, or less, should not suffer long-term problems. A standard drink contains 10 grams of alcohol.

4.21 Alcohol and Sleep

Alcohol has a detrimental effect on both the quality of sleep and on daytime attention. Sleep problems are common in alcoholics and also in some people who have completely stopped drinking. The effects of alcohol on sleep and attention are complicated to define and have considerable variability in individuals.

4.21.1 Disturbance of paradoxical (REM) sleep/slow wave sleep cycle

Alcohol seems to accelerate falling asleep, at least in subjects who do not tend to fall asleep immediately. The negative effects arise later and affect the quality and duration of sleep. Sleep is a complex phenomenon in which there are alternating phases of deep sleep, called paradoxical or REM sleep during which the subject dreams, and slow wave sleep. Undisturbed progression of these two phases of sleep is essential for an individual's well being. Alcohol disturbs or interrupts the sequence of paradoxical sleep and light sleep. Thus alcoholics and some people who have stopped drinking complain about disturbed and fragmented sleep, frightening dreams and insomnia.

The disruptive effects of alcohol last well into the night, even when alcohol has been eliminated. This is not a phenomenon specific to alcohol, it is seen with other sedative products. Snoring is abnormally frequent after taking alcoholic drinks in the evening before going to bed. This is due to the relaxing effects of alcohol on the pharyngeal muscles.

4.21.2 Daytime repercussions of alcohol's effects on sleep

Disturbed sleep or sleep deprivation exacerbate the sedative effects of alcohol during the day. Alcohol consumed late in the evening will noticeably reduce the performance of a subject (attention, dexterity,...) during the following morning. By producing an accumulation of nights of poor sleep, alcohol can disrupt the normal sleep/wake cycle, which is also essential for health and well being. Hence the negative effects of alcohol can have repercussions on daytime performance.

4.22 Research on Alcohol and Sleep

From: National institute on Alcohol Abuse and Alcoholism

Insomnia as a Pathway to Alcoholism

In healthy subjects, acute alcohol in doses of 0.16-1.0 g/kg suppresses REM sleep and increases deep non-rapid eye movement sleep (non-REM). Initial latency to sleep is reduced, but paradoxically, wake time during the latter half of the sleep period is increased. The reduced time to fall asleep produced by alcohol may encourage continued use of alcohol at bedtime.

Epidemiological studies have found that 28 percent of those who complain of insomnia reported using alcohol to help them sleep, and further, individuals who reported having two weeks or more of insomnia was more likely to have met diagnostic criteria for alcoholism at one year follow-up. A recent study found that insomniacs were more likely to self-administer ethanol before bedtime than non-insomniacs. Furthermore, a low dose of ethanol before bedtime made subtle improvements in the insomniacs' sleep and mood, suggesting that ethanol may be more reinforcing for insomniacs. Therefore, the degree to which ethanol use in insomniacs extends beyond the therapeutic context into daytime use is an important line of research. Tolerance development to low doses of alcohol in insomniacs is also a possibility, which could lead to increased doses, although this has not been investigated. Finally, for the elderly who use alcohol at bedtime to counteract insomnia, there is increased risk for falls during the night. Thus, whether insomnia precedes the development of alcohol abuse and the clinical significance of the sequencing of these two disorders particularly with respect to age and gender are important research questions.

Extract from the NIAAA Alcohol Alert

4.23 Alcohol and Sleep in Those Without Alcoholism

Alcohol consumed at bedtime, after an initial stimulating effect, may decrease the time required to fall asleep. Because of alcohol's sedating effect, many people with insomnia consume alcohol to promote sleep. However, alcohol consumed within an hour of bedtime appears to disrupt the second half of the sleep period. The subject may sleep fitfully during the second half of sleep, awakening from dreams and returning to sleep with difficulty. With continued consumption just before bedtime, alcohol's sleep-inducing effect may decrease, while its disruptive effects continue or increase. This sleep disruption may lead to daytime fatigue and sleepiness. The elderly are at particular risk, because they achieve higher levels of alcohol in the blood and brain than do younger persons after consuming an equivalent dose. Bedtime alcohol consumption among older persons may lead to unsteadiness if walking is attempted during the night, with increased risk of falls and injuries.

4.24 Alcohol and Attention

The sedative action of alcohol has variable degrees of effect on attention, reducing it and producing diminished performance. This action is particularly noticeable in subjects who lack sleep or who tend to be lethargic. Alcohol seems to reduce the ability of an individual to waken, even if consumed in moderate amounts, to the point where driving ability is affected, not just in the hours after consumption, but sometimes for days afterwards.

4.25 Medication

Any medication, no matter how common, can possibly have direct effects or side effects that may impair an engineer's performance in the workplace.

> Medication can be regarded as any over-the-counter or prescribed drug used for therapeutic purposes.

There is a risk that these effects can be amplified if an individual has a particular sensitivity to the medication or one of its ingredients. Hence, an aircraft maintenance engineer should be particularly careful when taking a medicine for the first time, and should ask his doctor whether any prescribed drug will affect his work performance. It is also wise with any medication to take the first dose at least 24 hours before any duty to ensure that it does not have any adverse effects.

> Medication is usually taken to relieve symptoms of an illness. Even if the drugs taken do not affect the engineer's performance, he should still ask himself whether the illness has made him temporarily unfit for work.

Various publications and especially CAAIP Leaflet 15-6 (previously published as Airworthiness Notice 47) give advice relevant to the aircraft maintenance engineer on some of the more common medications. This information is summarised below, however the engineer must use this with caution and should seek further clarification from a pharmacist, doctor or their company occupational health advisor if at all unsure of the impact on work performance.

- **Analgesics**: Analgesics are used for pain relief and to counter the symptoms of colds and 'flu. In the UK, paracetamol, aspirin and ibuprofen are the most common, and are generally considered safe if used as directed. They can be taken alone but are often used as an ingredient of a 'cold relief medicine. It is always worth bearing in mind that the pain or discomfort that you are attempting to treat with an analgesic (e.g. headache, sore throat, etc.) may be the symptom of some underlying illness that needs proper medical attention.
- **Antibiotics**: Antibiotics (such as Penicillin and the various mycins and cyclines) may have short term or delayed effects which 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 an individual unfit for work.
- **Anti-histamines**: Anti-histamines are used widely in 'cold cures' and in the treatment of allergies (e.g. hay fever). Most of this group of medicines tend to make the user feel drowsy, meaning that the use of

medicines containing anti-histamines is likely to be unacceptable when working as an aircraft maintenance engineer.

- **Cough suppressants**: Cough suppressants are generally safe in normal use, but if an over-the-counter product contains anti-histamine, decongestant, etc., the engineer should exercise caution about its use when working.
- **Decongestants**: Decongestants (i.e. treatments for nasal congestion) may contain chemicals such as pseudo-ephedrine hydrochloride (e.g. 'Sudafed') and phenylphrine. Side-effects reported, are anxiety, tremor, rapid pulse and headache. AWN47 forbids the use of medications containing this ingredient to aircraft maintenance engineers when working, as the effects compromise skilled performance.
- **'Pep' pills**: 'Pep' pills are used to maintain wakefulness. They often contain caffeine, dexedrine or benzedrine. Their use is often habit forming. Over-dosage may cause headaches, dizziness and mental disturbances. CAAIP Leaflet 15-6 (previously published as Airworthiness Notice 47) states that "the use of 'pep' pills whilst working cannot be permitted. If coffee is insufficient, you are not fit for work."
- **Sleeping tablets**: Sleeping tablets (often anti-histamine based) tend to slow reaction times and generally dull the senses. The duration of effect is variable from person to person. Individuals should obtain expert medical advice before taking them.
- **Melatonin**: Melatonin (a natural hormone) deserves a special mention. Although not available without a prescription in the UK, it is classed as a food supplement in the USA (and is readily available in health food shops). It has been claimed to be effective as a sleep aid, and to help promote the resynchronisation of disturbed circadian rhythms. Its effectiveness and safety are still yet to be proven and current best advice is to avoid this product.

If the aircraft maintenance engineer has any doubts about the suitability of working whilst taking medication, he must seek appropriate professional advice.

4.26 Drugs & Non-Prescribed Drugs

Don't touch them.

Illicit drugs such as ecstasy, cocaine and heroin all affect the central nervous system and impair mental function. They are known to have significant effects upon performance and have no place within the aviation maintenance environment. Of course, their possession and use are also illegal in the UK.

Smoking cannabis can subtly impair performance for up to 24 hours. In particular, it affects the ability to concentrate, retain information and make reasoned judgments, especially on difficult tasks.

4.27 Tobacco

Nothing good can be said about smoking. Smoking is detrimental to good health, both in the short term and in the long term. Smoking also significantly decreases a person's capacity to perform by reducing the amount of oxygen carried in the blood, replacing it with the useless and potentially poisonous by-products of cigarette smoke. A person does not have to be the active smoker to suffer the effects; smoke from any person in the cockpit (or anywhere in the aircraft, if it is small) will affect everyone. Carbon monoxide, which is present in cigarette smoke, is absorbed into the blood in preference to oxygen. The maximum blood oxygen concentration for a smoker is 90 per cent of that for a non-smoker. This means that, at sea level, a smoker is already as hypoxic as a non-smoker at an altitude of about eight thousand feet. A smoker's night vision is affected by hypoxia, even at sea level. Any oxygen deficiency reduces the body's ability to produce energy (and it affects brain functions).

The level of carbon monoxide in the blood is measured by the carboxyhaemoglobin level (COHb). Smokers with a COHb of 5% are already equivalent to an altitude of 8,000 feet and, at an actual cabin altitude of 5,000 feet, are at a personal altitude of 10,000 feet. (They should already be on oxygen.) An average smoker will have a

COHb level of 4-10%. A passive smoker may be as high as 5%. It is now recognised that cigarette smoking plays a significant role in cardiovascular (heart) diseases, cancer and other mental and physical diseases.

Most doctors will now tell you that whatever else you do for your health do not smoke. Besides, it is unfair to threaten the health of those who choose not to. If you must smoke, smoke alone.

4.28 Diet and Nutrition

We are what we eat. Diet concerns what we eat, how much and in what proportions. It receives much attention in the media these days because in Western society our dietary intake is poorly managed: too much animal fat, too much processed sugar, too few vegetables, cereals and fruit. In all, too much quantity and too little activity.

4.28.1 Eating Habits/Patterns

We are habitual eaters. The suggested eating pattern is to have small, varied serves often rather than sporadic large serves. Snacks, such as fruit, yoghurt, muesli bars and cereals keep the hunger at bay and avoid the temptation to eat a large meal too quickly. Eating slowly allows the digestive system to process the food and to feel satisfied with a lesser quantity.

4.28.2 Culture

We are heavily influenced by the diet of our culture and our forebears. Some are very favourable. Some are damaging. Our cuisine, style of cooking and the frequency and size of meals are related to our upbringing. All affect our health, energy and well-being. The Mediterranean cuisine is currently assessed as best: sea foods, salads, olive oil, fruit and time spent enjoying it.

4.28.3 Nutrition

Nutrition is fuel for the body and mind. We have discussed the importance of oxygen for generation of energy, and there is a need for fuel in the form of nutrients, which the body converts from the food we eat, and roughage, which is important for internal hygiene.

4.28.4 Glycaemic Index (GI)

There is much discussion regarding the natural sugar content of foods. A rating called the glycaemic index (GI) has been adopted and may appear on the packaging of foods in future, similar to the fat and cholesterol content. High GI foods give a quick but short-lived boost followed by a depressed level of energy and focus. OK for sprint athletes; not so good for long-haul flight crew.

4.28.5 Elements of Our Diet

- **Fats**. Intake of animal fat, in any form, should be carefully controlled. Meat does not necessarily mean fat, nor does milk. There are lean choices for both.
- **Meat**. Choose lean lamb, beef and chicken, no skin on the chicken. Keep fatty bacon to a minimum. Do not be too heavy on the sauces. Minimise preserved or processed meats, such as sausages and hams. Women don't eat enough meat. Lean meat is the best source of protein and iron.
- **Fish**. Oily fish/bluefish, sardines, kippers, herrings, salmon and tuna are marvelous. All grilled, steamed or poached fish is great. Avoid fried, battered or crumbed as the coating collects the fats and the calories.
- **Oils**. Vegetable and fish oils are good. Olive oil is best but don't overheat when cooking. Limit coconut and palm oils.
- **Legumes**. Peas, and all types of beans, are good for you (pulsars). The cowboys' staple diet of baked beans has much to be commended for it. Lentils are a good source of protein.

- ✈ **Salad**. Any salad is wonderful if raw, fresh and clean. If you are sure of the source, eat lots. Watch the dressings though. Light oil and vinegar is good. Mayonnaise not so. Moderate the additives such as cheese, bacon, potatoes and eggs. Salad, fruit and vegetables protect against cancers and heart disease.
- ✈ **Vegetables**. Vegetables should be undercooked and undressed, and steamed or stir-fried rather than boiled to death — crunchy is good. Eat lots of them. Go overboard. Spinach or silver beet is a good source of iron. Have many different-coloured vegetables on your plate. Brighter-coloured vegetables contain greater levels of anti-oxidants. These neutralise free radicals, the ageing and health-threatening agents that encourage cancers and heart disease. Soups are a wonderful way to serve fresh vegetables as the juices remain in the serve. Don't add too much salt. Potatoes boost energy but only in the short term (that GI again). Rice has the same effect. Avoid bulk quantities of either.
- ✈ **Fruit**. Eat unlimited amounts, if fresh. Fruit is the best source of vitamins, energy and water and also acts as anti-oxidants, especially red fruits, strawberries, and tomatoes. However, tropical fruits increase blood supply quickly (GI) and lead to an immediate uplift that is short-lived. It is followed by a loss of energy and concentration. They provide short-lived energy.
- ✈ **Nuts**. Nuts should be eaten sparingly — watch the oil and salt.
- ✈ **Carbohydrates - Fibre/Cereals/Grains/Rice**. Bread is the staff of life Granular and unprocessed is best with oil rather than butter. Rice and potatoes are good — steamed or boiled rather than fried. However, large amounts of rice or potatoes act to rapidly build the glycaemic level (blood sugar), but there follows a sudden let-down. Ever feel hungry and weak not long after a rice meal? It is doubly negative when it happens halfway into a long flight sector. Additionally, watch the sauce, cheese and butter.
- ✈ **Milk and Dairy Products**. Choose the low-fat/high-calcium versions. Restrict intake to small amounts of good cheese. Use vegetable oil or margarine in preference to butter. Low-salt, low-fat versions should be selected.
- ✈ **Yoghurt**. Yoghurt is excellent. Natural unsweetened varieties are best. Acidophilus is an important element in the functioning of the bowel. Some yoghurts culture forms of this essential bacterium (e.g. lactobacillus).
- ✈ **Eggs**. Cholesterol is high in egg yolk so keep to only two or three eggs a week. Poached or boiled is better than fried. Omelettes and custards can be high in egg content. Nevertheless, eggs are good food.
- ✈ **Desserts, Cakes, Sweets, Chocolates**. Fruits are better than sweet snacks but avoid adding sugar and serve the fruit with yoghurt rather than cream or ice cream. Biscuits, cakes, puddings, sauces, custards and chocolates should be a special (rare) treat.
- ✈ **Snacks**. Fresh fruit is best, or vegetables (celery, carrots, etc.), yoghurt, dry biscuits, or small amounts of nuts or seeds. Health bars are okay. No chips, hot or cold, in any guise.

Undercooking versus Overcooking. Always steam or poach rather than boil, and grill rather than fry. Undercooked. Is better for most foods, but some personal taste must be allowed, and also the source of the food. In some areas, well-cooked food, stewed or curried, is safest provided it is not reheated, nor presented in full public view to customers and to flies.

- ✈ **Minerals, Vitamins and Nutrients**. Previously, we could assume that a daily intake of calories, in the form of a varied diet, would automatically ensure that we had sufficient vitamins and minerals. Later research is suggesting that, in modern society, the food value and eating habits are not the same as they were and that supplementary vitamins and minerals may be essential. The body does not store all vitamins and so a daily need has to be met by a daily supply. The general recommendation is that we take supplementary multi-vitamins. We are also only beginning to understand the roles of various elements, minerals and anti-oxidants.

- ✈ **Salt** (Sodium Chloride). We no longer need to preserve meat or fish in salt and so our taste must change to value food without salt. We have grown accustomed to salt in and on our meals but our diet contains too much. It does take time to lower the salt level as meals initially taste less flavoured. It's like giving up sugar or stopping smoking: our taste buds adjust and we eventually appreciate the taste of the actual ingredients. There is enough salt naturally in all food. If there is a need for supplementary salt to replace that lost by perspiration, for example, in the tropics or when exercising severely, then the doctor will prescribe it.
- ✈ **Minerals and Mineral Salts**. Calcium, iron, magnesium and other elements are essential in our diet. They are inherent in a balanced diet. Iron deficiency is common in women and specific advice should be sought for your individual cycles. New dairy products include high-calcium, low-fat alternatives.
- ✈ **Sugar**. Minimise your intake of unprocessed sugar — preferably none. Eat sweet fruit rather than chocolate. Bananas are great.
- ✈ **Fast Foods/Take-Away**. So much to eat in so little time.
  - o Chinese and Thai - yes but choose those with no MSG and avoid deep fried meals. Steamed rice rather than fried or noodles - in small quantities.
  - o Indian - okay if high turnover and not reheated - but watch out for the fat in curries.
  - o Western - burgers are not so good on a regular basis but quite okay occasionally.
  - o Have lots of salad or coleslaw and less of the bread, butter and fries. Tomato sauce is good. Have chicken without the skin. Sandwiches are good if you choose the right contents. Grainy bread and no butter are ideal.
  - o Seafood plus salad - good.
  - o Fish and chips - not so good. Crumbed, or grilled, fish and chips cooked in vegetable oil are much better. Potato cakes, dim-sims and pluto-pops are not so good.
  - o Chicken - better without skin and with salad, or coleslaw, rather than mashed potato and gravy.

4.29 Drinking Habits

4.29.1 Fruit and Vegetable Juices and Water

Good, good, good. Water is best. Drink lots of it. Don't wait until you feel thirsty. Drink regularly. The colour of your urine should be light straw or paler. Any darker means potential dehydration. Too much fruit juice can cause bowel problems and also adds calories.

4.29.2 Soft Drinks

The mineral-enriched health drinks are for athletes. Use them for severe exercise; otherwise, drink straight mineral water. Avoid sweet, sticky, sugary soft drinks. They make you even thirstier.

4.29.3 Tea and Coffee

Caffeine is a drug and a stimulant. Coffee has most (especially espresso). Excess caffeine increases pulse rate, prevents sleep, increases urination and therefore fluid loss (it is a diuretic), causes headaches and increases the level of stress. It may wake you up but it won't let you rest. Keep caffeine to a minimum (one or two cups a day) and drink plenty of water.

4.30 Dehydration

A Hidden Source of Fatigue

By Gordon Dupont - February 2001

Fatigue is an industry problem that we are finally just beginning to come to grips with. It is a problem that our industry has vastly underestimated and that we have vastly overestimated our ability to cope with.

Well, now it appears that we have a further problem that both we and the industry are totally ignorant of — at least I sure was — dehydration. Dehydration has the ability to induce fatigue with the resulting reduction in judgment — all without us even being aware of it. Let's start with a few interesting facts:

1. Our body is made up of about 60 percent water (women a little less than men for some reason).
2. Our brain is made up of 85 percent water and requires a very narrow range of water content to remain at its peak.
3. We lose about 8 to 10 cups, or just over 2 litres of water per normal day through breathing, urinating, perspiring, and bowel movements.
4. Without water, we can live about 3 days.
5. If working outside on a hot day, we can lose about two pounds or one litre of water per hour.
6. Doctors now say that a whopping 75 percent of people don't have enough water, which translates to — dehydration.

4.30.1 What are the symptoms?

Surprisingly, thirst is not at the top of the list. We depend on feeling thirsty to keep us from becoming dehydrated and it has been shown to be a poor indicator.

Dr. F. Batmanghelidj, in his book Your Body's Many Cries for Water, states that in over one-third of us (37 percent), the thirst mechanism is so weak that it's often mistaken for hunger. It is only when we are moderately dehydrated, (6 to 10 percent) that we begin to pay attention to our thirst. By that time, our mental alertness has dropped dramatically. As dehydration becomes severe, the person slips into a coma and if the cardiovascular system collapses, the person dies.

4.30.2 Only two percent

As little as a two percent drop in body water can begin to affect mental alertness as the brain reacts to the fluid loss. Dr. Susan M. Kleiner, author of Power Eating, states "... this two percent triggers fuzzy, short-term memory; particularly, trouble with basic math and focusing on the problems on the printed page or computer screen. The problem is, we are becoming dehydrated and we may not even feel thirsty yet. We will begin to feel fatigued as our metabolism begins to slow down."

Putting two percent into perspective: A 150 Ib. person would need to lose only 1.8 Ibs. of water to be two percent dehydrated. On a hot day, you can lose that in less than an hour. If, as they say, 75 percent of us are chronically dehydrated, then we may be looking at a major contributing factor to maintenance errors — and we don't even know it!

4.30.3 Cold weather preservation

In cold climates, we often don't think of drinking water, choosing rather, a cup of hot coffee or tea. Humidity is very low in cold conditions and we still lose water through breathing and other body functions. The unknown dehydration leads to a feeling of fatigue and decreased mental alertness with never a thought that a simple glass of water will make us feel better.

4.30.4 The formula

Unlike fatigue, the solution is simple — drink lots of water. The old eight, 8-oz. glasses of water per day isn't very accurate because it doesn't take into account body weight, climate, or activity.

A more accurate figure calls for taking your body weight in pounds and dividing that number in half. That result is the ounces of water that you require daily. To that, add 12- to 16-oz. for hot, dry weather and a further 12- to 16-oz. if you are doing strenuous physical work.

This is considered a minimum to be sure that you are not dehydrated. Drinking more than that will do no harm as the kidneys maintain the correct water content and will simply "expel" the excess. This excess is thought to help flush out the toxins or at least dilute them, and can reduce the chances of colon cancer by possibly 45 percent and bladder cancer by 50 percent.

Perspiring heavily will require replenishment of some essential body salts that are being lost — sodium, potassium, calcium bicarbonate and phosphate. Salt tablets will help, as will some vitamin tablets.

There are many sport drinks on the market that offer replenishment of these salts. If you want to make your own "tonic," here is a recipe that will work:

- 1 litter (or quart) of water
- Pinch of salt
- 75 ml (1/3cup) of sugar*
- 100 ml (1/2 cup) of orange juice

*Add an optional drink crystal packet of any flavour you want. If it has sugar already added, then skip the sugar listed above. If you have a blender, you can even blend in a banana to help balance the potassium.

Now, if you're working out in the heat, you will need to drink at least one of these per hour just to keep balanced. You should also be drinking fluid about every 20 minutes in these conditions.

4.30.5 Fruits with your labour

Another often forgotten source of fluid as well as some those missing salts are fresh fruits and vegetables. They are made up of up to 90 percent water and are, as we know, good for you.

4.30.6 Diuretics

By fluid, we mean, the "tonic," water, milk, juice, mineral water, flavoured seltzers but NOT tea, coffee, soft drinks with caffeine, or alcohol.

Tea, coffee, and alcohol are diuretics and cause the kidneys to release more water, resulting in greater dehydration. If you are going to drink coffee, tea, alcohol and to a lesser extent affricated soft drinks, then you better add a water chaser to them just to counteract their diuretic effect.

Give this article some serious thought and remember; if we are to reduce maintenance errors we have to use all means possible. Dehydration is an easy one to fix — let's at least eliminate this potential source of error. While the industry may not, at least your body will thank you for it.

By the numbers...

As little as two percent loss in water content begins to cause the brain to lose alertness and the body to feel fatigued.

- 2% to 5% - Mild dehydration but sufficient to influence how the body will react.

- 6% to 10% - Moderate dehydration and is cause for immediate concern.
- 11% to 15% - Severe. Hospitalisation and intravenous will likely be required.
- Beyond 15% - Can end in death.

Some Common Indicators of Dehydration:

- Lips and later mouth feel dry
- Heart rate and breathing increases
- Blood pressure begins to drop
- Begin to feel fatigued
- Nagging headache that becomes progressively worse
- Decreased urine output
- Begin to feel thirsty
- Eyes begin to become sunken
- Become mentally irritated and depressed
- Skin begins to become wrinkled
- May develop a stomach ache
- May begin to experience lower back pain
- Become dizzy
- Become mentally confused

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Chapter 5. Physical Environment

5 Introduction

The aircraft maintenance engineer can expect to work in a variety of different environments, from **'line'** (generally outside the hangar) to **'base'** (usually inside a hangar or workshop), in all types of weather and climatic conditions, day and night. This depends largely on the company he works for, and the function he fulfils in the company. Both physical environments have their own specific features or factors that may impinge on human performance. This chapter considers the impact of noise, fumes, illumination, climate and temperature, motion and vibration, as well as the requirement to work in confined spaces and issues associated with the general working environment.

5.1 Noise

The impact of noise on human performance has already been discussed in Chapter 2, when examining 'hearing'. To recap, noise in the workplace can have both short-term and long-term negative effects: it can be annoying, can interfere with verbal communication and mask warnings, and it can damage workers' hearing (either temporarily or permanently). It was noted that the ear is sensitive to sounds between certain frequencies (20 HZ to 20 KHz) and that intensity of sound is measured in decibels (dB), where exposure in excess of 115 dB without ear protection even for a short duration is not recommended. This equates to standing within a few hundred metres of a moving jet aircraft.

Noise can be thought of as any unwanted sound, especially if it is loud, unpleasant and annoying.

General background noise can be 'filtered out' by the brain through focused attention (as noted in Chapter 2). Otherwise, for more problematic noise, some form of hearing protection (e.g. ear plugs and ear muffs) is commonly used by aircraft maintenance engineers, both on the line and in the hangar, to help the engineer to concentrate.

The noise environment in which the aircraft maintenance engineer works can vary considerably. For instance, the airport ramp or apron area is clearly noisy, due to running aircraft engines or auxiliary power units (APUs), moving vehicles and so on. It is not unusual for this to exceed 85 dB - 90 dB which can cause hearing damage if the time of exposure is prolonged. The hangar area can also be noisy, usually due to the use of various tools during aircraft maintenance. Short periods of intense noise are not uncommon here and can cause temporary hearing loss. Engineers may move to and from these noisy areas into the relative quiet of rest rooms, aircraft cabins, stores and offices.

It is very important that aircraft maintenance engineers remain aware of the extent of the noise around them. It is likely that some form of hearing protection should be carried with them at all times and, as a rule of thumb, used when remaining in an area where normal speech cannot be heard clearly at 2 metres.

In their day-to-day work, aircraft maintenance engineers will often need to discuss matters relating to a task with colleagues and also, at the end of a shift, handover to an incoming engineer. Clearly, in both cases it is important that noise does not impair their ability to communicate, as this could obviously have a bearing on the successful completion of the task (i.e. safety). Common sense dictates that important matters are discussed away from noisy areas.

5.2 Fumes

By its nature, the maintenance of aircraft involves working with a variety of fluids and chemical substances. For instance, engineers may come across various lubricants (oils and greases), hydraulic fluids, paints, cleaning compounds and solder. They will also be exposed to aircraft fuel and exhaust. In fact, there is every possibility that an engineer could be exposed to a number of these at any one time in the workplace. Each substance gives off some form of vapour or fumes which can be inhaled by the aircraft maintenance engineer. Some fumes will be obvious as a result of their odour, whereas others have no smell to indicate their presence. Some substances will be benign most of the time, but may, in certain circumstances, produce fumes (e.g. overheated grease or oils, smouldering insulation).

Fumes can cause problems for engineers mainly as a result of inhalation, but they can also cause other problems, such as eye irritation. The problem may be exacerbated in aircraft maintenance engineering by the confined spaces in which work must sometimes be carried out (e.g. fuel tanks). Here the fumes cannot dissipate easily and it may be appropriate to use breathing apparatus.

It may not always be practical to eradicate fumes from the aircraft maintenance engineer's work place, but where possible, steps should be taken to minimise them. It is also common sense that if noxious fumes are detected, an engineer should immediately inform his colleagues and supervisor so that the area can be evacuated and suitable steps taken to investigate the source and remove them.

Apart from noxious fumes that have serious health implications and must be avoided, working in the presence of fumes can affect an engineer's performance, as he may rush a job in order to escape them. If the fumes are likely to have this effect, the engineer should increase the ventilation locally or use breathing apparatus to dissipate the fumes.

5.3 Illumination

In order that aircraft maintenance engineers are able to carry out their work safely and efficiently, it is imperative that their work be conducted under proper lighting conditions. It was noted in Chapter 2, that the cones in the retina of the eye require good light to resolve fine detail. Furthermore, colour vision requires adequate light to stimulate the cones. Inappropriate or insufficient lighting can lead to mistakes in work tasks or can increase the time required to do the work.

Illumination refers to the lighting both within the general working environment and also in the locality of the engineer and the task he is carrying out. It can be defined as the amount of light striking a surface.

When working outside during daylight, the engineer may have sufficient **natural light** to see well by. It is possible however that he may be in shadow (possibly caused by the aircraft) or a building. Similarly, cramped equipment compartments will not be illuminated by ambient hangar lighting. In these cases, additional local **artificial lighting** is usually required (known as **task lighting).** At night, aerodromes may appear to be awash with floodlights and other aerodrome lighting, but these are unlikely to provide sufficient illumination for an engineer to be able to see what he is doing when working on an aircraft. These lights are not designed and placed for this purpose. Again, additional local artificial lighting is needed, which may be nothing more than a good torch (i.e. one which does not have a dark area in the centre of the beam). However, the drawback of a torch is that it leaves the engineer with only one hand available with which to work. A light mounted on a headband gets round this problem.

A torch can be very useful to the engineer, but Murphy's Law dictates that the torch batteries will run down when the engineer is across the airfield from the stores. It is much wiser to carry a spare set of batteries than 'take a chance' by attempting a job without enough light.

Within the hangar, general area lighting tends to be some distance from the aircraft on which an engineer might work, as it is usually attached to the very high ceiling of these buildings. This makes these lights hard to reach, meaning that they tend to get dusty, making them less effective and, in addition, failed bulbs tend not to be replaced as soon as they go out. In general, area lighting in hangars is unlikely to be as bright as natural daylight and, as a consequence, local task lighting is often needed, especially for work of a precise nature (particularly visual inspection tasks).

An extract from the NTSB report on the Northwest Airlines accident at Tokyo, 1994, illustrates these points:

"*The Safety Board believes that the "OK to Close" inspector was hindered considerably by the environment of the pylon area. He indicated, for example, that the combination of location of the scaffolding (at a level just below the underside of the wing that forced him into unusual and uncomfortable physical positions) and inadequate lighting from the base of the scaffolding up toward the pylon, hampered his inspection efforts. Moreover, the underside of the pylon was illuminated by portable fluorescent lights that had been placed along the floor of the scaffolding. These lights had previously been used in areas where airplanes were painted, and, as a result, had been covered with the residue of numerous paint applications that diminished their brightness. These factors combined to cause the inspector to view the fuse pin retainers by holding onto the airplane structure with one hand, leaning under the bat wing doors at an angle of at least 30°, holding a flashlight with the other hand pointing to the area, and moving his head awkwardly to face up into the pylon area.*"

It is also important that illumination is available **where** the engineer needs it (i.e. both in the hangar and one the line). Any supplemental task lighting must be adequate in terms of its brightness for the task at hand, which is best judged by the engineer. When using task lighting, it should be placed close to the work being done, but should not be in the engineer's line of sight as this will result in **direct glare.** It must also be arranged so that it does not reflect off surfaces near where the engineer is working causing **indirect** or **reflected glare.** Glare of either kind will be a distraction from the task and may cause mistakes.

Poor ambient illumination of work areas has been identified as a significant deficiency during the investigation of certain engineering incidents. It is equally important that lighting in ancillary areas, such as offices and stores, is good.

The AAIB report for the BAC 1-11 accident says of the unmanned stores area: "The ambient illumination in this area was poor and the Shift Maintenance Manager had to interpose himself between the carousel and the light source to gain access to the relevant carousel drawers. He did not use the drawer labels, even though he now knew the part number of the removed bolt, but identified what he thought were identical bolts by placing the bolts together and comparing them." He also failed to make use of his spectacles.

Relying on touch when lighting is poor is no substitute for actually being able to see what you are doing. If necessary, tools such as mirrors and borescopes may be needed to help the engineer see into remote areas.

5.4 Climate and Temperature

Humans can work within quite a wide range of temperatures and climatic conditions, but performance is adversely affected at extremes of these. Thus, as can be seen in Figure 5.1, when it is either too cold and/or wet or too hot and/or humid, performance diminishes.

As has been noted throughout this document, aircraft maintenance engineers routinely work both within the hangar and outside. Clearly, exposure to the widest range of temperature and climate is likely to be encountered outdoors. Here, an engineer may have to work in direct summer sun, strong winds, heavy rain, high humidity, or in the depths of winter. Although hangars must exclude inclement weather, they can be cold and draughty, especially if the hangar doors have to remain open.

EASA Part-145, AMC 145.25 (c) states: "*Hangars used to house aircraft together with office accommodation should be such as to ensure the working environment permits personnel to carry out work tasks in an effective manner. Temperatures should be maintained such that personnel can carry out required tasks without undue discomfort.*"

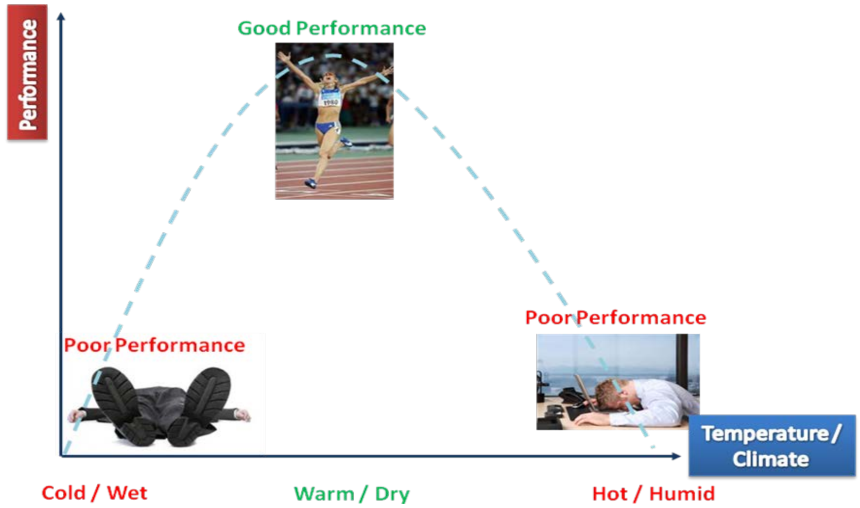

Figure 5-1: The relationship between climate, temperature and performance.

Engineers cannot be expected to maintain the rigorous standards expected in their profession in all environmental conditions. EASA Part-145 Acceptable Means of Compliance (AMC) 145.25(c) requires that environmental conditions be adequate for work to be carried out, stating:

"The working environment for line maintenance should be such that the particular maintenance or inspection task can be carried out without undue distraction. It therefore follows that where the working environment deteriorates to an unacceptable level in respect of temperature, moisture, hail, ice, snow, wind, light, dust/other airborne contamination, the particular maintenance or inspection tasks should be suspended until satisfactory conditions are re-established"

Unfortunately, in reality, pressure to turn aircraft round rapidly means that some maintenance tasks are not put off until the conditions are more conducive to work.

There was an instance in Scotland, where work on an aircraft was only suspended when it became so cold that the lubricants being used actually froze.

Environmental conditions can affect physical performance. For example, cold conditions make numb fingers, reducing the engineer's ability to carry out fiddly repairs, and working in strong winds can be distracting, especially if having to work at height (e.g. on staging). Extreme environmental conditions may also be fatiguing, both physically and mentally.

There are no simple solutions to the effects of temperature and climate on the engineer. For example, an aircraft being turned around on the apron cannot usually be moved into the hangar so that the engineer avoids the worst of the weather. In the cold, gloves can be worn, but obviously the gloves themselves may interfere with fine motor skills. In the direct heat of the sun or driving rain, it is usually impossible to set up a temporary shelter when working outside.

5.5 Motion and Vibration

Aircraft maintenance engineers often make use of staging and mobile access platforms to reach various parts of an aircraft. As these get higher, they tend to become less stable. For example when working at height on a scissors platform or 'cherry picker', applying force to a bolt being fixed to the aircraft may cause the platform to move away from the aircraft. The extent to which this occurs does not just depend on the height of the platform, but its design and serviceability. Any sensation of unsteadiness may distract an engineer, as he may concentrate more on keeping his balance than the task. Furthermore, it is vitally important that engineers use mobile access platforms properly in order to avoid serious injury.

Vibration in aircraft maintenance engineering is usually associated with the use of rotating or percussive tools and ancillary equipment, such as generators. Low frequency noise, such as that associated with aircraft engines, can also cause vibration. Vibration between 0.5 Hz to 20 Hz is most problematic, as the human body absorbs most of the vibratory energy in this range. The range between 50-150 Hz is most troublesome for the hand and is associated with **Vibratory-induced White Finger Syndrome (VWF).** Pneumatic tools can produce troublesome vibrations in this range and frequent use can lead to reduced local blood flow and pain associated with VWF. Vibration can be annoying, possibly disrupting an engineer's concentration.

5.6 Confined Spaces

Chapter 2 highlighted the possibility of claustrophobia being a problem in aircraft maintenance engineering. Working in any confined space, especially with limited means of entry or exit (e.g. fuel tanks) needs to be managed carefully. As noted previously, engineers should ideally work with a colleague who would assist their ingress into and egress out of the confined space. Good illumination and ventilation within the confined space will reduce any feelings of discomfort. In addition, appropriate safety equipment, such as breathing apparatus or lines must be used when required.

5.7 Working Environment

Various factors that impinge upon the engineer's physical working environment have been highlighted in this chapter. Apart from those already discussed, other physical influences include:

- workplace layout and the cleanliness and general tidiness of the workplace (e.g. storage facilities for tools, manuals and information, a means of checking that all tools have been retrieved from the aircraft, etc.);
- the proper provision and use of safety equipment and signage (such as non-slip surfaces, safety harnesses, etc.);
- the storage and use of toxic chemical and fluids (as distinct from fumes) (e.g. avoiding confusion between similar looking canisters and containers by clear labeling or storage in different locations, etc.).

To some extent, some or all of the factors associated with the engineer's workplace may affect his ability to work safely and efficiently. EASA Part-145.25(c) - Facility Requirements states:

"*The working environment must be appropriate for the task carried out and in particular special requirements observed. Unless otherwise dictated by the particular task environment, the working environment must be such that the effectiveness of personnel is not impaired*." This is expanded upon in AMC 145.25(c).

The working environment comprises the physical environment encapsulated in this chapter, the social environment described in Chapter 3 and the tasks that need to be carried out (examined in the next chapter). Each of these three components of the working environment interact, for example:

- engineers are trained to perform various tasks;
- successful task execution requires a suitable physical environment;
- an unsuitable or unpleasant physical environment is likely to be de-motivating.

Aircraft maintenance engineering requires all three components of the working environment to be managed carefully in order to achieve a safe and efficient system

It is important to recognise that engineers are typically highly professional and pragmatic in their outlook, and generally attempt to do the best work possible regardless of their working environment. Good maintenance organisations do their best to support this dedication by providing the necessary conditions for safe and efficient work.

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Chapter 6. Tasks

6 Introduction

Licensed aircraft engineering is a specialist occupation undertaken by men and women who have received appropriate training.

As a self starter, training is obtained mainly on-the-job, whereas an approved course is largely classroom-based with a condensed on-the-job element. Given the varied nature of the maintenance tasks in aircraft maintenance, few engineers are 'jacks of all trades'. Most engineers opt to specialise in the tasks they carry out, either as an **Airframe and Powerplant** specialist, or as an **Avionics** specialist (both disciplines include Electrical tasks).

When working within an aircraft maintenance organisation, an engineer will also be sent on **'type courses'.** These courses provide the engineer with requisite skills and knowledge to carry out tasks on specific aircraft, engines or aircraft systems.

The rest of this chapter examines the nature of the tasks that aircraft maintenance engineers carry out, looking at the physical work, repetitive tasks, visual inspection and the complex systems that they work on.

6.1 Physical Work

6.1.1 Planning

Blindly starting a task without **planning** how best to do it is almost certainly the best way to invite problems. Before commencing a task, an individual engineer, engineering team or planner should ask themselves a number of questions. These may include:

- Do I/we know exactly what the task is that has to be done?
- Are the resources available to do it effectively (safely, accurately and within the time permitted)? Where resources include:
    - personnel;
    - equipment/spares;
    - documentation, information and guidance;
    - facilities such as hangar space, lighting, etc.
- Do I / we have the skills and proficiency necessary to complete the task?

Information about specific tasks should be detailed on job cards or task sheets. These will indicate the task (e.g. checks or inspection, repair, replacement, overhaul) and often further details to aid the engineer (such as maintenance manual references, part numbers, etc.).

> If the engineer is in any doubt what needs to be done, written guidance material is the best resource. Colleagues may unintentionally give incorrect or imprecise direction (the exception to this is discussing problems that arise that are not covered in the guidance material).

It is generally the shift supervisor's job to ensure that the resources are available for his staff to carry out their tasks. As noted in Chapter 3, (Time Pressure and Deadlines), it is likely that, within a shift or a team, various sub-tasks are allocated to individuals by the supervisor. Alternatively, he may encourage a team to take ownership of the tasks that need to be completed, giving them the discretion to manage a package of work (as noted in Chapter 3, Team Working). Exactly 'who does what' is likely to be based on factors such as individuals' specialisation (i.e. mechanical or avionics) and their experience with the task.

Although management have a responsibility to ensure that their engineers have suitable training, at the end of the day, it is up to the individual engineer to decide whether he has the necessary skills and has the proficiency and experience to do what he has been asked to do. He should not be afraid to voice any misgivings, although it is recognised that peer and management pressure may make this difficult.

6.1.2 Physical Tasks

Aircraft maintenance engineering is a relatively active occupation. Regardless of the job being done, most tasks tend to have elements of fine motor control, requiring precision, as well as activities requiring strength and gross manipulation.

From a biomechanical perspective, the human body is a series of physical links (bones) connected at certain points (joints) that allow various movements. Muscles provide the motive force for all movements, both fine and gross. This is known as the **musculoskeletal system.** The force that can be applied in any given posture is dependent on the strength available from muscles and the mechanical advantage provided by the relative positions of the load, muscle connections, and joints.

> As an engineer gets older, the musculoskeletal system stiffens and muscles become weaker. Injuries become more likely and take longer to heal. Staying in shape will minimize the effects of ageing, but they still occur.

It is important that maintenance tasks on aircraft are within the physical limitations of aircraft maintenance engineers. Boeing use a computerised tool, based on human performance data (body sizes, strengths, leverages, pivots, etc.), to ensure that modern aircraft are designed such that the majority of maintenance engineers will be able to access aircraft equipment, apply the necessary strength to loosen or tighten objects, etc. (i.e. designed for **ease of maintainability).**

Clearly we are all different in terms of physical stature and strength and as a consequence, our physical limitations vary. Attempting to lift a heavy object which is beyond our physical capabilities is likely to lead to injury. The use of tools generally make tasks easier, and in some situations, may make a task achievable that was hitherto outside our physical powers (e.g. lifting an aircraft panel with the aid of a hoist).

As noted in Chapter 4, (Fatigue), physical work over a period of time will result in fatigue. This is normally not a problem if there is adequate rest and recovery time between work periods. It can, however, become a problem if the body is not allowed to recover, possibly leading to illness or injuries. Hence, engineers should try to take their allocated breaks.

> Missing a break in an effort to get a job done within a certain time frame can be counterproductive, as fatigue diminishes motor skills, perception, awareness and standards. As a consequence, work may slow and mistakes may occur that need to be rectified.

As discussed at some length in Chapter 4, (Day-to-Day Fitness and Health), it is very important that engineers should try to ensure that their physical fitness is good enough for the type of tasks which they normally do.

6.1.3 Repetitive Tasks

Repetitive tasks can be tedious and reduce arousal (i.e. be boring). Most of the human factors research associated with repetitive tasks have been carried out in manufacturing environments where workers carry out the same action many times a minute. This does not generally apply to maintenance engineering.

> Repetitive tasks in aircraft maintenance engineering typically refer to tasks that are performed several times during a shift, or a number of times during a short time period, e.g. in the course of a week. An example of this would be the checking life jackets on an aircraft during daily inspections.

Some engineers may specialise in a certain aspect of maintenance, such as engines. As a result, they may possibly carry out the same or similar tasks several times a day.

The main danger with repetitive tasks is that engineers may become so **practised** at such tasks that they may cease to consult the maintenance manual, or to use job cards. Thus, if something about a task is changed, the engineer may not be aware of the change. **Complacency** is also a danger, whereby an engineer may skip steps or fail to give due attention to steps in a procedure, especially if it is to check something which is rarely found to be wrong, damaged or out of tolerance. This applies particularly to visual inspection, which is covered in greater detail in the next section.

In the Aloha accident report, the NTSB raised the problem of repetitive tasks:

"The concern was expressed about what kinds of characteristics are appropriate to consider when selecting persons to perform an obviously tedious, repetitive task such as a protracted NDI inspection. Inspectors normally come up through the seniority ranks. If they have the desire, knowledge and skills, they bid on the position and are selected for the inspector job on that basis. However, to ask a technically knowledgeable person to perform an obviously tedious and exceedingly boring task, rather than to have him supervise the quality of the task, may not be an appropriate use of personnel..."

Making **assumptions** along the lines of '*Oh I've done that job dozens of times!*' can occur even if a task has not been undertaken for some time. It is always advisable to be wary of changes to procedures or parts, remembering that 'familiarity breeds contempt'.

6.1.4 Visual Inspection

Visual inspection is one of the primary methods employed during maintenance to ensure the aircraft remains in an airworthy condition.

Visual inspection can be described as the process of using the eye, alone or in conjunction with various aids to examine and evaluate the condition of systems or components of an aircraft.

Aircraft maintenance engineers may use magnifiers and borescopes to enhance their visual capabilities. The engineer may accompany his visual inspection by examining the element using his other senses (touch, hearing, smell, etc.). He may also manipulate the element being inspected to make further judgments about its condition. For instance, he might feel a surface for unevenness, or push against it to look for any unanticipated movement.

As highlighted in Chapter 2, ("Vision and the Aircraft Maintenance Engineer"), good **eyesight** is of prime importance in visual inspection, and it was noted that the UK CAA have provided some guidance on eyesight in CAAIP Leaflet 15-6 (previously published as Airworthiness Notice 47). Amongst other things, this calls for glasses or contact lenses to be used where prescribed and regular eyesight checks to be made.

Visual inspection is often the principal method used to identify degradation or defect in systems or components of aircraft. Although the engineer's vision is important, he also has to make **judgments** about what he sees. To do this, he brings to bear training, experience and common sense. Thus, reliable visual inspection requires that the engineer first sees the defect and then actually recognises that it is a defect. Of course, experience comes with practice, but tell tale signs to look for can be passed on by more experienced colleagues.

Information such as technical bulletins are important as they prime the inspector of known and potential defects and he should keep abreast of these. For example, blue staining on an aircraft fuselage may be considered insignificant at first sight, but information from a Technical Bulletin of 'blue ice' and external toilet leaks may make the engineer suspicious of a more serious problem.

There are various steps that an engineer can take to help him carry out a reliable visual inspection. The engineer should:

- ensure that he understands the area, component or system he has been asked to inspect (e.g. as specified on the work card);
- locate the corresponding area, component or system on the aircraft itself;

- ✈ make sure the environment is conducive to the visual inspection task (considering factors described in Chapter 5 - "Physical Environment", such as lighting, access, etc.);
- ✈ conduct a systematic visual search, moving his eyes carefully in a set pattern so that all parts are inspected;
- ✈ examine thoroughly any potential degradation or defect that is seen and decide whether it constitutes a problem;
- ✈ record any problem that is found and continue the search a few steps prior to where he left off.

Visual inspection requires a considerable amount of **concentration.** Long spells of continuous inspection can be tedious and result in low arousal. An engineer's low arousal or lack of motivation can contribute to a failure to spot *a* potential problem or a failure in recognising a defect during visual inspection. The effects are potentially worse when an inspector has a very low expectation of finding a defect, e.g. on a new aircraft.

Engineers may find it beneficial to take short breaks between discrete visual inspection tasks, such as at a particular system component, frame, lap joint, etc. This is much better than pausing midway through an inspection.

> The Aloha accident highlights what can happen when visual inspection is poor. The accident report included two findings that suggest visual inspection was one of the main contributors to the accident:
>
> "There are human factors issues associated with visual and non-destructive inspection which can degrade inspector performance to the extent that theoretically detectable damage is overlooked."
>
> "Aloha Airlines management failed to recognise the human performance factors of inspection and to fully motivate and focus their inspector force toward the critical nature of lap joint inspection, corrosion control and crack detection....."

Finally, non-destructive inspection (NDI) includes an element of visual inspection, but usually permits detection of defects below visual thresholds. Various specialist tools are used for this purpose, such as the use of eddy currents and fluorescent penetrant inspection (FPI).

6.1.5 Complex Systems

All large modern aircraft can be described as complex systems. Within these aircraft, there are a myriad of separate systems, many of which themselves may be considered complex, e.g. flying controls, landing gear, air conditioning, flight management computers. Table 6.1 gives an example of the breadth of complexity in aircraft systems.

> Any complex system can be thought of as having a wide variety of inputs. The system typically performs complex modifications on these inputs or the inputs trigger complex responses. There may be a single output, or many distributed outputs from the system.

The purpose, composition and function of a simple system is usually easily understood by an aircraft maintenance engineer. In other words, the system is transparent to him. Fault finding and diagnosis should be relatively simple with such systems (although appropriate manuals etc. should be referred to where necessary).

TYPE OF AILERON	NATURE OF SYSTEM
Simple aileron	Direct connection from control column to control surface; direct movement.
Servo tab aileron	Direct connection from control column to servo tab; aerodynamic movement of surface.
Powered aileron	Connection from control column to servo valve via input; hydraulic movement of surface; feedback mechanism; position indication.
Powered aileron / roll spoiler	As above but with interface to spoiler input system to provide additional roll capability.
Fly-by-wire aileron system	No connection from control column to surface. Electrical command signal to electro-hydraulic servo valve on actuator; signal modified and limited by intermediate influence of flight control computer.

Table 6-1: Example of increasing complexity - the aileron system

With a complex system, it should still be clear to an aircraft maintenance engineer what the system's purpose is. However, its composition and function may be harder to conceptualise - it is opaque to the engineer.

To maintain such complex systems, it is likely that the engineer will need to have carried out some form of system-specific training which would have furnished him with an understanding of how it works (and how it can fail) and what it is made up of (and how components can fail). It is important that the engineer understands enough about the overall functioning of a large, complex aircraft, but not so much that he is overwhelmed by its complexity. Thus, system-specific training must achieve the correct balance between detailed system knowledge and analytical troubleshooting skills.

With complex systems within aircraft, written procedures and reference material become an even more important source of guidance than with simple systems. They may describe comprehensively the method of performing maintenance tasks, such as inspections, adjustments and tests. They may describe the relationship of one system to other systems and often, most importantly, provide cautions or bring attention to specific areas or components. It is important to follow the procedures to the letter, since deviations from procedures may have implication on other parts of the system of which the engineer may be unaware.

When working with complex systems, it is important that the aircraft maintenance engineer makes reference to appropriate guidance material. This typically breaks down the system conceptually or physically, making it easier to understand and work on.

In modern aircraft, it is likely that the expertise to maintain a complex system may be distributed among individual engineers. Thus, avionics engineers and mechanical engineers may need to work in concert to examine completely a system that has an interface to the pilot in the cockpit (such as the undercarriage controls and indications).

A single modern aircraft is complex enough, but many engineers are qualified on several types and variants of aircraft. This will usually mean that he has less opportunity to become familiar with one type, making it even more important that he sticks to the prescribed procedures and refers to the reference manual wherever necessary. There is a particular vulnerability where tasks are very similar between a number of different aircraft (e.g. spoiler systems on the A320, B757 and B767), and may be more easily confused if no reference is made to the manual.

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Chapter 7. Communication

7 Introduction

Good communication is important in every industry. In aircraft maintenance engineering, it is vital. Communication, or more often a breakdown in communication, is often cited as a contributor to aviation incidents and accidents. It is for this very reason that it has its own section in the EASA Part-66 Module 9 for Human Factors. This chapter examines the various aspects of communication that affect the aircraft maintenance engineer.

> Communication is defined in the Penguin Dictionary of Psychology as:
>
> "The transmission of something from one location to another. The 'thing' that is transmitted may be a message, a signal, a meaning, etc. In order to have communication both the transmitter and the receiver must share a common code, so that the meaning or information contained in the message may be interpreted without error".

7.1 Within and Between Teams

As noted in previous chapters, aircraft maintenance engineers often work as teams. Individuals within teams exchange information and need to receive instructions, guidance, etc. Moreover, one team will have to pass on tasks to another team at shift handover. An engineer needs a good understanding of the various processes of communication, as without this, it is impossible to appreciate how communication can go wrong.

7.1.1 Modes of Communication

We are communicating almost constantly, whether consciously or otherwise. An aircraft maintenance engineer might regularly communicate:

- information;
- ideas;
- feelings;
- attitudes and beliefs

As the **sender** of a message, he will typically expect some kind of **response** from the person he is communicating with (the **recipient),** which could range from a simple acknowledgement that his message has been received (and hopefully understood), to a considered and detailed reply. The response constitutes **feedback.**

As can be seen in the above definition, communication can be:

- verbal/spoken - e.g. a single word, a phrase or sentence, a grunt;
- written/textual - e.g. printed words and/or numbers on paper or on a screen, hand written notes;
- non-verbal -
    - graphic - e.g. pictures, diagrams, hand drawn sketches, indications on a cockpit instrument;
    - symbolic - e.g. 'thumbs up', wave of the hand, nod of the head;
    - body language - e.g. facial expressions, touch such as a pat on the back, posture.

7.2 Transactional Analysis (TA)

Transactional Analysis (or TA as it is often called) is a model of people and relationships that was developed during the 1960s by Dr. Eric Berne. It is based on two notions: first that we have three parts or 'ego-states' to our 'personality. The other assumption is that these converse with one another in 'transactions' (hence the name). TA is a very common model used in therapy and study of human interactions and there is a great deal written about it.

7.2.1 Parent, Adult and Child

We each have internal models of parents, children and also adults, and we play these roles with one another in our relationships. We even do it with ourselves, in our internal conversations.

- **Parent**: There are two forms of Parent we can play:
  1. The Nurturing Parent is caring and concerned and often may appear as a mother-figure (though men can play it too). They seek to keep the Child safe and offer unconditional love, calming them when they are troubled.
  2. The Controlling (or Critical) Parent, on the other hand, tries to make the Child do as the parent wants them to do, perhaps transferring values or beliefs or helping the Child to understand and live in society. They may also have negative intent, using the Child as a whipping-boy or worse.
- **Adult**: The Adult in us is the 'grown up' rational person who talks reasonably and assertively, neither trying to control nor reacting. The Adult is comfortable with themselves and is, for many of us, our 'ideal self.
- **Child**: There are three types of Child we can play.
  1. The Natural Child is largely un-self-aware and is characterized by the non-speech noises they make (yahoo, etc.). They like playing and are open and vulnerable.
  2. The cutely-named Little Professor is the curious and exploring Child who is always trying out new stuff (often much to their Controlling Parent's annoyance). Together with the Natural Child they make up the Free Child.
  3. The Adaptive Child reacts to the world around them, either changing themselves to fit in or rebelling against the forces they feel.

7.3 Communications (Transactions)

When two people communicate, each exchange is a transaction. Many of our problems come from transactions which are unsuccessful.

Parents naturally speak to Children, as this is their role as a parent. They can talk with other Parents and Adults, although the subject still may be about the children.

The Nurturing Parent naturally talks to the Natural Child and the Controlling Parent to the Adaptive Child. In fact these parts of our personality are evoked by the opposite. Thus if I act as an Adaptive Child, I will most likely evoke the Controlling Parent in the other person.

We also play many games between these positions, and there are rituals from greetings to whole conversations (such as the weather) where we take different positions for different events. These are often 'pre-recorded' as scripts we just play out. They give us a sense of control and identity and reassure us that all is still well in the world. Other games can be negative and destructive and we play them more out of sense of habit and addiction than constructive pleasure.

7.4 Conflict

Complementary transactions occur when both people are at the same level. Thus Parent talking to Parent, etc. Here, both are often thinking in the same way and communication is easy. Problems usually occur in Crossed transactions, where the other person is at a different level.

The parent is either nurturing or controlling, and often speaks to the child, who is either adaptive or 'natural' in their response. When both people talk as a Parent to the other's Child, their wires get crossed and conflict results. The ideal line of communication is the mature and rational Adult-Adult relationship.

- There are no "good" nor "bad" ego states.
- A healthy personality comprises of all three of them.
- What is decisive, is to be able to choose the suitable ego state in a difficult situation (which should be ADULT ego).
- Unfortunately, in such a situation we often tend to react with one of the other ego states which usually doesn't solve the problem.
- As a rule, communication can go on as long as the people involved use the same ego state.
- If this is not the case, we will get stuck.
- A new common basis will have to be found.

Figure 7-1: Ego states

7.5 The Freudian Approach

Sigmund Freud described several components which have been very influential in understanding personality and communication.

7.5.1 Three levels of awareness

Freud identified three different parts of the mind, based on our level of awareness.

7.5.2 Conscious mind

The conscious mind is where we are paying attention at the moment. It includes only our current thinking processes and objects of attention, and hence constitutes a very large part of our current awareness.

7.5.3 Preconscious mind

The preconscious includes those things of which we are aware, but where we are not paying attention. We can choose to pay attention to these and deliberately bring them into the conscious mind.

We can control our awareness to a certain extent, from focusing in very closely on one conscious act to a wider awareness that seeks to expand consciousness to include as much of preconscious information as possible.

7.5.4 Subconscious mind

At the subconscious level, the process and content are out of direct reach of the conscious mind. The subconscious thus thinks and acts independently.

One of Freud's key findings was that much behaviour is driven directly from the subconscious mind. This has the alarming consequence that we are largely unable to control our behaviour, and in particular that which we would sometimes prefer to avoid.

More recent research has shown that the subconscious mind is probably even more in charge of our actions than even Freud had realized.

7.6 Three components of personality

Clinical psychologist Don Bannister has described Freud's position on the human personality as being:

"*...basically a battlefield. He is a dark-cellar in which a well-bred spinster lady (the superego) and a sex-crazed monkey (the id) are forever engaged in mortal combat, the struggle being refereed by a rather nervous bank clerk (the ego)*."

Thus an individual's feelings, thoughts, and behaviours are the result of the interaction of the id, the superego, and the ego.

This creates conflict, which creates anxiety, which leads to Defence Mechanisms.

7.6.1 Id

The Id contains our primitive drives and operates largely according to the pleasure principle, whereby its two main goals are the seeking of pleasure and the avoidance of pain.

It has no real perception of reality and seeks to satisfy its needs through what Freud called the primary processes that dominate the existence of infants, including hunger and self-protection.

The energy for the Id's actions come from libido, which is the energy storehouse.

7.6.2 Ego

Unlike the Id, the Ego is aware of reality and hence operates via the reality principle, whereby it recognizes what is real and understands that behaviours have consequences. This includes the effects of social rules that are necessary in order to live and socialize with other people. It uses secondary processes (perception, recognition, judgment and memory) that are developed during childhood.

The dilemma of the Ego is that it has to somehow balance the demands of the Id and Super ego with the constraints of reality.

The Ego controls higher mental processes such as reasoning and problem-solving, which it uses to solve the Id-Super ego dilemma, creatively finding ways to safely satisfy the Id's basic urges within the constraints of the Super ego.

7.6.3 Super ego

The Super ego contains our values and social morals, which often come from the rules of right and wrong that we learned in childhood from our parents and are contained in the conscience.

The Super ego has a model of an ego ideal and which it uses as a prototype against which to compare the ego (and towards which it encourages the ego to move).

The Super ego is a counterbalance to the Id, and seeks to inhibit the Id's pleasure-seeking demands, particularly those for sex and aggression.

7.7 Verbal and Written Communication

Generally speaking, verbal and written communications are purposeful. For a spoken or written message to be understood, the sender has to make sure that the receiver:

- is using the same **channel** of communication;
- recognises and understands his **language;**
- is able to make sense of the message's **meaning;**

The channel of communication is the medium used to convey the message. For spoken communication, this might be face-to-face, or via the telephone. Written messages might be notes, memos, documents or e-mails.

In most countries it is expected that aircraft maintenance engineers will communicate in English. However, it is also vital that the message **coding** used by the sender is appreciated by the recipient so that he can **decode** the message accurately. This means that engineers must have a similar knowledge of technical language, jargon and acronyms.

Assuming the channel and language used are compatible, to extract meaning, the engineer has to understand the **content** of the message. This means that it has to be clear and unambiguous. The message must also be appropriate to the **context** of the workplace and preferably be compatible with the receiver's **expectations.** Where any **ambiguity** exists, the engineer must seek **clarification.**

7.8 Non-verbal Communication

Non-verbal communication can accompany verbal communication, such as a smile during a face-to-face chat. It can also occur independently, for instance a colleague may pass on his ideas by using a sketch rather than the use of words. It can also be used when verbal communication is impossible, such as a nod of the head in a noisy environment.

Non-verbal communication is also the predominant manner by which systems communicate their status. For instance, most displays in the aircraft cockpit present their information graphically.

Body language can be very subtle, but often quite powerful. For example, the message "No" accompanied by a smile will be interpreted quite differently from the same word said whilst the sender scowls.

7.8.1 Communication within Teams

Individual aircraft maintenance engineers need to communicate:

- before starting a task - to find out what to do;
- during a task - to discuss work in progress, ask colleagues questions, confirm actions or intentions, or to ensure that others are informed of the maintenance state at any particular time;
- at the end of a task - to report its completion and highlight any problems.

Spoken communication makes up a large proportion of day-to-day communication within teams in aircraft maintenance. It relies both on clear transmission of the message (i.e. not mumbled or obscured by background noise) and the ability of the recipient of the message to hear it (i.e. active listening followed by accurate interpretation of the message). Good communication within a team helps to maintain **group cohesion.**

Spoken messages provide considerable flexibility and informality to express work-related matters when necessary. The key to such communication is to use words effectively and obtain feedback to make sure your message has been heard and understood.

It is much less common for individuals within teams to use written communication. They would however be expected to obtain pertinent written information communicated by service bulletins and work cards and to complete documentation associated with a task.

7.8.2 Communication between Teams

Communication between teams is critical in aircraft maintenance engineering. It is the means by which one team passes on tasks to another team. This usually occurs at **shift handover.** The information conveyed will include:

- tasks that have been completed;
- tasks in progress, their status, any problems encountered, etc.;
- tasks to be carried out;

- general company and technical information.

Communication between teams will involve passing on **written reports** of tasks from one shift supervisor to another. Ideally, this should be backed up by **spoken details** passed between supervisors and, where appropriate, individual engineers. This means that, wherever necessary, outgoing engineers personally brief their incoming colleagues. The written reports (maintenance cards, procedures, work orders, logs, etc.) and warning flags / placards provide a record of work completed and work yet to be completed - in other words, they provide **traceability.** Furthermore, information communicated at shift handover ensures good **continuity.**

It is important that handovers are not rushed, so as to minimise omissions.

7.9 Shift Handover

It is universally recognised that at the point of changing shift, the need for effective communication between the out-going and in-coming personnel in aircraft maintenance is extremely important. The absence of such effective communication has been evident in many accident reports from various industries, not just aircraft maintenance. Well known examples are the Air Accidents Investigation Branch (AAIB) report 2/95 on the incident to Airbus A320 G-KMAM at Gatwick in 1993 which highlighted an inadequate handover, and the Cullen Report for the Piper Alpha disaster which concluded that one of the factors which contributed to the disaster was the failure to transmit key information at shift handover.

Whilst history is littered with past experiences of poor shift handover contributing to accidents and incidents there is little regulatory or guidance material regarding what constitutes a good handover process relevant to aircraft maintenance. This section attempts to provide guidelines on such a process and is drawn from work performed by the UK Health and Safety Executive (HSE), US Department of Energy (DOE) and the Federal Aviation Administration (FAA).

7.9.1 Concepts

Effective shift handover depends on three basic elements:

- The outgoing person's ability to understand and communicate the important elements of the job or task being passed over to the incoming person.
- The incoming person's ability to understand and assimilate the information being provided by the outgoing person.
- A formalised process for exchanging information between outgoing and incoming people and a place for such exchanges to take place.

The DOE shift handover standards stress two characteristics that must be present for effective shift handover to take place: ownership and formality. Individuals must assume personal ownership and responsibility for the tasks they perform. They must want to ensure that their tasks are completed correctly, even when those tasks extend across shifts and are completed by somebody else. The opposite of this mental attitude is "It didn't happen on my shift", which essentially absolves the outgoing person from all responsibility for what happens on the next shift.

Formality relates to the level of recognition given to the shift handover procedures. Formalism exists when the shift handover process is defined in the Maintenance Organisation Exposition (MOE) and managers and supervisors are committed to ensuring that cross-shift information is effectively delivered. Demonstrable commitment is important as workers quickly perceive a lack of management commitment when they fail to provide ample shift overlap time, adequate job aids and dedicated facilities for the handovers to take place.

In such cases the procedures are just seen as the company covering their backsides and paying lip service as they don't consider the matter important enough to spend effort and money on.

7.9.2 Aids to Effective Communication at Shift Handover

Research has shown that certain processes, practices and skills aid effective communication at shift handover.

- People have to physically transmit information in written, spoken or gestured (nonverbal or body language) form. If only one medium is used there is a risk of erroneous transmission. The introduction of redundancy, by using more than one way of communicating i.e. written, verbal or non verbal, greatly reduces this risk.
- For this reason information should be repeated via more than one medium. For example verbal and one other method such as written or diagrams etc.
- The availability of feedback, to allow testing of comprehension etc. during communication increases the accuracy. The ability for two-way communication to take place is therefore important at shift handover.
- A part of the shift handover process is to facilitate the formulation of a shared mental model of the maintenance system, aircraft configuration, tasks in work etc. Misunderstandings are most likely to occur when people do not have this same mental 'picture[1] of the state of things. This is particularly true when deviations from normal working has occurred such as having the aircraft in the flight mode at a point in a maintenance check when this is not normally done. Other considerations are when people have returned following a lengthy absence (the state of things could have changed considerably during this time) and when handovers are carried out between experienced and inexperienced personnel (experienced people may make assumptions about their knowledge that may not be true of inexperienced people). In all these cases handovers can be expected to take longer and should be allowed for.
- Written communication is helped by the design of the documents, such as the handover log, which consider the information needs of those people who are expected to use it. By involving the people who conduct shift handovers and asking them what key information should be included and in what format it should be helps accurate communication and their 'buy-in' contributes to its use and acceptance of the process.

7.9.3 Barriers To Effective Communication At Shift Handover

Research has also shown that certain practices, attitudes and human limitations act as barriers to effective communication at shift handover.

- Key information can be lost if the message also contains irrelevant, unwanted information. We also only have a limited capability to absorb and process what is being communicated to us. In these circumstances it requires time and effort to interpret what is being said and extract the important information. It is important that only key information is presented, and irrelevant information excluded.
- The language we use in everyday life is inherently ambiguous. Effort therefore needs to be expended to reduce ambiguity by:
  - i. carefully specifying the information to be communicated e.g. by specifying the actual component, tooling or document,
  - ii. facilitating two-way communication which permits clarification of any ambiguity (e.g. do you mean the inboard or out board wing flap?)
- Misunderstandings are a natural and inevitable feature of human communication and effort has to be expended to identify, minimise and repair misunderstandings as they occur. Communication therefore has to be two-way, with both participants taking responsibility for achieving full and accurate communication.
- People and organisations frequently refer to communication as unproblematic, implying that successful communication is easy and requires little effort. This leads to over-confidence and complacency becoming common place. Organisations need to expend effort to address complacency by:
  - i. emphasising the potential for miscommunication and its possible consequences

ii. developing the communication skills of people who are involved in shift handovers

7.10 Guidelines

In considering the theories of communication and the research that has been performed the following guidelines apply for operations that are manned on multiple shifts to allow for continuous 24 hour maintenance. When shifts are adopted which do not cover a full 24 hour period, for example early and late shifts with no night shift, the handover where face to face communication is not possible posses an inherent risk. In such cases organisations should be aware that the potential for ineffective and inefficient communication is much higher.

7.11 Shift Handover Meetings

It could be said that the primary objective of the shift handover is to ensure accurate, reliable communication of *task-relevant* information across the shifts. However this does not recognise the user's needs for other information which may also be required to enable a complete mental model to be formed which will allow safe and efficient continuation of the maintenance process. Examples of such information could be manning levels, Authorisation coverage, staff sickness, people working extended hours (overtime), personnel issues etc.

An important aspect related to individual shift handover is when it actually begins. The common perception is that shift handover occurs only at the transition between the shifts. However, DOE shift handover standards make the point that shift handover should really begin as soon as the shift starts. Throughout their shift people should be thinking about, and recording, what information should be included in their handover to the next person or shift.

The following table lists the sort of topics that should be covered in the managers'/supervisors' handover meeting:

Status of the Facility	Work Status	Manning Levels and Status	Problems	Information
•Work stands / Docking •Visitors •Construction work •Health & Safety issues	•Aircraft being worked •Scheduled aircraft incoming / departing •Deadlines •Aircraft status vs planned status	•Authorisation coverage •Certifying staff •Non certifying staff •Personnel working overtime •Contract staff •Sickness •Injuries •Training •Out of base •Other personnel issues	•Outstanding / in work / status •Solved	•AD's, SB's, etc. •Company technical notices •Company policy notices

Table 7-1: Topics to be covered during a handover meeting

The shift handover process should comprise at least two meetings. It starts with a meeting between the incoming and outgoing shift managers/supervisors. This meeting should be conducted in an environment free from time pressure and distractions.

Shift managers/supervisors need to discuss and up-date themselves on tactical and managerial matters affecting the continued and timely operation of the maintenance process. The purpose of this meeting is therefore to acquaint themselves with the general state of the facility and the overall status of the work for which they are responsible. Outgoing managers/supervisors should summarise any significant problems they have encountered during their shift, especially any problems for which solutions have not been developed or are still in progress.

7.12 Walkthroughs

After the meeting between shift managers, and assignment of tasks, there is a need for Supervisors and certifying staff to meet and exchange detailed information related to individual jobs and tasks. The most effective way to communicate this information is for the affected incoming and outgoing personnel to go over the task issues while examining the actual jobs on the hangar floor or at the workplace. A mutual inspection and discussion of this nature is called a "Walkthrough".

The following lists the sort of topics that should be covered in the supervisors / certifying staffs walkthrough meeting:

- Jobs / tasks in progress
- Work cards being used
- Last step(s) completed
- Problems encountered
- Outstanding / in work / status
- Solved
- Unusual occurrences
- Unusual defects
- Resources required / available
- Location of removed parts, tooling etc.
- Parts and tools ordered and when expected
- Parts shortages
- Proposed next steps
- Communication with Planners, Tech Services, workshops
- Communication with managers etc.

NOTE: Task handover report should be read in conjunction with the section on Non-Routine Tasks and Process Sheets.

7.13 Task Handover

The handing over of tasks from one person to another does not always occur at the point of changing shifts. Tasks are frequently required to be handed over during a shift. This Section deals with two common situations. When a task is being handed over to someone who is present at the time, and when a job is being stopped part.

7.13.1 Handing Over A Task Directly To Another Person

When the task is being directly handed over to someone who is present at the time the process and concepts are the same as for a Walkthrough described in the Shift Handover Section of this handbook. That is to say it is done face to face using verbal and written communication. In these cases the written element is normally by ensuring that the task cards or non routine process sheets are accurately completed clearly identifying at what stage in the task the job has reached. Any deviations from normal working practices or procedures must be clearly highlighted during the Walkthrough. An example of this would be if in changing a valve, a clamp, not required to be removed by the maintenance manual, is disturbed to aid removal and installation. Many mishaps have occurred in these circumstances as the person taking over the job assumes that the task was being performed as per the maintenance manual, drawings, procedures etc. It is a CAA requirement that this deviation is recorded by the outgoing person, and it is essential from a communication effectiveness point of view that this is reinforced during the Walkthrough.

7.13.2 Handing Over a Task for Somebody to Complete at a Later Stage

It is not uncommon that a job is left incomplete during a shift, say in the case of someone being called away to attend to a more urgent task on another aircraft. In these cases it is often not known who will eventually pick up the job of completing and certifying the release to service. These situations present a far greater risk and challenge to effectively communicate the stage of task accomplishment and what is required to complete the job. Face to face communication is not possible therefore total reliance has to be placed on written communication, a single medium with no redundancy and opportunity to question and test a true understanding by the person expected to finish the job.

7.14 Scheduled Tasks

The paperwork normally associated with scheduled tasks are the Task Cards that are issued at the beginning of the maintenance input. These may have been written by the manufacturer, maintenance organisation or the operator of the aircraft. In all cases the card and associated task breakdown written on it, assume that the same person will start and finish the job. It was not designed to be used as a handover document.

That is not to say that it could not be the handover, or that it could not form part of one. It really depends on the circumstances.

Task Cards break down jobs in to discrete stages, and ideally jobs should always be stopped at one of these stages so that the last sign oft on the card is the exact stage of the job reached. In this case the card is the handover. However, a job is sometimes stopped at a point which is between the stages identified on the card, the stage sequencing has not been followed, or a deviation from normal working has occurred (such as in the example of disturbing the additional clamp to aid removal and installation of a valve). When this occurs additional written information must be used to clearly identify the point of exit from the task and what is required to complete the job and restore serviceability. Non-routine cards or sheets should then be used to record and transmit the relevant information necessary. Figure 7.3 is an example of a Task Card.

MAINTENANCE INSPECTION TASKCARD
FORM 110

A/C REG: SX-BIO	A/C MSN: 330	A/C MODEL DASH8-102	AMPM DOC No T-003	REV No: 012	REV DATE: 26/08/2007
STATION:	TASK TC168	MI / SPIN No:	WO No		
THRESH: (Next A check)	INTVL: 6000 FH or 36 Months	MPD MH: 0,000	PACK PAGE 1 of 1		

COMPONENT AFFECTED (if applicable): | COMPONENT S/N:

TASK DB ID: 658 | SOURCE: PART1 SECTION 2

SOURCE REF No: FSL-01 | REQMNT REF: -

ZONE: 531

TITTLE: **Fuel System Limitations** | MECH | INSP

TASK:
Detailed Inspection of the Flap Shroud Lightning Strips. Note: This is a CDCCL item task

ACCESS: -

PROCEDURE REF: MCTM/New section FSL/Task No FSL-01

COMMENTS:
CDCCL stands for Critical Design Configuration Contol Limitation. Damage, Wear or Changes to a CDCCL item can cause a possible fuel tank explosion

FINDINGS/ ACTION:

A strip (IPC ref.:XXX) found corroded but there were no spares in the stores. Order has been raised.

AWC RAISED

PARTS USED:

P/N	KEYWORD	STOCK No	S/N	QTY

CERTIFICATE OF RELEASE TO SERVICE
Certifies that the work specified, except as otherwise specified was carried out in accordance with Part-145 when applicable and in respect to that work the aircraft / aircraft component is considered ready to release to service

CERTIFICATION DATE

Figure 7-2: Typical Task Card

In the case above, the job has not been accomplished fully due to lack of spare parts. An additional work card, or worksheet or non routine card (the terminology will vary from one company to another) must be raised to communicate that the Task Card does not reflect the true state of the aircraft. In this case the wording could be:

Defect	Action Taken	Mechanic	Inspector
Reference card task No TC168. Work has not been completed due to the lack of spare part.			

Figure 7-3: Additional work card

The combination of both documents provides sufficient information for the person picking up the job to know what stage the work is up to and what is required to complete it.

7.15 Non-scheduled Tasks

Complex or lengthy non-scheduled tasks should always be broken down in to a number of discrete steps using stage or process sheets (the terminology will vary from one company to another). Many incidents have occurred when people have started a straight forward job but had to exit the task part way through without anybody to handover to. These situations by their nature are unplanned and are normally associated with time pressure or emergency situations. In spite of this it is vital that time is taken by the person leaving the job to comprehensively record what activities have taken place and what is required to complete the job. This would be recorded on stage sheets and should emphasis any deviations from the normal or expected way of working. Management and supervisors have a responsibility to ensure that adequate time is given to maintenance staff to record their work if they require tasks to be suspended for any reason.

7.16 Non-routine Task and Process Sheets

Task Cards for scheduled maintenance are an everyday document for aircraft engineers. They not only identify the job to be performed, but they also break down the task in to stages to allow for individuals to sign or certify the various stages The reasons for breaking down the job in to discrete tasks is often wrongly seen as record keeping, and of being able to identify who did what part of a job so that if there is an incident the employer or regulator can take action against the person. Whilst it does confer accountability for the work this could be achieved by other means. The primary purpose of a job card is to identify the task to be performed but then act as a job aid to help the engineer plan, complete the task fully, and in the correct sequence. Maintenance Programmes today are frequently based on the principles of Condition Monitoring. Most components on the aircraft therefore have no specific period defined as to when they will be removed for repair, overhaul etc. The time to remove them is determined by a reliability programme or scheduled inspections which assess their serviceability. Operator's Task Cards are normally derived, or copied from those provided by the aircraft manufacturer. Unfortunately these are usually only the required tasks and do not include those tasks which have to be performed as a consequence. An example of this is an engine change. The manufacturer will have written cards describing the break down of various inspections such as borescope, oil sampling and magnetic chip detectors but not a card on changing the engine. This had led to the situation whereby many jobs, often long and complex, have no pre-printed task cards or process sheets which break down the job in to stages and so help the engineers.

7.17 Shift and task handover systems: A review across industries

Effective shift handovers should be:

- conducted face-to-face
- two-way, with both participants taking responsibility for accurate communication
- via verbal <u>and</u> written means
- based on analysis of information needs of incoming staff
- given as much time as is necessary for accurate communication.

7.18 Communication Problems

There are two main ways in which communication can cause problems. These are **lack of communication and poor communication.** The former is characterised by the engineer who forgets to pass on pertinent information to a colleague, or when a written message is mislaid. The latter is typified by the engineer who does not make it clear what he needs to know and consequently receives inappropriate information, or a written report in barely legible handwriting. Both problems can lead to subsequent human error.

Communication also goes wrong when one of the parties involved makes some kind of **assumption.** The sender of a message may assume that the receiver understands the terms he has used. The receiver of a message may assume that the message means one thing when in fact he has misinterpreted it. Assumptions may be based on context and expectations, which have already been mentioned in this chapter. Problems with assumptions can be minimised if messages are unambiguous and proper feedback is given.

Basic rules of thumb to help aircraft maintenance engineers minimise poor communication are:

- think about what you want to say before speaking or writing;
- speak or write clearly;
- listen or read carefully;
- seek clarification wherever necessary.

7.19 Major risk areas for poor communication

- Work that continues over a shift change.
- When safety systems have been over-ridden.
- During deviations from normal working.
- Following a lengthy absence from work.
- When handovers are between experienced and inexperienced staff.

7.20 Work Logging and Recording

This is one of the most critical aspects of communication within aviation maintenance, since inadequate logging or recording of work has been cited as a contributor to several incidents.

In the B737 double engine oil loss incident in February 1995, for instance, one of the AAIB conclusions was:

"...the Line Engineer...had not made a written statement or annotation on a work stage sheet to show where he had got to in the inspections".

The reason for this was because he had intended completing the job himself and, therefore, did not consider that detailed work logging was necessary. However, this contributed towards the incident in that:

"the Night Base Maintenance Controller accepted the tasks on a verbal handover [and] he did not fully appreciate what had been done and what remained to be done".

Even if engineers think that they are going to complete a job, it is always necessary to keep the record of work up-to-date just in case the job has to be handed over. This may not necessarily be as a result of a shift change, but might be due to a rest break, illness, the need to move to another (possibly more urgent) task, etc.

The exact manner in which work should be logged tends to be prescribed by company procedures. It is usually recorded in written form. However, there is no logical reason why symbols and pictures should not also be used to record work or problems, especially when used for handovers. There are many cases where it may be clearer to draw a diagram rather than to try to explain something in words (i.e. 'a picture is worth a thousand words').

The key aspects of work logging and recording are captured in the CAA's Airworthiness Notice No. 3 (AWN3). This states:

"In relation to work carried out on an aircraft, it is the duty of all persons to whom this Notice applies to ensure that an adequate record of the work carried out is maintained. This is particularly important where such work carries on beyond a working period or shift, or is handed over from one person to another. The work accomplished, particularly if only disassembly or disturbance of components or aircraft systems, should be recorded as the work progresses or prior to undertaking a disassociated task. In any event, records should be completed no later than the end of the work period or shift of the individual undertaking the work. Such records should include Open' entries to reflect the remaining actions necessary to restore the aircraft to a serviceable condition prior to release. In the case of complex tasks which are undertaken frequently, consideration should be given to the use of pre-planned stage sheets to assist in the control, management and recording of these tasks. Where such sheets are used, care must be taken to ensure that they accurately reflect the current requirements and recommendations of the manufacturer and that all key stages, inspections, or replacements are recorded."

New technology is likely to help engineers to record work more easily and effectively in the future. ICAO Digest No. 12: "Human Factors in Aircraft Maintenance and Inspection", refers to hand-held computers and an Integrated Maintenance Information System (IMIS). It points out that these devices are likely to encourage the prompt and accurate recording of maintenance tasks.

Modern technology is also being implemented to improve the transfer of information in maintenance manuals to worksheets and workcards. These help to communicate pertinent information to engineers in an accessible and useable format. A contributory factor in the B737 double engine oil loss incident was that the information which should have prompted the engineer to carry out a post-inspection idle engine run to check for leaks was in the maintenance manual but not carried over to the task cards.

7.21 Keeping Up-to-Date, Currency

As discussed in Chapter 6, aircraft maintenance engineers undertake an approved course to obtain the knowledge and basic skills to enter the profession. This training is followed by instruction in more specific areas, such as maintenance of individual aircraft and specific systems (as discussed in Chapter 6, on "Complex Systems"). However, the aviation industry is dynamic: operators change their aircraft, new aircraft types and variants are introduced, new aircraft maintenance practices are introduced. As a consequence, the engineer needs to keep his knowledge and skills up-to-date.

To maintain his currency, he must keep abreast of pertinent information relating to:

- new aircraft types or variants;
- new technologies and new aircraft systems;
- new tools and maintenance practices;
- modifications to current aircraft and systems he works on;
- revised maintenance procedures and practices.

Engineers are likely to keep up-to-date by:

- undertaking update courses;
- reading briefing material, memos and bulletins;
- studying maintenance manual amendments

Responsibility for maintaining currency lies with both the individual engineer and the maintenance organisation for which he works. The engineer should make it his business to keep up-to-date with changes in his profession (remembering that making assumptions can be dangerous). The organisation should provide the appropriate training and allow their staff time to undertake the training before working on a new aircraft type or variant. It should also make written information easily accessible to engineers and encourage them to read it. It is, of course, vital that those producing the information make it easy for engineers to understand (i.e. avoid ambiguity).

Anecdotal evidence describes a case where a certain maintenance procedure was "proscribed" (i.e. prohibited) in a service bulletin. The technician reading this concluded that the procedure was "prescribed" (i.e. defined, laid down) and proceeded to perform the forbidden action.

From a human factors point of view, small changes to the technology or procedures concerning existing aircraft carry potentially the greatest risk. These do not usually warrant formal training and may merely be minor changes to the maintenance manual. Although there should be mechanisms in place to record all such changes, this presumes that the engineer will consult the updates. It is part of the engineer's individual **responsibility** to maintain his currency.

7.22 Dissemination of Information

As highlighted in the previous section, both the individual engineer and the organisation in which he works have a shared responsibility to keep abreast of new information. Good dissemination of information within an organisation forms part of its **safety culture** (Chapter 3). Typically, the maintenance organisation will be the sender and the individual engineer will be the recipient.

It was noted in Chapter 6, "Planning", that an aircraft maintenance engineer or team of engineers need to plan the way work will be performed. Part of this process should be checking that all information relating to the task has been gathered and understood. This includes checking to see if there is any information highlighting a change associated with the task (e.g. the way something should be done, the tools to be used, the components or parts involved).

It is imperative that engineers working remotely from the engineering base (e.g. on the line) familiarise themselves with new information (on notice boards, in maintenance manuals, etc.) on a regular basis.

There should normally be someone within the maintenance organisation with the responsibility for disseminating information. Supervisors can play an important role by ensuring that the engineers within their team have seen and understood any communicated information.

Poor dissemination of information was judged to have been a contributory factor to the Eastern Airlines accident in 1983. The NTSB accident report stated:
"*On May 17, 1983, Eastern Air Lines issued a revised work card 7204 [master chip detector installation procedures, including the fitment of O-ring seals]. ... the material was posted and all mechanics were expected to comply with the guidance. However, there was no supervisory follow-up to insure that mechanics and foremen were incorporating the training material into the work requirements... Use of binders and bulletin boards is not an effective means of controlling the dissemination of important work procedures, especially when there is no accountability system in place to enable supervisors to ensure that all mechanics had seen the applicable training and procedural information.*"

Communication is an **active** process whereby both the organisation and engineer have to play their part.

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Chapter 8. Human Error

8 Introduction

It has long been acknowledged that human performance is at times imperfect. Nearly two thousand years ago, the Roman philosopher Cicero cautioned "It is the nature of man to err". It is an unequivocal fact that whenever men and women are involved in an activity, human error will occur at some point.

> In his book "Human Error", Professor James Reason defines error as follows:
>
> "Error will be taken as a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency".

It is clear that aircraft maintenance engineering depends on the competence of engineers. Many of the examples presented in Chapter 1 "Incidents Attributable to Human Factors / Human Error" and throughout the rest of this document highlight errors that aircraft maintenance engineers have made which have contributed to aircraft incidents or accidents.

In the past, aircraft components and systems were relatively unreliable. Modern aircraft by comparison are designed and manufactured to be highly reliable. As a consequence, it is more common nowadays to hear that an aviation incident or accident has been caused by "human error".

The following quotation illustrates how aircraft maintenance engineers play a key role in keeping modern aircraft reliable:

"*Because civil aircraft are designed to fly safely for unlimited time provided defects are detected and repaired, safety becomes a matter of detection and repair rather than one of aircraft structure failure. In an ideal system, all defects which could affect flight safety will have been predicted in advance, located positively before they become dangerous, and eliminated by effective repair. In one sense, then, we have changed the safety system from one of physical defects in aircraft to one of errors in complex human-centred systems*"

The rest of this chapter examines some of the various ways in which human error has been conceptualised. It then considers the likely types of error that occur during aircraft maintenance and the implications if these errors are not spotted and corrected. Finally, means of managing human error in aircraft maintenance are discussed.

8.1 Error Models and Theories

To appreciate the types of error that it is possible to make, researchers have looked at human error in a number of ways and proposed various models and theories. These attempt to capture the nature of the error and its characteristics. To illustrate this, the following models and theories will be briefly highlighted:

- design- versus operator-induced errors;
- variable versus constant errors;
- reversible versus irreversible errors;
- slips, lapses and mistakes;
- skill-, rule- and knowledge-based behaviours and associated errors;
- the 'Swiss Cheese Model'.
- failures

8.1.1 Design vs Operator - Induced Errors

In aviation, emphasis is often placed upon the error(s) of the front line operators, who may include flight crew, air traffic controllers and aircraft maintenance engineers.

However, errors may have been made before an aircraft ever leaves the ground by aircraft designers. This may mean that, even if an aircraft is maintained and flown as it is designed to be, a flaw in its original design may lead to operational safety being compromised. Alternatively, flawed procedures put in place by airline, maintenance organisation or air traffic control management may also lead to operational problems.

It is common to find when investigating an incident or accident that more than one error has been made and often by more than one person. It may be that, only when a certain combination of errors arises and error 'defences' breached (see the 'Swiss Cheese Model') will safety be compromised.

8.1.2 Variable Vs Constant Errors

In his book "Human Error", Professor Reason discusses two types of human error: variable and constant. It can be seen in Figure 8.1 that variable errors in (A) are random in nature, whereas the constant errors in (B) follow some kind of consistent, systematic (yet erroneous) pattern. The implication is that constant errors may be predicted and therefore controlled, whereas variable errors cannot be predicted and are much harder to deal with. If we know enough about the nature of the task, the environment it is performed in, the mechanisms governing performance, and the nature of the individual, we have a greater chance of predicting an error.

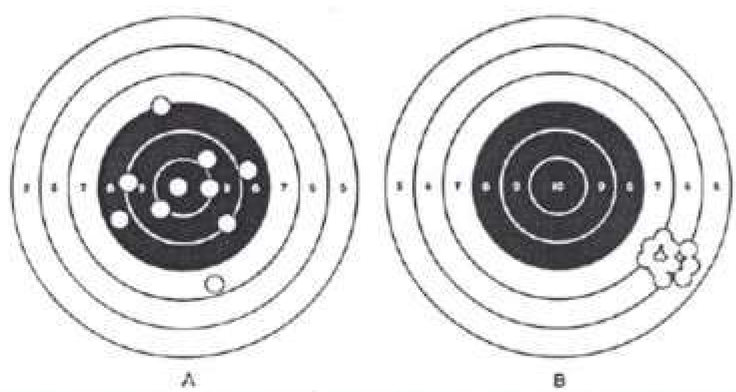

Figure 8-1: Variable versus Constant Errors

Target patterns of 5 shots fired by two riflemen. Rifleman A's pattern exhibits no constant error, but large variable errors; rifleman B's pattern exhibit's a large constant error but small variable errors. The latter would, potentially, be easier to predict and to correct (e.g. by correctly aligning the rifle sight). Chapanis, 1951

However, it is rare to have enough information to permit accurate predictions; we can generally only predict along the lines of "re-assembly tasks are more likely to incur errors than dismantling tasks", or "an engineer is more likely to make an error at 3 a.m., after having worked 12 hours, than at 10 a.m. after having worked only 2 hours". It is possible to refine these predictions with more information, but there will always be random errors or elements which cannot be predicted.

8.1.3 Reversible Vs Irreversible Errors

Another way of categorising errors is to determine whether they are reversible or irreversible. The former can be recovered from, whereas the latter typically cannot be. For example, if a pilot miscalculates the fuel he should carry, he may have to divert to a closer airfield, but if he accidentally dumps his fuel, he may not have many options open to him.

A well designed system or procedure should mean that errors made by aircraft maintenance engineers are reversible. Thus, if an engineer installs a part incorrectly, it should be spotted and corrected before the aircraft is released back to service by supervisory procedures in place.

8.1.4 Slips, Lapses and Mistakes

Reason highlights the notion of 'intention' when considering the nature of error, asking the questions:

- Were the actions directed by some prior intention?
- Did the actions proceed as planned?
- Did they achieve their desired end?

Reason then suggests an error classification based upon the answers to these questions as shown in Figure 8.2.

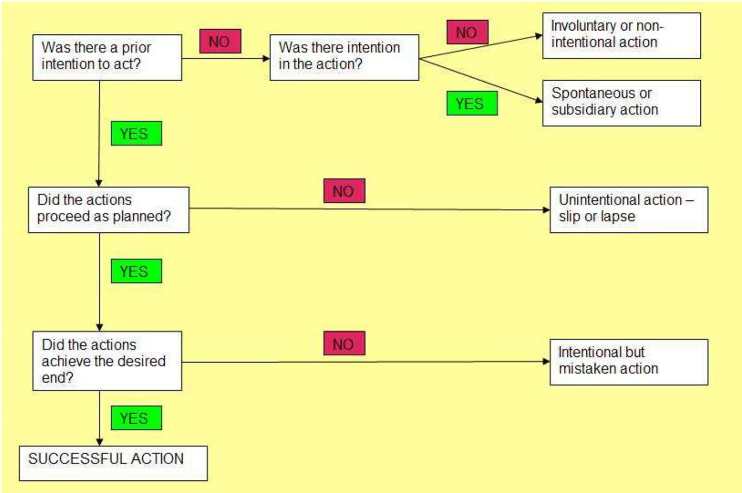

Figure 8-2: Error types based on intention. Source: Reason, 1990

The most well-known of these are:

- **Slips**: can be thought of as actions not carried out as intended or planned, e.g. 'transposing digits when copying out numbers, or mis-ordering steps in a procedure. Slips typically occur at the task execution stage, lapses at the storage (memory) stage and mistakes at the planning stage.
- **Lapses**: are missed actions and omissions, i.e. when somebody has failed to do something due to lapses of memory and/or attention or because they have forgotten something, e.g. forgetting to rep ace an engine cowling.
- **Mistakes**: are a specific type of error brought about by a faulty plan/intention, i.e. somebody did something believing it to be correct when it was, in fact, wrong, e.g. an error of judgment such as mis-selection of bolts when fitting an aircraft windscreen.

Violations sometimes appear to be human errors, but they differ from slips, lapses and mistakes because they are **deliberate** 'illegal' actions, i.e. somebody did something knowing it to be against the rules (e.g. deliberately failing to follow proper procedures). Aircraft maintenance engineers may consider that a violation is well intentioned, i.e. 'cutting corners' to get a job done on time. However, procedures must be followed appropriately to help safeguard safety.

8.1.5 Skill-, Rule- and Knowledge-Based Behaviours and Associated Errors

The behaviour of aircraft maintenance engineers can be broken down into three distinct categories:

- **Skill-based behaviours**: are those that rely on stored routines or motor programmes that have been earned with practice and may be executed without conscious thought.
- **Rule-based behaviours**: are those for which a routine or procedure has been learned. The components of a rule-based behaviour may comprise a set of discrete skills.

- **Knowledge-based behaviours**: are those for which no procedure has been established. These require the [aircraft maintenance engineer] to evaluate information, and then use his knowledge and experience to formulate a plan for dealing with the situation.

Each of these behaviour types have specific errors associated with them.

Examples of skill-based errors are **action slips, environmental capture** and **reversion.**

- **Action slips** as the name implies are the same as slips, i.e. an action not carried out as intended. The example given in Figure 8.3 may consist of an engineer realising he needs a certain wrench to complete a job but, because he is distracted by a colleague, picks up another set to the wrong torque and fails to notice that he has tightened the bolts incorrectly.

Figure 8-3: Example of an Action Slip

Environmental capture may occur when an engineer carries out a certain task very frequently in a certain location. Thus, an engineer used to carrying out a certain maintenance adjustment on an Airbus A300, may inadvertently carry out this adjustment on the next A300 he works on, even if it is not required (and he has not made a conscious decision to operate the skill).

Reversion can occur once a certain pattern of behaviour has been established, primarily because it can be very difficult to abandon or unlearn it when it is no longer appropriate. Thus, an engineer may accidentally carry out a procedure that he has used for years, even though it has been recently revised. This is more likely to happen when people are not concentrating or when they are in a stressful situation.

- **Rule-based behaviour** is generally fairly robust and this is why the use of procedures and rules is emphasised in aircraft maintenance. However, errors here are related to the use of the wrong rule or procedure. For example, an engineer may misdiagnose a fault and thus apply the wrong procedure, thus not clearing the fault. Errors here are also sometimes due to faulty recall of procedures. For instance, not remembering the correct sequence when performing a procedure.

- Errors at the **knowledge-based** performance level are related to incomplete or incorrect knowledge or interpreting the situation incorrectly. An example of this might be when an engineer attempts an unfamiliar repair task and assumes he can 'work it out'. Once he has set out in this way, he is likely to take more notice of things that suggest he is succeeding in his repair, while ignoring evidence to the contrary (known as **confirmation bias).**

8.2 Three basic error types

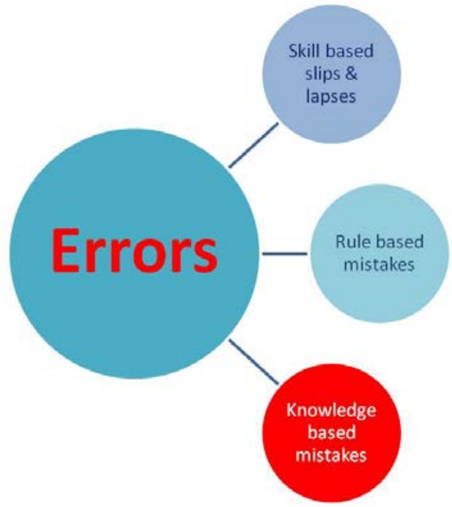

Figure 8-4: The three categories of error

Figure 8.4 shows the three categories of error linked to three human performance levels:

- The **skill-based** (SB) level involves the largely automatic control of habitual task in routine surroundings.
- The **rule based** (RB) level switches in when we encounter some trained-for or familiar problem.
- The **knowledge-based** (KB) level only occurs when we are faced with an entirely novel situation.

Errors can thus be sub-divided into three distinct categories:

- Skill based (SB) slips and lapses.
- Rule based (RB) mistakes.
- knowledge-based (KB) mistakes.

The next set of diagrams deal with skill-based slips and lapses. Thereafter we will focus on mistakes, most particularly on the three varieties of rule-based mistake.

- Rule based (RB) mistakes arise from:
    - Misapplication of good rules.
    - Application of bad rules.
    - Non-application of good rules (violations).
- Knowledge-based (KB) mistakes are more varied. They arise when people have to improvise in a novel situation. However, as the next figure shows, KB mistakes are fairly rare occurrence in aircraft engineering, so we will not consider them in the further.

8.3 Maintenance error types (classified by performance level)

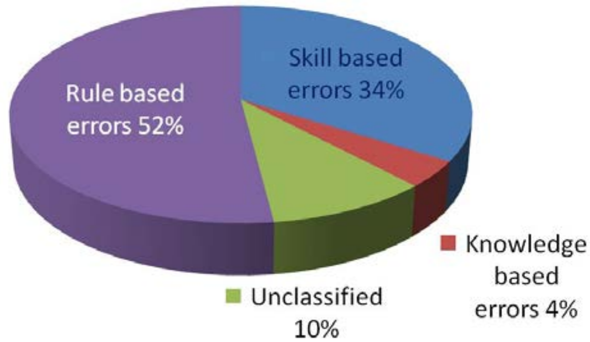

Figure 8-5: Variable versus Constant Errors

Figure 8.5 shows an analysis of the performance levels involved in the Hobbs critical incident study. It shows that Knowledge Based errors occur very rarely in aircraft maintenance activities. Hence, we will not discuss them any further. We will focus only on the Skill Based slips and lapses and the Rule Based mistakes.

8.3.1 Slips & lapses

Three main types:

- Recognition failures
- Memory failures
- Attentional failures

This sets out the major sub-divisions of slips and lapses. Each one is linked to a different mental function: perception (i.e., taking in and interpreting relevant sensory inputs), remembering to carry out the actions (i.e., prospective memory), deploying the limited attentional resource over the various actions in an appropriate manner (as we shall see, various mis-directions of attention are a major factor in the production of slips and lapses), and selecting the pre-programmed actions that are to be carried out (in skilled action, this selection process is largely automatic and outside of consciousness).

8.3.2 Recognition failures

- The **misidentification** of objects, messages, signals, etc.
- The **non-detection** of problem states (inspection or monitoring failures).

Recognition failures break down into two main groups: misidentifications and non-detections (false-negatives).
A third class is wrongly detecting defects that were not actually present (false-positives). These are logically possible and do actually occur, but they are unlikely to carry a major safety penalty. Maintenance systems are designed to be fairly tolerant of false-positives (better to be safe than sorry), but they are highly intolerant of false-negatives.

8.3.3 Causes of misidentifications

- **Similarity:** (in appearance, location, function, etc.) between right and wrong objects.
- **Indistinctness:** poor illumination and signal-to-noise ratios.
- **Expectation:** we tend to see what we want to see (confirmation bias).
- **Habit:** in well-practised and familiar tasks, perceptions become less precise.

Misidentifications involve putting the wrong mental interpretation upon the evidence gathered by our senses. These errors have been the cause of many serious accidents. They include train drivers who misread a signal aspect and pilots who misinterpret the height information provided by their instruments.
A major factor in misidentifications is the similarity (in appearance, location, function, etc.) between the right and wrong objects.
This can be made worse by poor signal-to-noise ratios (i.e., poor illumination, static, inaccessibility and the like).
Misidentifications are also strongly influenced by expectation: we tend to see what we expect to see. What we perceive is derived from two types of information: the evidence of our senses and knowledge structures stored in long-term memory. The weaker or more ambiguous the sensory evidence, the more likely it is that our perceptions will be dominated by expectation, or the stored knowledge structures. This is termed 'confirmation

bias' or 'mindset' Once we have formed an impression or hunch about what is going on, we tend to select information that will confirm this hunch, even when there is contradictory evidence available.
Strong habits are also like expectations: we sometimes accept a crude match to what is expected, even when it is wrong.

8.4 The 'Swiss Cheese Model'

In his research, Reason has highlighted the concept of **defences** against human error within an organisation, and has coined the notion of 'defences in depth'. Examples of defences are duplicate inspections, pilot pre-flight functional checks, etc., which help prevent to 'trap' human errors, reducing the likelihood of negative consequences. It is when these defences are weakened and breached that human errors can result in incidents or accidents. These defences have been portrayed diagrammatically, as several slices of Swiss cheese (and hence the model has become known as Professor Reason's "Swiss cheese" model) (see Figure 8.6).

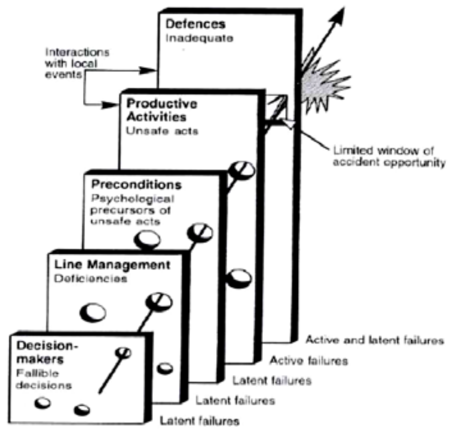

Figure 8-6: Reason's Swiss Cheese Model

Some failures are latent, meaning that they have been made at some point in the past and lay dormant. This may be introduced at the time an aircraft was designed or may be associated with a management decision. Errors made by front line personnel, such as aircraft maintenance engineers, are 'active' failures. The more holes in a system's defences, the more likely it is that errors result in incidents or accidents, but it is only in certain circumstances, when all holes 'line up', that these occur. Usually, if an error has breached the engineering defences, it reaches the flight operations defences (e.g. in flight warning) and is detected and handled at this stage. However, occasionally in aviation, an error can breach all the defences (e.g. a pilot ignores an in flight warning, believing it to be a false alarm) and a catastrophic situation ensues.

8.5 Failures

8.5.1 Memory failures

Memory can fail at one or more of three information-processing stages:

- ***input:*** Insufficient attention is given to the to-be-remembered material. Lost from short-term memory.
- ***storage:*** Material decays or suffers interference in long-term memory.
- ***retrieval:*** Known material not recalled at the appropriate time.

Here we move on to the second major heading in the overall '*wrong actions*' category: memory failures.

There are three basic memory processes:

- **Encoding** — taking information into memory.
- **Storage** — keeping it there.
- **Retrieval** — calling information to mind when it is needed.

Failures in each of these processes can cause forgetting.

8.5.2 Input failures

- ✈ Forgetting instructions, names, etc. Essentially a failure of attention at the time of presentation.
- ✈ Forgetting past actions, where tools were left, etc. During routine actions, mind is often on other things. Actions not attended to.
    - o **place-losing** (forget where you are in a sequence.)
    - o **time-gap experience** ('wake up' to find past actions a blank.)

What are we most likely to forget on being introduced to someone? The name. Why? Because the name is part of a flood of new information about this person and often fails to get taken in unless we make a special effort to focus on the name (then we often cannot remember what they looked like or what they did for a living). This tells us that giving just the right amount of attention to something is an important precondition for being able to remember it later.

The second kind of input failure is the forgetting of previous actions. Again, this is due to a failure of attention. When we are doing very familiar and routine tasks, our minds are almost always on something other than the job in hand. That's a necessary feature for the task to be done smoothly. The result is that we ‘f*orget*’ where we put our tools down, or find ourselves walking around looking for something that we are still carrying.

Some other consequences of this kind of forgetting are:

a. Losing our place in a series of actions: we 'wake up' and don't know immediately where we are in the sequence.

b. The time-gap experience: we can't remember things about where we've been walking or driving in the last few minutes, or what we've been doing exactly. For example, we can be in the shower and can't remember whether or not we've put shampoo on our hair. The evidence (if there was any) has been washed away, and we have been thinking about something else. In short, we've not been attending to the routine details.

8.5.3 Storage failures

- ✈ **Forgetting the plan** — a vague feeling that you should be doing something, but can't recall what.
- ✈ **'What am I doing-here?' experience** — find yourself in front of open drawer or cupboard, but can't recall what you came to get.
- ✈ **Forgetting items in a plan** — necessary steps omitted.

An intention to do something is rarely put into action immediately. Usually, it has to be held in memory until the right time and place for its execution. Memory for intentions is called *prospective memory,* and it is particularly prone to forgetting or sidetracking, so that the action is not carried out as intended.

It is, of course, possible to forget an intention completely, so that no trace of it remains. More usually, the forgetting occurs in degrees.

Almost forgetting the plan entirely turns into the vague ΄I should be doing something' feeling. Here, you have a vague and uneasy sense that you should be doing something, but you can't remember what, or where and when it should be done.

Another fairly common experience is that you remember the intention and start out to carry it through, but somewhere along the line (usually because you are preoccupied with something else) you forget what it is that you came to some place to do. The place could be a shop or you could find yourself standing in front of an open drawer or cupboard. You simply can't recall what it is you came to fetch. This is the 'what am I doing?' or 'what am I doing here?' feeling.

The third possibility is that you set out to perform a plan of action, think you have completed it, but later discover that you've left something out. A common experience is to return home to find a letter you intended to post.

8.5.4 Retrieval failures

- ✈ Fail to recall something you know you know. Often a name, a word or a fact.
- ✈ Frequently, the memory search is blocked by some other word or name that you know to be wrong, but which keeps coming to mind.
- ✈ 'tip-of-the-tongue' (TOT) states ended by further search, pop-ups (just comes to mind later) or external prompts.

Retrieval failures are among the commonest ways that your memory can let you down, and increasingly so as you grow older.

At its most acute, it shows itself as the TOT state when you realise that you can't call to mind a name or a word that you know you know. The searched-for word seems tantalizingly close - on the tip of your tongue, in fact. The problem is usually made worse because some word or name comes into your mind, but you know it's not the one you are trying to find. However, you have a strong sense that somehow it's close to the target item, you may feel it sounds similar, or has the same number of syllables, or is a name that belongs to someone who is related to or works with the person whose name you are trying to find.

Research on TOT states has shown that these painful searches get resolved in one of three ways:

a. The lost word or name appears as the result of a deliberate search, though this could be one of many attempts,

b. The searched-for name or word just pops into your mind out of the blue, usually when you are doing some routine job like washing up,

c. A TV programme or newspaper or some other external source mentions the word or name and you recognise it as the one you have been hunting for. Each of these three methods of concluding a memory search is equally likely.

It is unlikely that TOT states are much involved in maintenance errors. They are mentioned here for two reasons:

a. They are a common everyday experience,

b. They complete the trio of memory stages mentioned earlier.

8.5.5 Attentional failures

- ✈ Attention is a limited resource.
- ✈ Direct it to one thing and it is withdrawn from another (attentional capture).
- ✈ When this happens, actions often proceed unintentionally along some well-trodden pathway: strong habit intrusions.

It would be useful to explaining what attention is and what it does:

- ✈ Attention is closely bound up with conscious awareness.

- It can vary in both direction and intensity
- It selects some part of a much larger array of information for further processing.
- It has limited capacity.
- It is necessary for effective information-processing.

Two kinds of attentional problems:

- Inattention at critical decision points in an action sequence. The attentional investment is necessary to direct actions along their currently intended pathways. This is especially important when there has been some change, either in the customary plan or in the surroundings.
- We can also have the opposite: too much attention given to routine or pre-programmed segments of action that are best left to run their course automatically. These periods of over-attention usually follow times when you have been thinking about something other than the job in hand and 'wake up[1] to ask yourself where you are in the sequence. Too much attention given to these automatic runs of action can be highly disruptive, as will be discussed later.

8.5.6 A typical pattern

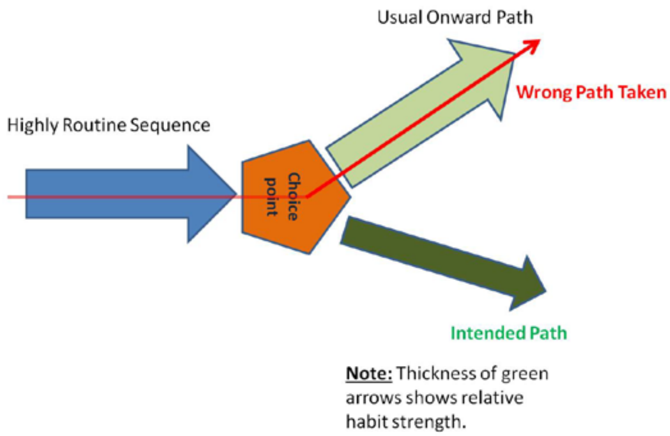

Figure 8-7: A typical failure pattern

Figure 8.7 represents the makings of a typical absent-minded slip.

Imagine that you are carrying out a highly practised action routine, like boiling an electric kettle preparatory to making a beverage. Imagine also that you have a guest who has asked for tea, while you are a habitual coffee-drinker.

You go to the kitchen, fill the kettle and set it to boil. In the meantime, you start thinking about something else. As a result you miss the choice point and fill both cups with instant coffee and pour on the water.

In this case, the kettle sequence is the fat arrow on the left. The fatter of the two arrows on the right is the coffee-making routine. The thinner arrow is the tea-making routine. You miss the choice point and your actions run, as on rails, along the familiar route. But this time, because of a change in circumstances, it is an absent-minded slip.

8.5.7 Slips of action (attentional failures)

- Strong habit intrusions
- Omissions following interruptions
- Premature exits

8.5.8 Strong habit intrusions

- ✈ Make tea instead of coffee. You are a tea drinker, but guest asks for coffee.
- ✈ Drive to work on Saturday morning when you meant to go to elsewhere.
- ✈ Intend to stop off to buy groceries on the way home, but drive straight past.

Branching slips, as the name indicates, involve actions where two different outcomes have an initial common pathway. Boiling a kettle of water, for example, is the first stage in achieving a variety of goals: making tea, making coffee, speeding up the cooking of vegetables, etc. The defining feature of these slips is that the wrong route (i.e., the one not currently intended) is taken. This 'wrong route' is almost invariably more familiar and frequently travelled than the one that was currently intended.

The slip is triggered by a change in plan (see tea-making slip described earlier).

8.5.9 Omissions following interruptions

- ✈ The failure to make the proper attentional check on progress is caused by distraction:-
- ✈ Intend to collect manual, but on removing it from shelf other books fall down. You replace books but depart without the manual.
- ✈ Actions associated with the interruption can get unconsciously 'counted in' as part of the intended sequence.

This is another type of slip that is a relatively common occurrence in aircraft engineering. They are also a frequent error type in everyday life.

On some occasions, the interruption causes the person to 'forget' the subsequent actions, or allows him or her to get sidetracked into something else. On others, the actions involved in dealing with an interruption get unconsciously counted in as part of the original action sequence. For example, a person is making tea and finds that the tea caddy is empty. They go to the cupboard and put fresh tea into the caddy. Then they pour boiling water into an empty teapot having omitted to put the tea in.

8.5.10 Premature exits

Terminate job before all fastenings are attached, or oil/fluid replaced, or caps secured, or all tools and foreign objects removed. Actual examples:

- ✈ Nuts left finger tight and not torqued.
- ✈ Centre P_2 instrument panel slid out on takeoff.
- ✈ Pre-flight checks revealed that control column could not be moved backwards. 3 cm hole cutter found wedged between balance weight and a/c structure.

Another name for undershoots is 'premature exits'. That is, departing from an action sequence before all the component actions are carried out. Slips of this kind feature very commonly among aircraft engineering quality lapses.

8.5.11 General factors promoting wrong actions

- ✈ The performance of a routine, habitual task in familiar surroundings.
- ✈ Attentional capture by preoccupation or distraction.
- ✈ Change, either in the plan of action or in the surroundings.

Several studies of everyday absent-minded actions, in which people kept diaries of the occasions when their actions did not go as planned, have shown that there are a number of conditions that are invariably associated with these wrong actions.

a. Paradoxically, absent-mindedness is the penalty we pay for being skilled; that is, for being able to control our routine actions in a largely automatic fashion. It is therefore natural that slips and lapses are most likely to occur during the execution of well-practised habitual tasks in familiar surroundings. Of course, we do commit errors when we are learning a new skill (like using a computer keyboard), but these errors are most likely to be fumbles and mishits due to inexperience and lack of motor coordination.

b. Attention is a limited commodity. If it is given to one thing it is necessarily withdrawn from other things. Attentional 'capture' happens when almost all of this limited attentional resource is devoted to one thing. If it is an internal worry, we call it preoccupation; if it is something happening externally in our immediate vicinity, we call it distraction. The evidence shows very clearly that attentional capture, of one kind or another, is an indispensable condition for an absent-minded (AM) slip or lapse.

c. Many action slips involve carrying out a set of actions that is highly usual or habitual in that situation, but was not what was wanted or intended at the time. The trigger for the slip was some kind of change, either in the plan or in the surroundings. If that change had not occurred then the actions would have run along their accustomed tracks as intended. Thus, change of any kind is a powerful error-producer.

8.5.12 Slips versus mistakes

- Installation problems (omissions) are the largest class of maintenance errors.
- While many of them are due to slips, this is not the whole story.
- Omissions can also occur because of mistakes: having the wrong idea about something, or using the wrong procedure.
- Slips are hardly ever repeated, but mistakes are.

8.6 Three Common Mistakes in Aircraft Maintenance

- Misapply a good rule
- Apply a bad rule
- Fail to apply a good rule (violation)

This identifies the three main classes of rule-based mistakes:

- We can misapply a normally good rule: that is, we can use it in a situation for which it is not appropriate because of some changed circumstance.
- We can apply a bad rule that may get the job done but can have unwanted consequences.
- Logically, there is also a third class: we can fail to apply a good rule that was appropriate and should have been followed. These are violations, rule-bendings and non-compliances.

The next few examples look at examples of misapplying good rules and applying bad rules.

8.6.1 Misapplying good rules

- A 'good rule or principle' is one that has been generally useful in the past.
- But sometimes the rule/principle is wrongly applied:
    - In a situation that shares many common features with the one for which rule was intended.
    - But where the differences are overlooked.

This explains what is meant by a 'good rule'. It also spells out some of the situations in which a good rule can be wrongly applied.

The business of applying problem-solving rules is often complicated by the fact that different problems can share common features. In other words, it is possible that a given problem presents *both* indications suggesting that the common rule (common because it's a useful rule) should be applied as *well as* counter-indications directing the person to apply a less commonly-used rule.

Here is an example. A family doctor is holding surgery during winter time in, say, the UK. A mother comes in with a baby that has a runny nose and a high fever. The doctor sees a lot of patients with influenza in Northern European winters and prescribes penicillin. But the baby actually has meningitis that does not respond that dosage of penicillin. The counter-indications are a bad headache and a stiff neck, but these are difficult to establish in a young child who doesn't talk and doesn't have much of a neck. The consequence of this RB mistake is that the child either dies or suffers severe brain damage.

8.6.2 Misapplication: BAC 1-11

- Engineer involved in 1-11 accident ignored storeman's comment that the required bolt was an 8D — a slightly longer bolt than the 7D that he was searching for.
- A general rule-of-thumb in maintenance is to replace like with like.
- In this case, the IPC called for 8D's. But he did not consult IPC (a violation) and had used 7D's in the past. The a/c had flown safely with 7D's for past 4 years.

8.6.3 Misapplication: B747 Incident

- During 'C' check, NDT inspector marked work card steps covering replacement of secondary fuse pin retainers as 'N/A' (not applicable).
- He did not believe that secondary retainers were required on this aircraft and thus did not realise that they had been removed.
- Only 7 of airline's fleet of forty one 747s required secondary retainers.

This example is drawn from the 747 dropped engine incident, and explains why the inspector failed to spot the missing retainers. Since only 7 of the airline's fleet of forty one 747s were fitted with these secondary retainers, he did not expect them to be present.

8.7 Applying bad rules

- Most people pick up some 'bad rules' (bad habits) when learning a job.
- They are 'bad' because they can lead to something going wrong at a later time, even though they might serve their immediate purpose on many occasions.
- Such 'bad rules' become established as part of the person's 'toolbag'.

Bad rules can become established as part of our normal behaviour for a number of reasons:

- No one corrects us at the time.
- Applying the bad rule seems to get the job done.
- And most of the time, there are no bad consequences.

8.7.1 Bad rules: Clapham Junction.

- British Rail technician had acquired the habit of bending back old wire rather than removing it when rewiring a signal box.
- Old wire made a false connection causing signal to fail unsafe (green aspect). Commuter train crashed into back of a stationary train contributing to worst British railway accident for 40 years (Clapham Junction disaster, 1987).

The British Rail (BR) technician was a very keen and hard-working person who had never (in his 12 years of service) received any proper training. He had picked up the job by watching other people and trying things out for himself.

The other part of the story is that the system had procedures for checking on the quality of signal wiring work, but these were not put into operation at this time. The person who was supposed to have done the checks was very busy with the Waterloo rewiring scheme and the checks simply fell out of his list of things to be done. Managerial and supervisory oversights are very common. It's not necessarily the case that these people are lazy or incompetent. It is often that they are just very busy with other things.

Someone has called the Clapham accident 'the case of the unrocked boat'. BR had seven years without a passenger fatality and the normal checks and balances had grown imperceptibly slack.

The second example is a case of 'naive physics' in which a large proportion of intelligent students assumed - as they did in ancient times - that the trajectory of a moving body reflects the shape of the structure that ejected it. Nearly all of us have got some misconceptions about the world. Most of the time, they have no consequences; but, occasionally, they can lead to bad outcomes.

8.8 Summarising Error Types

- Slips and lapses fall into three groups:
  - Recognition failures
  - Memory failures
  - Attentional failures
- Mistakes can arise from:
  - misapplying good rules
  - applying bad rules
  - not applying good rules (violations)

8.9 Types of Error in Maintenance Tasks

As aircraft maintenance engineers are human, errors in the industry are inevitable.

Any maintenance task performed on an aircraft is an opportunity for human error to be introduced. Errors in aircraft maintenance engineering tend to take two specific forms:

- ✈ an error that results in a specific aircraft problem that was not there before the maintenance task was initiated (e.g. installation of line replaceable units, failure to remove a protective cap from a hydraulic line before reassembly or damaging an air duct used as a foothold while gaining access to perform a task.)
- ✈ an error that results in an unwanted or unsafe condition remaining undetected while performing a maintenance task designed to detect aircraft problems, i.e. something is missed (a structural crack unnoticed during a visual inspection task or a faulty avionics box that remains on the aircraft because incorrect diagnosis of the problem led to removal of the wrong box).

8.10 Errors During Regular and Less Frequent Maintenance Tasks

A large proportion of maintenance tasks are fairly routine, such as regular, periodic checks on aircraft. Thus, engineers will use a certain set of procedures relatively frequently and, as noted in the previous section, slips and lapses can occur when carrying out procedures in the busy hangar or line environment. Chapter 6 "Repetitive Tasks" noted that engineers will often become so accustomed to doing a regular, often repeated task, that they will dispense with written guidance altogether. It would be unrealistic and unnecessarily time consuming to expect them to constantly refer to familiar guidance material. However, errors may occur if they do not keep up-to-date with any changes that occur to these frequently used procedures. These routine tasks are also prone to **complacency, environmental capture and rule-based errors.**

When undertaking less frequently performed tasks, there is the possibility of errors of judgment. If the engineer does not familiarise or re-familiarise himself properly with what needs to be done, he may mistakenly select the wrong procedure or parts.

8.11 Violation in Aircraft Maintenance

It is an unfortunate fact of life that **violations** occur in aviation maintenance. Most stem from a genuine desire to do a good job. Seldom are they acts of vandalism or sabotage. However, they represent a significant threat to safety as systems are designed assuming people will follow the procedures. There are four types of violations:

- ✈ Routine violations;
- ✈ Situational violations;
- ✈ Optimising violations;
- ✈ Exceptional violations.

Routine violations are things which have become 'the normal way of doing something' within the person's work group (e.g. a maintenance team). They can become routine for a number of reasons: engineers may believe that procedures may be over prescriptive and violate them to simplify a task **(cutting corners),** to save time and effort.

Situational violations occur due to the particular factors that exist at the time, such as time pressure, high workload, unworkable procedures, inadequate tooling, poor working conditions. These occur often when, in order to get the job done, engineers consider that a procedure cannot be followed.

Optimising violations involve breaking the rules for 'kicks'. These are often quite unrelated to the actual task. The person just uses the opportunity to satisfy a personal need.

Exceptional violations are typified by particular tasks or operating circumstances that make violations inevitable, no matter how well intentioned the engineer might be.

Examples of routine violations are not performing an engine run after a borescope inspection ("it never leaks"), or not changing the 'O' seals on the engine gearbox drive pad after a borescope inspection ("they are never damaged").

An example of a situational violation is an incident which occurred where the door of a B747 came open in-flight. An engineer with a tight deadline discovered that he needed a special jig to drill off a new door torque tube. The jig was not available, so the engineer decided to drill the holes by hand on a pillar drill. If he had complied with the maintenance manual he could not have done the job and the aircraft would have missed the service.

An example of an optimising violation would be an engineer who has to go across the airfield and drives there faster than permitted.

Time pressure and high workload increase the likelihood of all types of violations occurring. People weigh up the **perceived risks** against the **perceived benefits;** unfortunately the **actual risks** can be much higher.

8.12 Mental 'economics' of violations

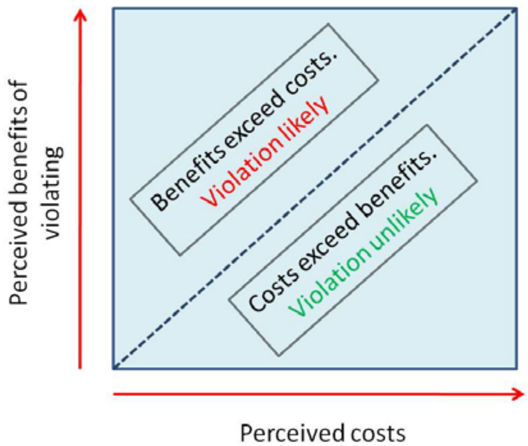

Figure 8-8: Relationship of benefits to cost of violations

Unlike errors, violations are deliberate acts. People weigh up the costs and benefits of an act of non-compliance and when the benefits exceed the possible costs they are likely to violate. The effects of 'mental economies' have been shown in a wide variety of work and everyday situations.

8.13 The violation 'balance sheet'

Perceived benefits	Perceived costs
✈ Easier way of working	✈ Accident to aircraft
✈ Saves time	✈ Injury to self or others
✈ More exciting	✈ Damage to assets
✈ Gets the job done	✈ Costly to repair
✈ Shows skill	✈ Sanctions / punishments
✈ Meets a deadline	✈ Loss of job / promotion
✈ Looks macho	✈ Disapproval of friends

Benefits are immediate.
Costs are remote from experience, and - in the case of accidents - seem unlikely.
Table 8-1: Perceived benefits and Perceived costs of violations

Table 8.1 shows the factors that might lie on the plus and minus sides of the mental balance sheet relating to violations.

For many acts of non-compliance, however, experience shows that violating is an easier way of working and brings no obvious bad effects. In short, the benefits of non-compliance are often seen to outweigh the costs.The challenge here is not so much to increase the costs of violating (by stiffer penalties, etc.) but to try to increase the perceived benefits of compliance. And that means having procedures that are workable and that describe what are obviously the quickest and most efficient ways of doing the job. Any lack of trust caused by inappropriate or clumsy procedures will increase the perceived benefits of violating. Indeed, some jobs can only be done by deviating from the procedures.

8.13.1 Why people violate good rules

- "I can handle it."
- "I can get way with it."
- "I can't help it."
- "Everyone does it."
- "It's what they want."
- "They'll turn a blind eye."

These are some of the beliefs that lead people to violate. A number of them relate to the widely held attitude that violating is the prerogative of the skilled person. Their skill shows them how to bend the rules and get away with it.

Other beliefs have to do with the fact that violations may be going on all over the worksite. Consequently people feel powerless to avoid them. Indeed, they might feel that violations are expected of them. They may also be aware that managers turn a blind eye to violations that get the job done and so meet tight deadlines.

8.13.2 Bad procedures

- Violations are only half the problem.
- The other half (or more) arises from bad procedures.
- In the nuclear power industry, 67% of all human performance problems have been traced to bad (incorrect, absent or unworkable) procedures.

It would be a mistake to think that most violations were due to bloody-mindedness on the part of the workforce. As we have already seen, situational or necessary violations arise because

a. People want to get the job done,

b. The tools or the situation make it impossible to do the job when following the procedures to the letter.

In the nuclear industry, for example, nearly 70 per cent of all human performance problems have been traced to bad procedures. That is, procedures that gave the wrong information, or were inappropriate or unworkable in the present situation, or were not known about, or were out of date, or that could not be found, or that could not be understood, or that simply had not been written to cover this job.

Bad, absent or unworkable documentation is not a monopoly of the nuclear power industry.

8.13.3 Situational factors

- Time pressure
- High workload
- Unworkable procedures
- Inadequate equipment
- Bad working conditions

- ✈ Supervisors turn blind eye

These are some of the situational factors that promote violations. Several of the factors also crop up on the list of local error-producing factors.

Removing or moderating these local error- and violation-producing factors is a major part of managing unsafe acts.

8.13.4 Use of informal procedures ('black books')

- ✈ Operators (56%)
- ✈ Managers (51%)

In many highly-proceduralised industries, it is common for the workforce to write their own procedures as to how jobs should be done. These are jealously guarded and passed on to new members of the workgroup. They are generally known as 'black books'.

Notice from the list above that over half of both operators and managers use these 'black books'.

8.14 Reasons for not following procedures

- ✈ If followed to the letter, job wouldn't get done.
- ✈ People are not aware that procedure exists.
- ✈ People prefer to rely on own skills and experience.
- ✈ People assume they know what is in the procedure.

These are some the reasons given why workers for not following procedures. These are universal reasons for not following procedures and manuals. Any attempt at improving compliance must address these problems.

8.15 Violation types

Here we have a preliminary break down of violation types:

- ✈ Corner-cutting-or routine violations-are committed to avoid unnecessary effort or to circumvent clumsy or inappropriate procedures.
    - o Cutting corners: Example
        - B747 was about to make first flight after servicing in which oil lines on one engine had been changed.
        - Finding oil leaks on engine run, technicians tightened suspect oil lines.
        - Skipped additional engine run because tug had arrived.
        - Tech's followed a/c to terminal where they performed an engine dry spin. No oil leaks were found.
        - Oil leak from engine caused IFSD and diversion.
- ✈ Thrill-seeking or optimising violations are committed for 'kicks' or to avoid boredom.
    - o Most obvious examples are to be found in the handling of vehicles: speeding, cutting in, tail-gating, 'road rage', etc.
    - o We do these things for the 'joy of speed' or to let out angry feelings.

- Many towing and ground contact accidents are due to thrill-seeking.
- Males violate more than females, the young violate more than the old. Similar differences not found for errors.

- Violations to get the job done-or necessary violations-occur in circumstances where it is impossible to get the job done by sticking to the rules.
  - Getting job done: Example

8.15.1 How violations differ from errors

Errors	Violations
Errors are unintended	Violations are deliberate (the act not the occasional bad consequences)
Errors arise from information problems	Violations are shaped mainly by attitudes, beliefs, group norms and safety culture

The distinction between errors and violations depends upon the following factors:

- **Intentionality**: We do not generally intend to make slips, lapses or mistakes. Except when they have become so routinised as to be automatic, people do generally intend to commit the actions that deviate from procedures. It is important to note, however, that while they may intend the non-compliant actions, they do not generally intend the occasionally bad consequences. Only saboteurs intend both the act and its bad consequences.
- **Information versus motivation**: Errors arise as the result of informational problems, either in the head or in the world. In short, errors arise from informational problems and are generally corrected by improving the information, either in the person's head or in the workplace. Violations, on the other hand, arise largely from motivational factors, from beliefs, attitudes, norms and from the organisational culture at large. These are the things that need to be fixed if we are to reduce the non-compliance to good rules.
- **Demographics**: Men violate more than women and the young violate more than the old. The same does not apply to errors.

8.16 Errors Due to Individual Practices and Habits

Where procedures allow some leeway, aircraft maintenance engineers often develop their own **strategies** or preferred way of carrying out a task. Often, a 'good' rule or principle is one that has been used successfully in the past. These good rules become **'rules of thumb'** that an engineer might adopt for day-to-day use. Problems occur when the rule or principle is wrongly applied. For example, aircraft pipe couplings are normally right hand threads but applying this 'normally good rule' to an oxygen pipe (having a different thread) could result in damage to the pipe. Also, there can be dangers in applying rules based on previous experience if, for example, design philosophy differs, as in the case of Airbus and Boeing. This may have been a factor in an A320 locked spoiler incident, where subtle differences between the operation of the spoilers on the A320 and those of the B767 (with which the engineers were more familiar) meant that actions which would have been appropriate on the B767 were inappropriate in the case of the A320.

In addition, engineers may pick up some 'bad rules', leading to **bad habits** during their working life.

8.17 Errors Associated With Visual Inspection

There are also two particular types of error which are referred to particularly in the context of visual inspection, namely **Type 1** and **Type 2 errors**:

- **Type 1 error** occurs when a good item is incorrectly identified as faulty. Type 1 errors are not a safety concern per se, except that it means that resources are not being used most effectively, time being wasted on further investigation of items which are not genuine faults.
- **Type 2 error** occurs when a faulty item is missed. Type 2 errors are of most concern since, if the fault (such as a crack) remains undetected, it can have serious consequences (as was the case in the Aloha accident, where cracks remained undetected).

8.18 Reason's Study of Aviation Maintenance Engineering

Reason analysed the reports of 122 maintenance incidents occurring within a major airline over a 3 year period. He identified the main causes as being:

- Omissions (56%)
- Incorrect installation (30%)
- Wrong parts (8%)
- Other (6%)

It is likely that Reason's findings are representative for the aircraft maintenance industry as a whole. Omissions can occur for a variety of reason, such as forgetting, deviation from a procedure (accidental or deliberate), or due to distraction. The B737 double engine oil loss incident, in which the HP rotor drive covers were not re-fitted is an example of omission. Incorrect installation is unsurprising, as there is usually only one way in which something can be taken apart but many possible ways in which it can be reassembled. Reason illustrates this with a simple example of a bolt and several nuts (see Figure 8.10), asking the questions:

a) how many ways can this be disassembled? (the answer being 1) and

b) how many ways can it be reassembled? (the answer being about 40,000, excluding errors of omission!).

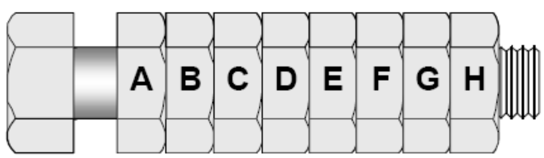

Figure 8-9: Reason's Bolt and Nuts Example.

In the BAC1-11 accident in June 1990, the error was fitting the wrong bolts to the windscreen. This illustrates well the category of 'wrong parts'.

8.19 Implications of Errors (i.e. Accidents)

In the worst cases, human errors in aviation maintenance can and do cause aircraft accidents. However, as portrayed in Figure 8.11, accidents are the observable manifestations of error. Like an iceberg which has most of its mass beneath the water line, the majority of errors do not result in actual accidents.

Figure 8-10: The "Iceberg Model" of Accidents

Thankfully, most errors made by aircraft maintenance engineers do not have catastrophic results. This does not mean that this might not be the result should they occur again.

Errors that do not cause accidents but still cause a problem are known as **incidents!** This subject was introduced at the beginning of this document in Chapter 1, "Incidents Attributable To Human Factors / Human Error", which gave examples of aviation incidents relating to aircraft maintenance errors. Some incidents are more high profile than others, such as errors causing significant in-flight events that, fortuitously, or because of the skills of the pilot, did not become accidents. Other incidents are more mundane and do not become serious because of **defences** built into the maintenance system. However, all incidents are significant to the aircraft maintenance industry, as they may warn of a potential future accident should the error occur in different circumstances. As a consequence, all maintenance incidents have to be reported to the UK Civil Aviation Authority **Mandatory Occurrence Reporting Scheme** (MORS). These data are used to disclose trends and, where necessary, implement action to reduce the likelihood or criticality of further errors. In the UK, the **Confidential Human Factors Incident Reporting Programme** (CHIRP) scheme provides an alternative reporting mechanism for individuals who want to report safety concerns and incidents confidentially.

It is likely that the greatest proportion of errors made by aircraft maintenance engineers are spotted almost immediately they are made and corrected. The engineer may detect his own error, or it may be picked up by colleagues, supervisors or quality control. In these cases, the engineer involved should (it is hoped) learn from his error and therefore (it is hoped) be less likely to make the same error again.

It is vital that aircraft maintenance engineers learn from their own errors and from the errors made by others in the industry. These powerful and persuasive lessons are the positive aspects of human error.

When an error occurs in the maintenance system of an airline, the engineer who last worked on the aircraft is usually considered to be 'at fault[1]. The engineer may be reprimanded, given remedial training or simply told not to make the same error again. However, **blame** does not necessarily act as a positive force in aircraft maintenance: it can discourage engineers from 'coming clean' about their errors. They may cover up a mistake or not report an incident. It may also be unfair to blame the engineer if the error results from a failure or weakness inherent in the system which the engineer has accidentally discovered (for example, a latent failure such as a poor procedure drawn up by an aircraft manufacturer - possibly an exceptional violation).

The UK Civil Aviation Authority has stressed in CAAIP Leaflet 11-50 (previously published as Airworthiness Notice No. 71) that it *"seeks to provide an environment in which errors may be openly investigated in order that the contributing factors and root causes of maintenance errors can be addressed".* To facilitate this, it is considered that an unpremeditated or inadvertent lapse should not incur any punitive action, but a breach of professionalism may do so (e.g. where an engineer causes deliberate harm or damage, has been involved previously in similar lapses, attempted to hide their lapse or part in a mishap, etc.).

8.20 Avoiding and Managing Errors

Whilst the aircraft maintenance engineering industry should always strive towards ensuring that errors do not occur in the first place, it will never be possible to eradicate them totally. Therefore all maintenance organisations should aim to **'manage' errors.**

Error management seeks to:

- prevent errors from occurring;
- eliminate or mitigate the bad effects of errors

Reason refers to the two components of error management as:

- error containment
- error reduction.

To prevent errors from occurring, it is necessary to predict where they are most likely to occur and then to put in place preventative measures. Incident reporting schemes (such as MORS) do this for the industry as a whole. Within a maintenance organisation, data on errors, incidents and accidents should be captured with a **Safety Management System** (SMS).

This should provide mechanisms for identifying potential weak spots and error-prone activities or situations. Output from this should guide local training, company procedures, the introduction of new defences, or the modification of existing defences.

According to Reason, error management includes measure to:

- minimise the error liability of the individual or the team;
- reduce the error vulnerability of particular tasks or task elements;
- discover, assess and then eliminate error-producing (and violation-producing) factors within the workplace;
- diagnose organisational factors that create error-producing factors within the individual, the team, the task or the workplace;
- enhance error detection;
- increase the error tolerance of the workplace or system;
- make latent conditions more visible to those who operate and manage the system;
- improve the organisation's intrinsic resistance to human fallibility.

It would be very difficult to list all means by which errors might be prevented or minimised in aircraft maintenance. In effect, the whole of this document discusses mechanisms for this, from ensuring that individuals are fit and alert, to making sure that the hangar lighting is adequate.

One of the things likely to be most effective in preventing error is to make sure that engineers follow procedures. This can be effected by ensuring that the procedures are correct and usable, that the means of presentation of the information is user friendly and appropriate to the task and context, that engineers are encouraged to follow procedures and not to cut corners.

Ultimately, maintenance organisations have to compromise between implementing measures to prevent, reduce or detect errors, and making a profit. Some measures cost little (such as renewing light bulbs in the hangar); others cost a lot (such as employing extra staff to spread

workload). Incidents tend to result in short term error mitigation measures but if an organisation has no incidents for a long time (or has them but does not know about them or appreciate their significance), there is a danger of **complacency** setting in and cost reduction strategies eroding the defences against error. Reason refers to this as "the unrocked boat" (Figure 8.12).

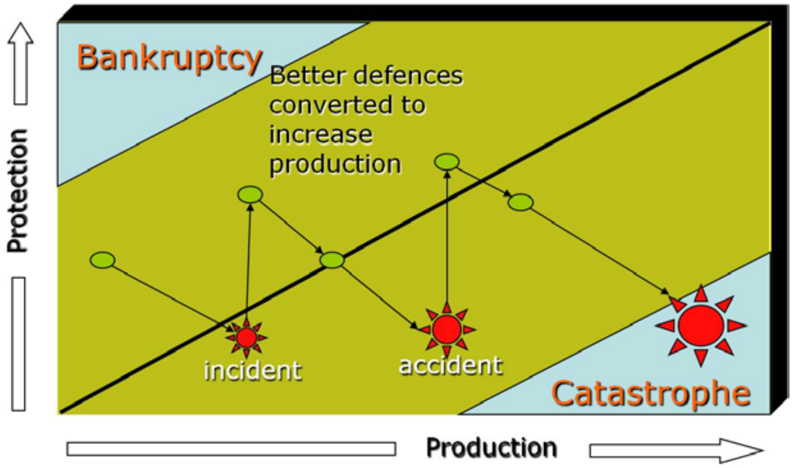

Figure 8-11: The lifespan of a hypothetical organisation through the production – protection space.

It is important that organisations balance profit and costs, and try to ensure that the defences which are put in place are the most cost-effective in terms of trapping errors and preventing catastrophic outcomes.

Ultimately, it is the responsibility of each and every aircraft maintenance engineer to take every possible care in his work and be vigilant for error (see Chapter 3). On the whole, aircraft maintenance engineers are very conscious of the importance of their work and typically expend considerable effort to prevent injuries, prevent damage, and to keep the aircraft they work on safe.

8.21 Error Management

The purpose is to provide maintenance organisations with a sense of what techniques are available to deal with 'here and now' human performance problems. It is not definitive. It merely provides a sample of what is being used in airline engineering organisations in various parts of the world. Details are given to enable you to follow up on techniques that you feel could be useful in your company.

It must be stressed that an effective Error Management system involves the whole organisation. Human Factors and Error Management training is not just for those who get their hands dirty. All the modules are designed to be suitable for all levels of the system. Comprehension and the judged relevance of this kind of training material has been trialled successfully in a number of aircraft maintenance organisations (British Airways Engineering, Singapore Airlines Engineering Company, Cathay Pacific).

There is no one best Error Management system. Different mixes of techniques and practices suit different organisations. What this package offers is a set of guiding principles for error management and a 'shopping list' of measures and techniques for managing error at different levels of the system. Of course, another way of looking at this catalogue is as a spur to creating your own home-grown Error Management system.

8.21.1 Eight reasons to have an Error Management system

- Flightdeck windscreen blowout, BAC 1-11
- Inflight structural break-up, Embraer 120
- Engine and pylon broke away, B747-258
- Un-commanded roll on takeoff, A320
- Engine drop on landing, B747-251
- Oil loss on both engines, B737-400
- Static ports covered with tape, B757-23A
- Oxygen generator fire, DC9-32

They have been selected for two reasons:

- **First,** they illustrate a range of initiating errors.
- **Second,** they demonstrate a variety of system failures that allowed these errors to go undetected.

8.21.2 Maintenance error accidents:

- BAC 1-11 (6/90): Left windscreen blown out at 17,300 ft. The Captain half sucked out of a/e. Window installed with wrong bolts.
- Embraer 120 (9/91): Fatal crash due to in-flight loss of a partially secured de-ice boot on left leading edge of horizontal stabiliser. Upper attachment screws missing.
- B747-258 (10/92): # 3 engine and pylon separated from wing. Fuse pin fatigue. Probable cause: System to ensure structural integrity by inspection failed.

  The B747 accident occurred shortly after takeoff on 4 October 1992. As the aircraft was climbing through 6500 ft, the no. 3 engine and pylon separated from the wing and collided with the no. 4 engine which was torn off. The flight crew declared a mayday and requested a return to runway 27. However, the leading edge of the wing was severely damaged and the use of several important flight systems was lost or limited. The aircraft crashed into a high-rise building. Two primary causes:

  - The design and certification of the B747 was found to be inadequate to provide the required level of safety.
  - The system to ensure structural integrity by inspection failed. The event was probably initiated by fatigue in the inboard midspar fuse-pin on the no. 3 engine and pylon.

- A320-212 (8/93): Undemanded roll to right on takeoff. Re-instatement and functional check of the spoilers after flap fitment was not carried out.
- B757-23A (10/96): Three static ports on left side obstructed by masking tape. Tape had been applied before washing and polishing of aircraft prior to crash flight.

  The B757 took off at 12.42 on 2 October 1996. Five minutes later, the crew reported instrument problems and requested a return to the airport. During the initial climb the airspeed and altitude indications were too low and a windshear warning sounded in calm winds. On its return, the aircraft kept descending and impacted the water with the left wing. Preliminary investigation of the wreckage found masking tape blocking three static ports on the left side. They had been applied before washing and polishing of the aircraft prior to the accident flight.

- DC9-32 (5/96): Fire in cargo compartment due to actuation of oxygen generator(s). Among the causes. **Failure to oversee contract maintenance programme**.

  Six minutes after takeoff on 11 May 1996, the aircraft dropped 815 ft and the IAS decreased 34 kts in 3 seconds. Shortly after smoke filled the cockpit. Subsequently, the aircraft crashed into the Everglades killing all on board. In the cargo hold were boxes containing oxygen generators. The accident investigators concluded that accident was due to:

  - Failure prepare, package, identify and track unexpended chemical oxygen generators before handing them over to the airline.
  - Failure of the airline to properly oversee its contract maintenance programme.
  - Failure of the Regulator to require smoke detection and fire suppression systems in Class D cargo compartments. The regulator also failed to monitor the airline's contracted maintenance program.

8.21.3 Two common elements of these accidents

- Various unsafe acts and/or equipment states that jeopardised the airworthiness of the aircraft.
- A failure of the system to detect and rectify these dangerous conditions before the aircraft was released to the line.

When we hear of maintenance-related accidents such as these, we naturally assume that the primary fault lies with the individual maintainer(s) at the sharp end, the person or people who actually touched the aircraft. True, these form an important part of the accident sequence, but they are only the initiating events. For them to have had a bad outcome, it means that the system's defences, barriers and safeguards failed as well. No accident is the sole responsibility of a single maintainer. We can never eliminate human error, but we can always improve the systems designed to check and correct errors. As we shall see later, systems are easier to manage than people-assuming, as is generally the case, that we have a competent and well-motivated workforce.

> YOU CAN'T CHANGE THE HUMAN CONDITION, BUT YOU CAN CHANGE THE CONDITIONS UNDER WHICH PEOPLE WORK.

8.22 Error management: What do you aim for?

How do you best reduce errors and limit their bad effects. They are four possible target areas: the person, the task, the workplace and the organisation as a whole. Most organisations aim for the person because they believe that people are more changeable than situations.

Figure 8-12: Most organisations go for the person

Typical responses to engineering quality lapses are as follows:-

Blame and train: 'Carpet' the error-maker, or discipline him, or tell him to be more careful, and then, if necessary, send him for retraining.

Write another procedure: All industries tend to write procedures to prohibit actions that have been implicated in some event or incident. The result is that the range of permitted actions is often less than the range of actions necessary to get the job done.

Search for the 'missing piece': When these measures fail (and they usually do), managers start looking for psychological ways of finding the piece that will remove violations and errors. Somewhere out there, they think, is a psychologist who can come up with the 'magic bullet' solution.

Comprehensive Error Management, however, prefers to focus most of its efforts on:

- Identifying and correcting error-prone tasks
- Improving error-producing work situations
- Identifying and correcting latent organisational conditions.

8.23 Summary: Managing the manageable

- Fallibility is part of the human condition.
- We are not going to change the human condition.
- But we can change the conditions under which people work.

"Changing situations is more effective than trying to change human nature."

Errors are like mosquitoes in at least two important ways:

- First, they are hard to deal with one by one.
- Second, they have their origins elsewhere: in the swamps and marshes in which they breed. In the case of maintenance, the 'swamps and marshes' are the workplace and organisational problems that give rise to unsafe acts. Dealing with these latent conditions goes beyond the 'here and now' and limits the chances of future generations of errors threatening the safety of your aircraft.

You can swat them and spray them

You can deal with errors one by one, but it is inefficient and ineffective. Swatting them and spraying them kills individual mosquitoes. But it is usually too late. By the time they have been discovered, they have already caused harm. And, in any case, once you have disposed of the immediate problems, there are still many more mosquitoes coming to bite you. Dealing with isolated errors is like dealing with the visible symptoms rather than with the underlying disease. To do this, we have to look into the future and ask: From where are our next problems likely to come? And what can we do to thwart them before they cause damage and losses?

The only effective measures are:

- To drain the swamps in which they breed.
- And to use various proven defences:
  - mosquito netting
  - mosquito repellent
  - quinine-based pills, etc.

With errors as with mosquitoes, it is crucial to deal with the problem at source. One way is to remove the 'swamps and marshes' in the workplace and in the system at large. The other is to erect ever more effective defences. The ones listed above have shown themselves effective against mosquitoes. What can you do that is equally effective against future unsafe acts?

In the case of maintenance errors...

- The 'swamps' are task, workplace and organisational factors that provoke errors.
- The defences are system safeguards and barriers that detect and recover errors before they can have a bad outcome.
- Both of these go to make up an effective HERO (Human Error Reduction Operation).

The future-directed measures in the HERO toolbox are aimed at identifying and removing 'swamps' and at creating more effective defences against those errors that will inevitably escape these measures.

Focusing on individual errors is like the futility of dealing with errors one by one. In the first place, the damage has usually been done. And, in the second, it is a waste of limited error management resources. Here, you can take the swatter and the spray can as being equivalent to disciplining someone for an error he or she did not intend to commit.

Changing the future means:

- ✈ **Learning the right lessons from past incidents**: Not 'who's to blame?' but what were the task, workplace and organisational factors that contributed to the incident?
- ✈ **Identifying task, workplace and organisational problems that could combine to cause some future incident or accident**. Being proactive as well as reactive.

To use the mosquito analogy again, there are two ways of dealing with the underlying and fundamental problems. One way is to trace mosquitoes (errors) back to their point of origin - to their breeding grounds - and then eliminate them. The other is to use this knowledge to destroy potential breeding grounds before they create problems.

In what follows, we will review a variety of techniques currently in use in the world's airline maintenance facilities. Some of them start with an event and then work back into the system to identify and remove their fundamental causes. Others involve regular system 'health checks' in which potential problems are identified and corrected before they cause trouble.

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9 Boeing Maintenance Error Decision Aid (MEDA)

9.1 Human Factors Process for Reducing Maintenance Errors

Since the introduction of Maintenance Error Decision Aid (MEDA) by Boeing, a growing number of maintenance organizations for Boeing-designed airplanes have adopted MEDA, which is a tool for investigating the factors that contribute to maintenance errors. MEDA provides a comprehensive approach for conducting thorough and consistent investigations, determining the factors that lead to an error, and making suggested improvements to reduce the likelihood of future errors.

Maintenance errors cost operators of commercial airplanes millions of dollars each year in rework and lost revenue, and present potential safety concerns. For example, aviation industry studies indicate that as many as 20 percent of all in-flight engine shut downs and up to 50 percent of all engine-related flight delays and cancellations can be traced to maintenance error. In response, Boeing developed the MEDA process to help maintenance organizations identify why these errors occur and how to prevent them in the future. Successful implementation of MEDA requires an understanding of the following:

1. The MEDA philosophy.
2. The MEDA process.
3. Management resolve.
4. Implementing MEDA.
5. The benefits of MEDA.

9.2 The MEDA Philosophy

Traditional efforts to investigate errors are often aimed at identifying the employee who made the error. The usual result is that the employee is defensive and is subjected to a combination of disciplinary action and recurrent training (which is actually retraining). Because retraining often adds little or no value to what the employee already knows, it may be ineffective in preventing future errors. In addition, by the time the employee is identified, information about the factors that contributed to the error has been lost. Because the factors that contributed to the error remain unchanged, the error is likely to recur, setting what is called the "blame and train" cycle in motion again.

To break this cycle, MEDA was developed in order to assist investigators to look for the factors that contributed to the error, rather than concentrate upon the employee who made the error. The MEDA philosophy is based on these principles:

- Positive employee intent (maintenance technicians want to do the best job
- possible and do not make errors intentionally).
- Contribution of multiple factors (a series of factors contributes to an error).
- Manageability of errors (most of the factors that contribute to an error can be managed).

9.2.1 POSITIVE EMPLOYEE INTENT

This principle is key to a successful investigation. Traditional "blame and train" investigations assume that errors result from individual carelessness or incompetence. Starting instead from the assumption that even careful employees can make errors, MEDA interviewers can gain the active participation of the technicians closest to the error. When technicians feel that their competence is not in question and that their contributions will not be used in disciplinary actions against them or their fellow employees, they willingly team with investigators to identify the factors that contribute to error and suggest solutions. By following this principle, operators can replace a negative "blame and train" pattern with a positive "blame the process, not the person" practice.

9.2.2 CONTRIBUTION OF MULTIPLE FACTORS

Technicians who perform maintenance tasks on a daily basis are often aware of factors that can contribute to error. These include information that is difficult to understand, such as work cards or maintenance manuals; inadequate lighting; poor communication between work shifts; and aircraft design. Technicians may even have their own strategies for addressing these factors. One of the objectives of a MEDA investigation is to discover these successful strategies and share them with the entire maintenance operation.

9.2.3 MANAGEABILITY OF ERRORS

Active involvement of the technicians closest to the error reflects the MEDA principle that most of the factors that contribute to an error can be managed. Processes can be changed, procedures improved or corrected, facilities enhanced, and best practices shared. Because error most often results from a series of contributing factors, correcting or removing just one or two of these factors can prevent the error from recurring.

9.2.4 Maintenance Errors

After conducting a study of maintenance sites in the United Kingdom in 1992, the British Civil Aviation Authority compiled the following list of the most commonly occurring maintenance errors:

- Incorrect installation of components.
- Fitting of wrong parts.
- Electrical wiring discrepancies.
- Loose objects left in airplane.
- Inadequate lubrication.
- Access panels, fairings, or cowlings not secured.
- Fuel or oil caps and fuel panels not secured.
- Gear pins not removed before departure.

9.3 The MEDA Process

To help maintenance organizations achieve the dual goals of identifying factors that contribute to existing errors and avoiding future errors, Boeing initially worked with British Airways, Continental Airlines, United Airlines, a maintenance workers' labour process for operators to follow

- Event.
- Decision.
- Investigation.
- Prevention strategies.
- Feedback.

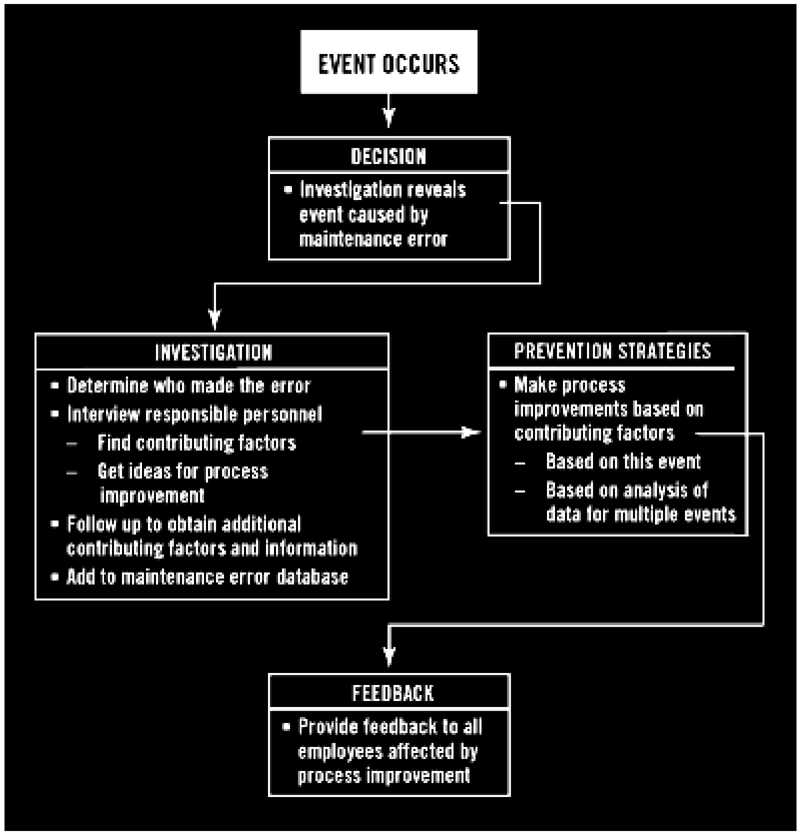

Figure 9-1: MEDA process flow chart

9.3.1 EVENT

An event occurs, such as a gate return or air turn back. It is the responsibility of the maintenance organization to select the error-caused events that will be investigated.

9.3.2 DECISION

After fixing the problem and returning the airplane to service, the operator makes a decision: Was the event maintenance-related? If yes, the operator performs a MEDA investigation.

9.3.3 INVESTIGATION

Using the MEDA results form, the operator carries out an investigation. The trained investigator uses the form to record general information about the airplane, when the maintenance and the event occurred, the event that began the investigation, the error that caused the event, the factors contributing to the error, and a list of possible prevention strategies.

9.3.4 PREVENTION STRATEGIES

The operator reviews, prioritises, implements, and then tracks prevention strategies (process improvements) in order to avoid or reduce the likelihood of similar errors in the future.

9.3.5 FEEDBACK

The operator provides feedback to the maintenance workforce so technicians know that changes have been made to the maintenance system as a result of the MEDA process. The operator is responsible for affirming the effectiveness of employees' participation and validating their contribution to the MEDA process by sharing investigation results with them.

- ✈ Event Occurs

- ✈ Investigation Finds that Event Was Caused by Mechanic Inspector Performance
- ✈ Find the Maintenance Mechanic or Inspector Who Did the Work
- ✈ Interview Person
  - o Find Contributing Factors
  - o Get Ideas for Process Improvement
- ✈ Carry out Follow-Up Interviews, as Necessary, in Order to Get All Relevant Contributing Factors Information
- ✈ Add the Results Form Investigation Information to a Maintenance Event Data Base
- ✈ Make Process Improvements
  - o Based on This Event
  - o Based on Data from
- ✈ Provide Feedback to All Employees Affected by the Process Improvements

9.4 Management Resolve

The resolve of management at the maintenance operation is key to successful MEDA implementation. Specifically, after completing a program of MEDA support from Boeing, managers must assume responsibility for the following activities before starting investigations:

MEDA is a long-term commitment, rather than a quick fix. Operators new to the process are susceptible to "normal workload syndrome". This occurs once the enthusiasm generated by initial training of investigation teams has diminished and the first few investigations have been completed. In addition to the expectation that they will continue to use MEDA, newly trained investigators are expected to maintain their normal responsibilities and workloads. Management at all levels can maintain the ongoing commitment required by providing systematic tracking of MEDA findings and visibility of error and improvement trends.

9.5 Implementing MEDA

Many operators have decided to use MEDA initially for investigations of serious, high-visibility events, such as in-flight shut downs and air turn backs. It is easy to track the results of such investigations, and the potential "payback" is very noticeable.

In contrast, according to David Hall, deputy regional manager in the British Civil Aviation Authority (CAA) Safety Regulation Group, a high-visibility event may not present the best opportunity to investigate error. The attention of operators' upper management and regulatory authorities could be intimidating to those involved in the process. In addition, the intensity of a high-level investigation may generate too many possible contributing factors to allow a clear-cut investigation of the event.

Hall has recommended that operators look at the broader potential for improvement by using MEDA to track the cumulative effects of less-visible errors. Providing management visibility of the most frequently occurring errors can, in the long run, produce profound improvements by interrupting the series of contributing factors. According to Dr. Jim Reason, professor of psychology at the University of Manchester, MEDA is "a good example of a measuring tool capable of identifying accident-producing factors before they combine to cause a bad event."

9.6 Benefits

About 60 operators have already implemented some or all of the MEDA process. Participating airlines have reported several benefits, including the following improvements:

- ✈ A 16 percent reduction in mechanical delays.
- ✈ Revised and improved maintenance procedures and airline work processes.

- A reduction in airplane damage through improved towing and headset procedures.
- Changes in the disciplinary culture of operations.
- Elimination of an engine servicing error by purchasing a filter-removal tool that had not previously been available where the service was being performed.
- Improvements in line maintenance workload planning.
- A program to reduce on-the-job accidents and injuries based on the MEDA results form and investigation methods.

9.7 Summary

The Maintenance Error Decision Aid (MEDA) process offered by Boeing continues to help operators of airplanes identify what causes maintenance errors and how to prevent similar errors in the future. Because MEDA is a tool for investigating the factors that contribute to an error, maintenance organizations can discover exactly what led to an error and remedy those factors. By using MEDA, operators can avoid the rework, lost revenue, and potential safety problems related to events caused by maintenance errors.

See Addendum II: Completing MEDA Form

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Chapter 10. Hazards in the Workplace

10 Introduction

Hazards in the workplace tend to be a **health and safety** issue, relating to the protection of individuals at work. All workplaces have hazards and aircraft maintenance engineering is no exception. Health and safety is somewhat separate from human factors and this chapter therefore gives only a very brief overview of the issues relating the aircraft maintenance engineering.

10.1 Recognising and Avoiding Hazards

10.1.1 Potential Hazards in Aircraft Maintenance Engineering

There are many potential hazards in the aircraft maintenance industry and it is impossible to list them all here. However, a thorough health and safety appraisal will reveal the hazards. Physical hazards may include:

- very bright lights (e.g. from welding);
- very loud sounds (sudden or continuous);
- confined or enclosed areas;
- working at significant heights;
- noxious substances (liquids, fumes, etc.);
- excessive temperature (i.e. too cold or too hot);
- moving equipment, moving vehicles and vibration.

Many of these have been addressed earlier in this document (e.g. Chapter 5 "Physical Environment").

10.2 Relevant Legislation and the Maintenance Organisation's Responsibilities

The UK Health and Safety Executive (HSE) have responsibility for overseeing safety in the workplace. The **Health and Safety at Work Act 1974** and accompanying Regulations are the relevant legislation and the HSE produce publications and leaflets summarising various aspects. The Health and Safety at Work Act 1974 places a responsibility on employers to produce a written statement of general policy with respect to the Health and Safety at Work of its employees. The employer is also obliged to bring to the notice of all its employees this policy together with the organisation and arrangements in force for carrying out that policy. Thus, in an aircraft maintenance organisation, the **health and safety policy** might include statements applicable to the organisation such as the need to:

- Carry out assessments of work including inspections to determine Health and Safety risks;
- Provide safe working practices and procedures for plant, machinery, work equipment, materials and substances;
- Inform employees and other persons including temporary workers of any risk;
- Provide suitable training and/or instruction to meet any Health and Safety risks;
- Develop and introduce practices and procedures to reduce risks to Health and Safety including the provision of special protective devices and personal protective equipment;
- Provide for the welfare of employees;

- Discuss with and consult employee representatives on Health and Safety matters.

Maintenance organisations should appoint someone with health and safety responsibilities.

In brief, a maintenance organisation has a duty under health and safety legislation to:

- identify hazards in the workplace;
- remove them where possible;
- mitigate the risks to employees.

If hazards cannot be removed from the workplace, employees should be made aware that they exist and how to avoid them. This can be effected through training and warning signs. To be effective, warnings signs must:

- clearly identify the hazard(s);
- describe the danger (i.e. electric shock, radiation, etc);
- inform employees what to do or not to do.

The sign must attract an engineer's attention, it must be visible and it must be understandable to the people it is aimed at. Additionally, in the maintenance industry, it must be durable enough to remain effective, often for years, in areas where dust and the elements can be present.

Positive recommendations are more effective than negative ones. For example, the statement "Stay behind yellow line on floor" is better than "Do not come near this equipment". Warning signs should contain a single word indicating the degree of risk associated with the hazard: DANGER denotes that the hazard is immediate and could cause grave, irreversible damage or injury. CAUTION indicates a hazard of lesser magnitude. The sign should also detail how to avoid or manage the risk.

CAUTION signs are generally yellow and black.

DANGER signs use red, black and white.

Figure 10-1: "Caution" and "Danger" signs

10.3 Engineer's Individual Responsibilities

The legislation notes that every individual in a workplace also has health and safety responsibilities.

Every aircraft maintenance engineer should be aware that he can influence the safety of those with whom he works.

Thus, in an aircraft maintenance organisation, the **health and safety policy** might include statements applicable to engineers such as the need to:

- Take reasonable care of the health and safety of themselves and others who may be affected by their acts or omissions at work;
- Co-operate with the maintenance organisation to ensure that statutory requirements concerning health and safety at work are met;

- ✈ Work in accordance with any safety instruction and/or training received;
- ✈ Inform their supervisor or management of work situations that represent an immediate or potential danger to health and safety at work and any shortcomings in protection arrangements;
- ✈ Not interfere intentionally or recklessly with, nor misuse, anything provided in the interests of health and safety.

The attitude of an individual engineer, team or maintenance organisation (i.e. **organisational culture)** can have a significant impact on health and safety. Individuals who display an anti-authority attitude, are impulsive, or reckless are a danger in aircraft maintenance.

10.4 Safety in the Working Environment

Engineers should ensure that they keep the working environment safe. Clutter, rubbish, etc. is not only a nuisance to others, but can constitute a danger (e.g. a trip hazard, fire hazard, etc.). In addition, engineers should be careful when working on the line not to leave objects when a job has been completed. Foreign Object Damage (FOD) is a risk to aircraft operating at an airfield.

10.5 Safety When Working On Aircraft

Before operating or working on aircraft system, an engineer should carry out clearance checks around moveable surfaces (e.g. flying controls, landing gear, flaps, etc.). Deactivation procedures should be followed (e.g. pull circuit breakers, isolate valves, disconnect power, etc.). Notification of deactivation through the provision of adequate placard in key locations is essential to inform others of system status.

10.6 Dealing with Emergencies

Careful handling of health and safety in the maintenance environment should serve to minimise risks. However, should health and safety problems occur, all personnel should know as far as reasonably practical how to deal with emergency situations.

Emergencies may include:

- ✈ An injury to oneself or to a colleague;
- ✈ A situation that is inherently dangerous, which has the potential to cause injury (such as the escape of a noxious substance, or a fire).

Appropriate guidance and training should be provided by the maintenance organisation. The organisation should also provide procedures and facilities for dealing with emergency situations and these must be adequately communicated to all personnel. Maintenance organisations should appoint and train one or more first aiders.

The basic actions in an emergency are to:

- ✈ Stay calm and assess the situation;
    - o Observe what has happened;
    - o Look for dangers to oneself and others;
    - o Never put oneself at risk.
- ✈ Make the area safe
    - o Protect any casualties from further danger;
    - o Remove the danger if it is safe to do so;
    - o Be aware of ones own limitations (e.g. do not fight a fire unless it is practical to do so).
- ✈ Assess all casualties to the best of ones abilities (especially if one is a qualified first aider)
- ✈ Call for help
    - o Summon help from those nearby if it is safe for them to become involved;
    - o Call for local emergency equipment (e.g. fire extinguisher);
    - o Call for emergency services (ambulance or fire brigade, etc.).
- ✈ Provide assistance as far *as* one feels competent to.

Emergency drills are of great value in potentially dangerous environments. Aircraft maintenance engineers should take part in these wherever possible. Knowledge of what to do in an emergency can save lives.

10.7 Risk Assessment

A risk assessment is an important step in protecting aircraft maintenance staff, as well as complying with the law. It helps you focus on the risks that really matter in your workplace - the ones with the potential to cause real harm. In many instances, straightforward measures can readily control risks, for example ensuring spillages are cleaned up promptly so people do not slip, or cupboard drawers are kept closed to ensure people do not trip.

The law does not expect you to eliminate all risk, but you are required to protect people as far as 'reasonably practicable'.

This is not the only way to do a risk assessment, there are other methods that work well, particularly for more complex risks and circumstances. However, this method is the most straightforward for most organisations.

10.7.1 What is risk assessment?

A risk assessment is simply a careful examination of what, in your work, could cause harm to people, so that you can weigh up whether you have taken enough precautions or should do more to prevent harm. Workers and others have a right to be protected from harm caused by a failure to take reasonable control measures.

Accidents and ill health can ruin lives and affect your business too if output is lost, machinery is damaged, insurance costs increase or you have to go to court. You are legally required to assess the risks in your workplace so that you put in place a plan to control the risks.

10.7.2 How to assess the risks in your workplace

Follow the five steps:

- ✈ Identify the hazards
- ✈ Decide who might be harmed and how
- ✈ Evaluate the risks and decide on precaution
- ✈ Record your findings and implement them
- ✈ Review your assessment and update if necessary

Don't overcomplicate the process. In many organisations, the risks are well known and the necessary control measures are easy to apply. You probably already know whether, for example, you have employees who move heavy loads and so could harm their backs, or where people are most likely to slip or trip. If so, check that you have taken reasonable precautions to avoid injury.

If you run a small organisation and you are confident you understand what's involved, you can do the assessment yourself. You don't have to be a health and safety expert.

If you work in a larger organisation, you could ask a health and safety adviser to help you. If you are not confident, get help from someone who is competent. In all cases, you should make sure that you involve your staff or their representatives in the process. They will have useful information about how the work is done that will make your assessment of the risk more thorough and effective. But remember, you are responsible for seeing that the assessment is carried out properly.

When thinking about your risk assessment, remember:

a hazard is anything that may cause harm, such as chemicals, electricity, working from ladders, an open drawer etc;

the risk is the chance, high or low, that somebody could be harmed by these and other hazards, together with an indication of how serious the harm could be.

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Chapter 11. Safety and Risk

11 Safety and Risk

11.1 The two faces of safety

- Negative face as revealed by bad events, near misses and the like.
- Positive face = system's intrinsic resistance to its operational hazards.
- Too few bad *outcomes* to steer by.
- We need to measure the *processes* contributing to resistance (or vulnerability)

Most of the time when we speak of 'safety' we are usually referring, either directly or indirectly, to moments of 'unsafely', or their comparative absence over a given period of time. Safety is usually measured in terms of the number of incidents or accidents that occur during a given interval of time, say a six- or twelve-month period. Most technical people like these kinds of measures because they can be quantified fairly easily. But what happens when you start having so few bad events that there is actually more noise present than signal. This is what has happened in the aviation industry. Yes, there are still accidents and maintenance incidents, but they are comparatively few and far between. And they tell you very little about the true safety health of your system.

We cannot always prevent the chance combinations of factors that cause accidents, but we can work to make our organisation less vulnerable to them. This is the true goal of risk management- not zero accidents, an impossible target when gravity, terrain, weather and human error continue to exist - but achieving the maximum degree of resistance to their bad effects.

11.2 Navigating the safety space

The realistic safety goal of every organisation is: to reach the zone of maximum resistance and then stay there for as long as possible. Two things are needed:

- **driving force** supplied by the cultural influences of commitment (a genuine top-level concern with safety issues), competence (the ability to collect, analyse and act upon the right kind of safety-related information) and cognisance (a correct awareness of the dangers), and
- **navigational aids** supplied by both reactive outcome measures (e.g., MEDA) and proactive process measures (e.g., MESH).

11.2.1 Safety is a dynamic non-event

- The fallacy: If we go on doing what we did yesterday, when nothing bad happened, then nothing bad will happen today.
- But that 'nothing bad' was achieved by many different people doing many different things to compensate for disturbances.
- To maintain 'nothing bad', we have to understand exactly what is happening.

11.2.2 The Safety Loop

This shows the main elements of a safety management system. Such systems have proven track records in a wide range of industries. In particular, they bring together the important managerial issues outlined in the previous bullet list.

11.2.3 The Risk Matrix

	Likelihood of Occurrence		
ev er	LOW	MEDIUM	HIGH

HIGH	C	B	A
MEDIUM	D	C	B
LOW	E	D	C

Table 11-1: Variable versus Constant Errors

Risk is calculated as a function of both the likelihood of occurrence and the severity of the likely outcome. The Risk Matrix shown in the table is based upon the one regularly used by British Airways Safety Services in their monthly safety bulletin 'Flywise'.

Five categories of risk are identified:

A: **Severe,** a rare incident requiring the highest priority for resources and action.

B: **High,** incidents of significant concern which take priority over other incidents.

C: **Medium,** incidents requiring the attention and action of a line department.

D: **Low**, an incident of low concern which normally requires no further action.

E: **Minimal,** incidents that are of statistical interest only.

Addendum I: Glossary

Ability	Basic characteristic or quality that an individual brings to a situation. It is the capacity or power to do something. Abilities can be cognitive (e.g. written comprehension, spatial orientation), psychomotor (e.g. reaction time, arm-hand steadiness) or sensory (e.g. vision, colour discrimination, hearing sensitivity).
Accident	ICAO's Definition (Annex 13, chapter 1): "Event linked to the use of an airplane, that occurs between the moment where one person goes on board with the intention to make a flight and the moment where all the persons on board with the same intention are out of the plane, and during which: one person is fatally or seriously injured and/or there is damage to property or equipment, and/or the airplane disappeared or is totally out of reach." Maintenance is not a frequent cause of accidents. It directly contributed (primary cause) to about 6% of accidents (from 1990 to 1999, source: Boeing) and is ranked number 4 in terms of frequency, just after 'Flight crew' (67%), 'Airplane'(11%) and 'Weather' (7%). Aircraft accidents involve multiple causes and contributing factors. Because only single cause coding was used, this statistic is a simplification which gives a good idea about the influence of the categories listed. If we don't focus only on maintenance as a primary cause of accident, a 1995 industry study found that maintenance was a contributing factor in about 15% of the accidents (39 out of 263). But, on average, maintenance related accidents tend to be very serious. As indicated by the statistics (source : Boeing), maintenance was the second highest cause of fatalities related to air accidents, from 1982 to 1991 (1481 fatalities, after CFIT: 2169, and before Loss of control: 1387). 15 % of accident fatalities have been attributed to maintenance in the official accident investigation reports. Note. We have no direct statistics about the number of accidents that have been prevented thanks to maintenance, and this is rather frustrating!
Active failure	Active failures are the errors & violations committed at the 'sharp end' of the system -by the front-line operators (for instance maintenance technicians, pilots). Such unsafe acts are likely to have a direct impact on the safety of the system, and because of the immediacy of their adverse effects, these acts are termed 'active' failures.
Advocacy	The ability to speak in favour of a position, supporting and defending that point of view by means of argument. Providing an explanation or rationale about a preferred option can improve decision making because everyone has to think about the other's proposal. This increases the chances to reject attractive but actually wrong options. Discussing alternatives can also favour insight (the discovery of a new solution).
Anticipation	To plan an action and anticipate the result according to a goal. A good anticipation, planning the action, means that the action itself will be more efficient because you will need less time to act and you will commit less errors. As a result, you will also have more time available to act, to monitor your actions and results, and to continue to anticipate the situation.
Aptitude	Personal characteristic, predictive for the ease of acquiring proficiency in specific tasks through training.
Assertiveness	Affirming, stating and defending what you consider to be right and appropriate in the context. To state your point of view firmly enough, with a calm and clear message, and assuming the responsibilities of your behaviour.
ATA 104	ATA 104 is a US regulation concerning maintenance stating that "safety and human factors related to the subjects should be discussed throughout the course". At Airbus, safety and human factors will be addressed in an integrated manner in your technical training, starting with the MTD 3D briefings of the ATA chapters.
Attention	The deliberate assignment of mental resources to a given subject or object. Vigilance is essential to attention but not enough on its own. In a working situation, attention is mainly guided by a plan of action. *Cf. Vigilance*
Automatic mode of behaviour	Opposite of the conscious mode: it is largely unconscious. We may be aware of the outcome of our action, idea, or perception but not of the process that created it. Limitless in capacity, it is very fast and operates in parallel (many things at once, rather than one thing after another). It is effortless and essential for handling the recurrences of everyday life. Naturally, we prefer to operate in the automatic mode whenever possible.

Automation Philosophy	A general term for a design approach as to how, and to what extent, automation is included in a system. It is, in effect, a strategy for allocation-of-functions. (also automation strategy or automation concept).
Buffer zone	In Rene Amalberti's model of Situation Control: Intermediate amber zone between the green 'in control' safety zone and the red 'losing control' risky zone. The buffer zone sends warning signals that one is starting to lose control. In most cases, losing control can be prevented because specific signals warn us that we are reaching the limits of the control envelope. Errors are warning signs of losing control, alerting the person to adjust the use of their mental resources.
Circadian rhythm	Many biological processes indeed evolve in a sinusoidal way over a period of about 24 hours. This circadian regulation tends to optimize human functional capabilities during the day and decrease them during the night (this is the case for the sleep/wake cycle, the body temperature cycle, the secretion of hormones, blood pressure, etc.)- The situation which results from that combination is thus different in day and night shifts. Maintenance technicians work in shifts, and everyone knows it is harder to work overnight. The explanation comes from the way fatigue combines to the negative effect of the circadian rhythm which is decreasing during the night. See fatigue.
Cognitive skill	Thinking: decision making, problem solving, logical thinking etc.
Communication	Communication involves the transmission of or interchange of information. Communication thus consists of an exchange of messages between one or several transmitters and one or several receivers using one or several modes or 'channels', including speech, writing, gestures, etc. In a larger perspective, communication can be defined as the motivated establishment of a relationship aimed at achieving one or several goals. Communication problems and solutions are reviewed in the course.
Competence	Ability to perform a particular skill or range of skills to a prescribed standard.
Confirmation Bias	Humans have the tendency to look for confirming cues or supporting evidence only. In other words, we tend to look for data that confirm our initial decision, and rarely look for evidence that would show us we are wrong. Because of this so-called "confirmation bias", it is very difficult to change an initial decision.
Conscious mode of behaviour	Opposite of the automatic mode. It is restricted in capacity, slow, sequential, laborious, error-prone but potentially very smart. This is the mode which is used to ' pay attention ' to something.
Control envelope	When brainpower and vigilance limitations are combined, we get a kind of control envelope (image, similar to a flight envelope). As long as the brainpower needed for a specific activity stays inside the envelope, we have a reasonable chance to keep control of the situation.
Control modes	There are different 'modes' of control: strategic control: long term planning, big picture, strategic decisions (e.g. fuel, diversion, etc.) tactical control: short term anticipation, procedures, tactical decisions (e.g. after failure decision or landing procedures; using 'selected' mode in the FCU to anticipate changes from ATC) opportunistic control: real time, relevant reactions to unexpected events, no anticipation, (e.g., There is a roadblock which interrupts your drive, but you see an alternate route you were not previously aware of) scrambled control: real time, irrelevant reactions to events; very close to loss of control; can reach the 'panic' behaviour, (e.g., sudden decompression - immediate reaction is reflexive. . . close to loss of control depending on the pilot's previous experience)
Crew resource management / Cockpit resource management	<u>Definition 1</u> - EU OPS: Crew Resource Management (CRM) is the effective utilization of all available resources (e.g. crew members, airplane systems and supporting facilities) to achieve safe and efficient flight operation. <u>Definition 2</u> (glass cockpit context): Includes issues such as decision making, cross checking, prioritizing and the allocation of tasks between crew members including automatic systems.
Critical task	A task which, if not accomplished in accordance with system requirements, will have adverse effects on cost, system reliability, efficiency, effectiveness, or safety.
Critical task	A task which, if not accomplished in accordance with system requirements, will have adverse effects on cost, system reliability, efficiency, effectiveness, or safety.
Cross checking	Monitoring of other crew members' activities as routine.

Cross checking	Monitoring of other team member activities as a standard practice. Cross checking is a powerful error detection tool. Its efficiency is due to the fact that errors are usually more easily detected by others than by those who make them. Cross checking thus makes the best use of human redundancy.
Cross crew qualification	Multi-rating concept introduced by Airbus Industrie involving structured training concepts producing potential of mixed fleet flying.
Decision Making	Ability to evaluate information in order to timely choose the optimal course of action, (does not include the initiation of standard procedures).
Decision making	Ability to evaluate information in order to (timely) choose the optimal course of action, or to select a solution among different available solutions (does not include the initiation of standard procedures). Decision making implies making a choice between different options.
Drill	An orderly, repetitive training activity intended to instil a stable specific behaviour or over-learned knowledge. Also a procedure to achieve standardized handling of a/c systems esp. in emergency situations using paper or electronic checklists.
Economic issues in maintenance	Here are some strong indicators of the role played by maintenance on quality and cost-related matters (flight delays, flight cancellations, IFTB & Diversions, IFSD). - 1 hour delay: 10,000 to 15,000 $ Maintenance contributed to about 75% of flight delays with respect to Airbus aircraft. It also contributed to 50% of delays due to engine problems (Source: General Electric). Besides the financial impact, delays can also impact safety due to the stress they generate on the crew. Further, delays attributed to maintenance may be partially due to constraints imposed by the overall system (technical resources and manpower available, planning and scheduling of flights, corporate policy,...)- Delays are also very often the result of maintaining safety. - Flight Cancellation: 50,000 to 90,000 $ Another A/C is needed for the passengers, that results in more than 1 hour delay. As shown on the slide, maintenance contributed to 50% of flight cancellations due to engine problems. - IFTB (In Flight Turn Back) / Diversion: about 300,000 $ The A/C returns to the main base to be repaired (IFTB). If it is diverted the cost can be higher if no other A/C is available because food and accommodation need to be provided to the passengers. - IFSD (In Flight Shut Down). Maintenance contributed to 20% of IFSD (Source: Boeing). The cost is not estimated because it can have very different consequences: a short delay if the problem is easily fixed, or a flight cancellation if the problem persists. If the cost of the engine repair or change is included it can easily reach 500,000 $ to a million dollars. - Another category is often referred to as well: AOG (Aircraft On Ground). It is not mentioned here because it results in a flight cancellation.
Error (human error)	<u>Definition 1 (Psychologists and Human Factors specialists):</u> Definition by James Reason in Human Error (1990): Error is intimately bound up with the notion of intention. The term 'error' can only be meaningfully applied to planned actions that fail to achieve their desired consequences without the intervention of some chance or unforeseeable agency. Two basic error types: slips and lapses, where the actions do not go according to plan, and mistakes, where the plan itself is inadequate to achieve its objectives. An error is NOT intentional. You make an error when: • what you do differs from what you intended, • or your plan was inappropriate. An error differs from a violation. The difference, simply, is that unlike an error, a violation is an intentional deviation. It is a deviation from a rule, a regulation, a procedure. <u>Definition 2 (Industry):</u> There is another way to define the term 'error' in the maintenance domain, and this is a source of ambiguity. ICAO for example states in its 1995 Circular that: "Human error in maintenance usually manifests itself as an unintended aircraft discrepancy (physical degradation or failure) attributable to the actions or non-actions of the aircraft maintenance technician". Notice that these 'actions' or 'non-actions' can be either 'errors' or 'violations', referring to Definition 1.
Error and learning	<u>Short-term</u>: we use our errors to regulate our difficulties and risks perception and then consequently adapt our performance. <u>Long-term</u>: we memorize what has happened. . . and benefit from it! "Error & intelligence are two faces of the same coin" (J. Reason). Error is the price to pay for our intelligence: flexibility, creativity, adaptation, learning,

	anticipation, economy of resources, etc. 'To err is human'. Human error is embedded in human performance. Error is like experimentation; from error we learn new ways of doing things. The same processes that lead to error also produce creative new ways of approaching and solving problems.
Error chain Reaction	We often hear about the "error chain". "Error chain reaction" is a more accurate presentation of how error can develop and spread. It underpins both the complexity of the phenomenon and its non- linearity: First, the negative effects of errors grow with time, and second, the negative effects of errors can often start a chain reaction by creating unstable conditions for more errors.
Error Management	*How do people manage their errors?* It is not the absolute number of errors which is important, though of course we are not suggesting you make as many errors as you like. Instead it is the ability to detect and recover errors which is important. This ability to detect and recover errors changes as a function of the workload and mental effort. Error Management is also the ability to discriminate those errors with consequences from those that can be ignored, either because they have no serious consequences, or because they will be corrected in a future process. Not all errors need to be corrected. It is this last process at which experts excel. Example: Novices try to clear all the messages in the MCDU: Experts know that the next screen will solve the problem. The types and absolute number of errors made by experts and novices differ. Experts tend to make many more routine, superficial errors (due to their automated skill base), but fewer 'serious' errors, while novices tend to obsess on a perfect performance. As a result, novices tend to make fewer routine errors (because that is the focus of their attention), but make many more 'serious' errors which often remain undetected and develop serious consequences. The novice's horizon is often short-sighted, they are trapped in the immediate present. 'Correction' embeds a notion of reversibility while 'recovery' doesn't. (For instance, when driving if we take the wrong road, making a U-turn on a country road is a correction, whereas taking another road later on - hence changing our initial route - is a recovery). 'Mitigation' means compensating consequences (e.g. extinguishing a fire). Here again, the tools and resources mentioned as prevention strategies can also serve the error correction, recovery and mitigation. As an example the Airbus Global Safety Strategy achieves error management through design of A/C systems and equipment (design for maintainability), operating procedures and personnel training. <u>General remarks:</u> Error detection and recovery improve error prevention, since we rarely commit the same error twice. The detection can take place just before the error is committed (in the course of action), just after or be delayed (several months later), then creating a latent condition. Because of the nature of its activity, maintenance is likely to produce a lot of latent conditions that may affect a flight days, months and even years later. Example In the case of the 1989 Iowa DC 10 engine disk failure, the suspected inspection failure occurred 17 months before the accident!
Error Management and Situation Control	Error management is more than error prevention. The goal is to keep control. Research shows that expert pilots are more efficient at recognizing which errors require attention and which do not. By doing so they better manage their resources. This skill comes with experience. The novice is often obsessed with correcting all errors, regardless of their relevance to keeping control. Experts tend to keep a higher-order control of the situation which allows them to discriminate significant from non-consequential errors.
Error tolerance	System design is of primary importance because it greatly undermines error propagation. The consequences of the same error drastically vary according to the system in which the error is made. For example pushing the wrong button on your television doesn't have the same impact as it would on the control panel of a nuclear power plant or on the MCDU of a glass cockpit. An error that yields serious consequences and that cannot be recovered is called a critical error, and a system in which errors can develop serious consequences is called vulnerable or error-intolerant towards this specific erroneous action. On the contrary, a system is error tolerant if it is designed so as to ensure that no error can have serious implications for overall safety.

Expert	Being an expert involves at least two components First, an expert has spent the time necessary to develop the appropriate skills for the job, and performs those skills accurately and efficiently. The skills can be physical (motor and manipulation skills) or mental (the ability to do quick calculations, ...) Experts have also developed the ability to quickly isolate relevant information or cues in their environment and can recognize significant patterns that will direct their actions more efficiently (e.g. Trouble-Shooting). Furthermore, experts better know what they know and what they don't, which allows them to remain in their domain of competence, avoiding risky attitudes.
Family concept	Airbus has wanted to facilitate the transition from an Airbus aircraft type to another, through the concept of Airbus Family. This concept means a commonality of philosophy and principles. For example, the way documentation is organized as well as the way to use it are also similar. They are 3 families which also represent subsequent aircraft generations: the A300-A310 family, the A319-A320-A321 family, and the A330-A340 family. They are more similarities within families than between families. For example an A340 is closer to an A330 than to an A320. Beware of the differences in order to avoid errors !
Fatigue	Fatigue comes from consuming our physical or mental resources. Our resources, mental and physical, are like fuel in a car. During a normal day, we consume our fuel at a fairly constant level (like being in 'cruise mode' on the highway). But if we have to go faster or if we have to work harder, then just like a car, we will consume our fuel more quickly. Maintenance technicians work in shifts, and everyone knows it is harder to work overnight. The explanation comes from the way fatigue combines with circadian rhythm. See circadian rhythm.
Feedback	Message to the trainee that contains information about his/her performance. Goal of feedback during training is to help the trainee utilize a learning strategy that results in the desired changes in knowledge, skills, behavior or attitude. To attain this goal, feedback has to be informative and motivating.
Followership	While leadership is the ability to lead the others, 'followership' is the ability to properly follow the leader. All team members must express their willingness to follow the leader, but not 'blindly' . So in case of doubt or if you have any question related to the job or to safety, you should express your concern (the concepts of 'assertiveness' and 'advocacy') in the most suitable manner according to your airline culture and policy. See leadership.
Glass Cockpit	Cockpit design characterized by computer generated visual display, at least a Primary Flight Display (PFD) and a Navigation Display (ND).
Glass Cockpit CRM	Crew Resource Management specifically tailored to the glass cockpit environment.
Human Factors	Originally and generally meaning, "Human Factors" refer to the role of men regarding safety or quality, in high-risk domains such as aviation, marine, nuclear power plants, railways, and all intrinsically hazardous processes where human operators interact with complex technical systems. "Human Factors" is about people in their living and working environments. It is about their relationship with machines and equipment, with procedures, and with the environment about them. It is also about their relationship with other people. . . Hence, addressing human factors is dealing with interactions within a large socio-technical system. Maintenance Human Factors: today's reality, taken from the ADAMS report: "Double standard of task performance: - quality of task documentation & usability of documentation technology in many maintenance organizations, quite inadequate from a users point of view - 'Black Books' are universally accepted to exist: illegal, unofficial manuals in which the technician records useful information for their own reference - making it more likely for a technician to use information that is not current, up to date and accurate. - A/C technicians report they do not follow documented procedures as prescribed in 1/3 of the tasks surveyed. - Technicians & their managers have a contradictory understanding of what the job of the Maintenance technician involves: * The technician sees himself as responsible for the A/C safety & of using his judgement to do what is necessary for that * The managers see the primary role of the tech to follow procedures as laid down (if this is done, safety is ensured). But they know that if the procedures were followed strictly nothing would be done on time"
Human limitations	Why do human beings make errors? There is a simple analogy we can use to explain this. Think first about a machine or a piece of equipment. It was engineered with specific thresholds in mind - weight tolerance, speed limit, etc. If

	you take the machine past its recommended limits, its performance is going to suffer. It may even shut down altogether. Humans are very similar. We have mental, physical and psychological limits to our performance. When we push ourselves past those optimums, the likelihood of error is going to increase. We make more errors when we are tired or when our mental resources are consumed with details of a novel and demanding situation. The biggest difference between humans and machines in this analogy is that humans can learn and adapt their performance. They can actually change their thresholds. How do we do this? One way that we learn is from the errors that we make. Have you heard anyone say «I know I'll never do that again!» - that is learning from error. Humans also differ to machines by the fact that they know they are limited and protect themselves about that. Our knowledge of both our weaknesses and forces explains why
Hybrid Cockpit/Aircraft	Aircraft, having one or two of the following systems are categorized as hybrid: a. EFIS (Electronic Flight Instrument System) displays on which data are presented in a computer-generated integrated manner b. FMS c. systems management that at least diagnoses system failures (EICAS, EC AM, etc.) When an aircraft has all three systems it is defined as a (fully) "glass" cockpit.
Hypo vigilance	Diffuse or semi-alertness; the level of vigilance is below the minimum required for safe flight. Can be caused by monotonous tasks (repetitive activities or monitoring continuous processes), low workload, or stimulus free environment A general slowing-down of the brain occurs, leading to slower reaction times. It's a non-conscious phenomena even though the eyes stay open. Stimulation in the environment can increase the level of alertness.
Incident	ICAO's Definition (Annex 13, chapter 1): "Any non-accident event, linked to the use of an airplane, that compromises or could compromise operating safety". "A serious incident is an incident whose circumstances could have lead to an accident (an accident was about to happen)." Note that the only difference between an accident and a serious incident lies in the outcome.
Knowledge	Difficult to define, but generally the following building blocks are recognized: a. Declarative knowledge: facts and concepts b. Procedural knowledge: procedures and strategies c. Conditional knowledge: principles and conditions
Latent condition	Latent conditions are to technological organizations what resident pathogens are to the human body. Like pathogens, latent conditions - such as poor design, gaps in supervision, undetected manufacturing defects or maintenance failures, unworkable procedures, clumsy automation, shortfalls in training, less than adequate tools and equipment - may be present for many years before they combine with local circumstances and active failures to penetrate the system's many layers of defences. They arise from strategic & other top-level decisions made by governments, regulators, manufacturers, designers, and organizational managers. The impact of those decisions spread throughout the organizations, shaping a distinctive corporate culture, and creating error-producing factors within the individual workplaces. Latent conditions can increase the likelihood of active failures through the creation of local factors promoting errors & violations, and can also aggravate the consequences of unsafe acts, by their effects upon the system's defences.
Leadership	By giving status - e.g. Foreman - the company assigns official authority. But it's also a matter of personal qualities: attitudes, motivation, experience, communication, social and human intelligence that confer on someone the capacity to influence and lead other persons. A good leader doesn't need to resort to authority to lead the others: he 'naturally' gets from the team members what he wants because he is trusted and respected.
Learning	Learning is the modification of the capacity of an individual to perform a task through interactions with the environment. Learning can refer either to the process or to its result. For education sciences, learning defines more precisely the modality of acquisition of knowledge, skills or aptitudes. Learning is greatly facilitated when you are motivated to learn. See motivation.
Long lasting team	Maintenance personnel often work in long lasting teams, i.e. in teams with low personnel turnover. Because they work and live together over a long period of time, team members get used to each other and know each other quite well. This work organization presents both advantages and drawbacks for safety. They are reviewed in the course. People working in the same long lasting team tend to

	form a 'clan'. A clan is a social structure based on relations of proximity and closed to the outside world in which everyone's roles are defined mainly through tacit rules, enforced through 'peer pressure' (group conformity). Clan members have the tendency to reject newcomers until they are considered to be worthy of becoming members of the clan.
Mental model	When people interact with the environment, other people, or the artifacts of technology, they develop interpretative representations that drive their performance. These representations are mental models, relating the different parts of knowledge (declarative, procedural, conditional) and including the perceptions of task demands and task performances.
Mental muscle	A metaphor to explain how expertise is built (The analogy of your brain as a Gymnasium wherein you are building Mental Muscle): As infants, we start with basic information that we perceive through our senses (seeing, hearing, touching,...), and we act. Then we gradually increase the mental strain by learning more formally (and also more quickly) from others. Watching others, imitating them, asking questions, learning.. With repetition, just as with a physical work-out, we repeat some actions and ideas until they become automatic. We develop automatic routines, we develop skills based on certain rules we have learned, and we build our knowledge of the world.
Mental picture	Pilots work in a dynamic environment. The situation changes continuously. To maintain good situation awareness, they need to update their mental picture of what is going on. As you take in more information, you start to build a mental picture of where you are (present), where you have been (past), and where you are going (future). To control the situation, your mental picture of the world has to match reality.
Mental simulation	The way you go through the options in your mind to discover if anything important could go wrong. Mental simulation will allow you to choose one option by evaluating consequences. In other words, it's a way to evaluate the adequacy of different options or solutions by mentally imagining their outcomes.
Mental template	The dictionary meaning of 'template' is "a pattern, mould, or the like, used as a guide in mechanical work; to transfer a design onto a work surface." A template is more than just a recipe or procedure for how to perform the relevant actions: A mental template includes the goal which drives the actions, the expectations that we develop for what is about to happen, our anticipative control. It also guides our scanning of the environment for relevant cues to test and confirm our understanding of the situation. With learning, repetition and experience, we develop hundreds of mental templates and store them in our brains, waiting for the appropriate situation to trigger them.
Monitoring	To scan one or more displays to keep abreast of the status of both the automated and the non-automated systems. Such information is imperative for failure detection, fault diagnosis, and problem solving in general.
Motivation	Motivation plays an important role in learning. In other words, how you approach your transition experience can greatly affect the efficiency of the learning. You can be negative and resistant, and you will find the work that much harder to master. A closed mind is a slow mind to learn. If you are reluctant to make errors (too fearful or too proud), you will be too cautious, and you will lose valuable opportunities to learn. Or you can be positive and enthusiastic. The more open you are to the new material, the faster you will become an expert on the new plane. Any problem or difficulty? Remember your AI instructors are here to help!
MRM Maintenance Resource Management	A terminology often used to designate a CRM for Maintenance personnel. See ACRM.
Negative transfer (in learning)	A condition in which previous experience negatively interferes with the learning of a new task, usually due to conflicting stimuli or response requirements. The opposite is called positive transfer.
No Fault Found policy	Maintenance personnel sometimes have difficulties in locating a fault. This often results in undue removals of properly working components, which represents costs for the airline. The 'No Fault Found' policy has been developed by Airbus Industrie in close collaboration with the major avionics manufacturers for coping with that problem. This policy remains the only NFF reduction procedure in use in the aerospace industry today. It states that the tests performed by Airbus or authorized repair stations are normally free of charge, unless: - The airline doesn't supply supporting data (or chooses not to provide the substantiating data

	after the request of the Supplier's repair station); - Supporting data doesn't substantiate the removal; - The relevant TSM procedures, in relation to a PFR warning message, provide the correct system trouble shooting. So if you encounter difficulties in locating a fault, don't remove a Unit only to prove that you have done something! By the way, it is very likely that applying the corresponding TS procedure will solve the problem. Furthermore, keep all historical data. It helps to put the TS cases in perspective. In case you sent the Unit to Airbus Industrie or the authorized repair station for testing. Remember that historical data will be required not to charge the test to your airline.
Opportunistic control	Cf. Control modes
Organizational learning	Individual behaviours are bounded by the fact that they work within an organization, which does not imply they have no degree of freedom. . . The safety of an organization partly depends on its capacity to learn from experience: organizational safety. This is based on systems of operational feedback, for example incident reporting systems.
Practice	A procedure is like a music score, it is 'interpreted' during the course of action and transformed into practice. In other words, instructions cannot tell you everything. You need to be knowledgeable and properly trained to follow instructions the way they were intended to be followed. Safe procedure application requires that maintenance staff understand the main reasons behind the procedures (i.e. that modern technology is too complex to be operated without proper guidelines) and the consequences of their actions. In real operational life, procedures are not always adhered to! Factors affecting compliance with procedures are reviewed in the course. Adhering to procedures is absolutely needed with modern technology aircraft!
Procedure	A procedure defines what the task is, when the task is conducted, by whom it is conducted, how the task is done, what the sequence of actions is and what type of feedback is required. A procedure also often includes warnings and cautions that must be complied with for its safe application. Role and features of procedures: - Predetermined framework for joint action - Common language which facilitates communication and make it more reliable - Error detection tool: a common reference makes it easier to detect deviations - Because A/C systems are complex, opaque and interconnected, procedures are the only way to interact safely with modern technology aircraft. Adhering to procedures is absolutely needed with modern technology aircraft!
Recurrent training Role	Regular refreshing and checking of pilot / mechanic skills as defined by Regulatory bodies (e.g. EASA/ National CAA) The set of tasks performed by a human controller/operator which constitute his/her purpose in the system. Recent descriptions of pilots as «system managers» or «supervisors» reflect their changing roles due to the introduction of automation.
Role	The set of tasks performed by a human operator which constitute his/her purpose in the system. For example, releasing the aircraft to service is one of the maintenance roles.
Scrambled control	Cf. Control modes
Situation assessment	We use our experience to assess the whole situation, often recognizing it as an instance of a familiar type, a "typical situation". The familiarity of the situation allows you to call up from memory a mental template of how to proceed. If the situation is not familiar, further situation assessment is required in order to make a decision.
Situation awareness	Having a clear and up to date understanding of what is going on around oneself and being able to answer relevant questions at all times.
Situation Control	Situation Control is the dynamic allocation of resources to maintain simultaneous control over your actions and your understanding of the situation. In other words, it's when you understand the situation and, in addition to that, you can act in a way that influences the situation in accordance with your plan. Situation Control involves 2 types of conditions: Controlling your physical actions in the real world, and controlling your mental picture of the world, your Situation Awareness
Skill	(1) A goal-directed, well-organized behaviour that is acquired through practice and performed with economy of effort (2) An organized and co-ordinated pattern of mental and/or physical activity. It is built up gradually in the course of repeated training or other experience. Skills

	can be described as motor, manual, intellectual etc. according to the context or the most important aspect of the skill pattern.
Status	A status is a recognized social position within an organization. For example, the status of Team Supervisor / Chief technician / Technician is always attributed by the airline. Status provides authority, and authority is a source of leadership. See leadership.
Strategic control	Cf. Control modes
Stress	Stress is an automatic response to a disturbing situation. Such a situation can be either unexpected (an emergency) or anticipated (ex. when you know in advance that you will work under time pressure, of when you know you will be overloaded - a lot of work to do). Stress is a vital adaptation mechanism, as it mobilizes resources against any kind of aggression agent also called a 'stressor'. Stress is not only a physical reaction but also an emotional one. Stress can either be good or bad, it is a matter of intensity: it is good when moderate, enabling us to adapt to the situation, but bad when in excess, resulting in drastic performance impairment. Main sources of stress in maintenance are physical working conditions (light, noise, temperature and weather conditions, etc.), production pressure (e.g. delivering the A/C on time) and conflicts (with maintenance, cockpit crew, cabin crew and other personnel). Stress can be managed, both at the individual and at the team level. Furthermore, the organization should prevent conditions favouring excessive stress.
Synergy	Synergy exists when the crew's performance exceeds the sum of individual performances (the 1+1>2 metaphor). Synergy needs some primary conditions to be built: a common goal, a leader recognized by team members (good leadership and followership), clear roles, tasks sharing, and communication. See leadership and followership.
Tactical control	Cf. Control modes
Transfer	The change in performance of a task as a result of previous learning. Transfer can be positive (former learning helps), negative (former learning negatively interferes) or absent (former learning plays no role).
Vigilance	Vigilance corresponds to the activation level of the central nervous system (level of alertness). The level of alertness is not constant during the day. It can go from deep sleep to extreme wakefulness. Important! Vigilance is different from attention. Attention is the deliberate devotion of the mind to a specific item. Man must be alert to be attentive but being alert is not sufficient to guarantee that attention will be paid to the relevant issue (the right item at the right time). Cf. Attention
Violation	The main difference between an error and a violation is that the violation is intentional -e.g. you intend to deliberately deviate from the procedure. Let us take car driving as an example. You know it is a red light, and you still go through it. You are aware of what you are doing when you do it. Sometimes, a violation can become routine. You have deviated in the past, with no apparent negative consequences, and probably some short-term advantages (e.g., like saving time by speeding or running a red light). So the behaviour is repeated, and starts to become automatic, a habit, albeit a bad habit. Or perhaps the violation has evolved throughout the fleet such that it becomes the norm, standard practice, «everyone does it». Here are some reasons why procedures are not followed: - Team values: The good mechanic is the one who can work without procedures! - Routine, Habit: I am used to doing it like this, and it works ... - Group Norms: That's the way we do it here... in the airline, the team - Time pressure: I don't need the procedure anymore, and it's urgent! - Economy of resources / Workload management: It's easier to do it this way and it saves time ... - Lack of knowledge / Lack of training . . .Understanding the why' s behind the procedure - To be of help or to do someone a favour, to save time and let others save time e.g. Refuelling above the High level (2%) to please the pilots

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Addendum II: Completing MEDA Form

Section I -- General Information

Reference #: ______________________ Interviewer's Name: ______________
Airline: ______________________ Interviewer's Telephone #: ______________
Station of Error: ______________________ Date of Investigation: ______________
Aircraft Type: ______________________ Date of Event: ______________
Engine Type: ______________________ Time of Event: ____ : ____ am pm
Reg. #: ______________________ Shift of Error: ______________
Fleet Number: ______________________ Type of Maintenance (Circle): ______________
ATA #: ______________________ 1. Line -- If Line, what type? ______________
Aircraft Zone: ______________________ 2. Base --If Base, what type? ______________
Ref. # of previous related event: ______________ Date Changes Implemented: ______________

Section II -- Event

Please select the event (check all that apply)

1. Operations Process Event
   - ( ) a. Flight Delay (write in length) _ days _ _ hrs. _ _ min.
   - ( ) b. Flight Cancellation
   - ( ) c. Gate Return
   - ( ) d. In-Flight Shut Down
   - ( ) e. Air Turn-Back
   - ( ) f. Diversion
   - ( ) g. Other (explain below)

( ) 2. Aircraft Damage Event
( ) 3. Personal Injury Event
( ) 4. Rework
( ) 5. Other Event (explain below)

Describe the incident/degradation/failure (e.g., could not pressurize) that caused the event.

Section III -- Maintenance Error

Please select the maintenance error(s) that caused the event:

1. Installation Error
( ) a. Equipment/part not installed
( ) b. Wrong equipment/part installed
( ) c. Wrong orientation
( ) d. Improper location
( ) e. Incomplete installation
( ) f. Extra parts installed
( ) g. Access not closed
( ) h. System/equipment not reactivated/deactivated
( ) i. Damaged on installation
( ) j. Cross connection
( ) k. Other (explain below)

2. Servicing Error
( ) a. Not enough fluid
( ) b. Too much fluid
( ) c. Wrong fluid type
( ) d. Required servicing not performed
( ) e. Access not closed
( ) f. System/equipment not deactivated/reactivated
( ) g. Other (explain below)

( ) 3. Repair Error (e.g., component or structural repair)

4. Fault Isolation/Test/Inspection Error
( ) a. Did not detect fault
( ) b. Not found by fault isolation
( ) c. Not found by operational/ functiona test
( ) d. Not found by inspection
( ) e. Access not closed
( ) f. System/equipment no deactivated/reactivated
( ) g. Other (explain below)

5. Foreign Object Damage Error
( ) a. Material left in aircraft/engine
( ) b. Debris on ramp
( ) c. Debris falling into open systems
( ) d. Other (explain below)

6. Airplane/Equipment Damage Error
( ) a. Tools/equipment used improperly
( ) b. Defective tools/equipment used
( ) c. Struck by/against
( ) d. Pulled/pushed/drove into
( ) e. Other (explain below)

( ) 7. Personal Injury Error
( ) a. Slip/trip/fall
( ) b. Caught in/on/between
( ) c. Struck by/against
( ) d. Hazard contacted (e.g, electricity, hot or cold surfaces, and sharp surfaces)
( ) e. Hazardous substance exposure toxic or noxious substances)
( ) f. Hazardous thermal environment exposure (heat, cold, or humidity)
( ) g. Other (explain below)

( ) 8. Other (explain below)

Describe the specific maintenance error (e.g., auto pressure controller installed in wrong location).

Section IV -- Contributing Factors Checklist

N/A ___ A. Information (e.g., work cards, maintenance manuals, service bulletins, maintenance tips, non-routines, IPC, etc.)

_____ 1. Not understandable

_____ 2. Unavailable/inaccessible

_____ 3. Incorrect

_____ 4. Too much/conflicting information

_____ 5. Update process is too long/complicated

_____ 6. Incorrectly modified manufacturer's MM/SB

_____ 7. Information not used

_____ 8. Other (explain below)

Describe specifically how the selected <u>information</u> factor(s) contributed to the error.

N/A ___ B. Equipment/Tools/Safety Equipment

____ 1. Unsafe

____ 2. Unreliable

____ 3. Layout of controls or displays

____ 4. Mis-calibrated

____ 5. Unavailable

____ 6. Inappropriate for the task

____ 7. Cannot use in intended environment

____ 8. No instructions

____ 9. Too complicated

____ 10. Incorrectly labelled

____ 11. Not used

____ 12. Incorrectly used

____ 13. Other (explain below)

Describe specifically how selected <u>equipment/tools/safety equipment</u> factor(s) contributed to the error.

N/A ___ C. Aircraft Design/Configuration/Parts

____ 1. Complex

____ 2. Inaccessible

____ 3. Aircraft configuration variability

____ 4. Parts unavailable

____ 5. Parts incorrectly labelled

____ 6. Easy to install incorrectly

____ 7. Other (explain below)

Describe specifically how the selected <u>aircraft design/configuration/parts</u> factor(s) contributed to error.

N/A ___ D. Job/Task

____ 1. Repetitive/monotonous

____ 2. Complex/confusing

____ 3. New task or task change

____ 4. Different from other similar tasks

____ 5. Other (explain below)

Describe specifically how the selected <u>job/task</u> factor(s) contributed to the error.

N/A ___ E. Technical Knowledge/Skills

____ 1. Skills

____ 2. Task knowledge

____ 3. Task planning

____ 4. Airline process knowledge

____ 5. Aircraft system knowledge

____ 6. Other (explain below)

Describe specifically how the selected <u>technical knowledge/skills</u> factor(s) contributed to the error.

N/A ___ F. Individual Factors

____ 1. Physical health (including hearing and sight)
____ 2. Fatigue
____ 3. Time constraints
____ 4. Peer pressure
____ 5. Complacency
____ 6. Body size/strength
____ 7. Personal event (e.g., family problem, car accident)
____ 8. Workplace distractions/interruptions during task performance
_____ 9. Memory lapse (forgot)
_____ 10. Other (explain below)

Describe specifically how the selected factors affecting individual performance contributed to the error.

N/A ___ G. Environment/Facilities

____ 1. High noise levels
____ 2. Hot
____ 3. Cold
____ 4. Humidity
____ 5. Rain
____ 6. Snow
____ 7. Lighting
____ 8. Wind
____ 9. Vibrations
____ 10. Cleanliness
____ 11. Hazardous/toxic substances
____ 12. Power sources
____ 13. Inadequate ventilation
____ 14. Other (explain below)

Describe specifically how the selected environment/facilities factor(s) contributed to the error.

N/A ___ H. Organizational Factors

_____ 1. Quality of support from technical organizations (e.g., engineering, planning, technical pubs)
_____ 2. Company policies
_____ 3. Not enough staff
_____ 4. Corporate change/restructuring
_____ 5. Union action
_____ 6. Work process/procedure
_____ 7. Work process/procedure not followed
_____ 8. Work process/procedure not documented
_____ 9. Work group normal practice (norm)
_____ 10. Other (explain below)

Describe specifically how the selected organizational factor(s) contributed to the error.

N/A ___ I. Leadership/Supervision

____ 1. Planning/organization of tasks
____ 2. Prioritization of work
_____ 3. Delegation/assignment of task
_____ 4. Unrealistic attitude/expectations
_____ 5. Amount of supervision
_____ 6. Other (explain below)

Describe specifically how the selected leadership/supervision factor(s) contributed to the error.

N/A ___ J. Communication

____ 1. Between departments
____ 2. Between mechanics
____ 3. Between shifts
____ 4. Between maintenance crew and lead
____ 5. Between lead and management
____ 6. Between flight crew and maintenance
_____ 7. Other (explain below)

Describe specifically how the selected communication factor(s) contributed to the error.

N/A ___ K. Other Contributing Factors (explain below)

Describe specifically how this other factor contributed to the error.

Section V – Error Prevention Strategies

A. What current existing procedures, processes, and/or policies in your organization are intended to prevent the incident, but didn't?

( ) **Maintenance Policies or Processes** (specify) ____________________

( ) **Inspection or Functional Check** (specify) ____________________

Required Maintenance Documentation

- ( ) Maintenance manuals (specify) ____________________
- ( ) Logbooks (specify) ____________________
- ( ) Work cards (specify) ____________________
- ( ) Engineering documents (specify) ____________________
- ( ) Other (specify) ____________________

Supporting Documentation

- ( ) Service Bulletins (specify) ____________________
- ( ) Training materials (specify) ____________________
- ( ) All-operator letters (specify) ____________________
- ( ) Inter-company bulletins (specify) ____________________
- ( ) Other (specify) ____________________

( ) **Other** (specify) ____________________

B. List recommendations for error prevention strategies.

Recommendation #	Contributing Factor #	

(Use additional pages, as necessary)

Section VI – Summary of Contributing Factors, Error, and Event

Provide a brief summary of the event.

(Use additional pages, as necessary)

Instructions for Completing the MEDA Form

Table of Contents

Introduction

There are four objectives of the User's Guide:

- To give the user an overview of the MEDA philosophy and process.
- To provide information on how to complete the Results Form.
- To give the user examples of contributing factors to look for during the investigations.

This guide assumes that the user has been through the MEDA investigator workshop, understands basic Windows navigation functions and understands the following:

- The definition of an event.
- The definition of a maintenance error.
- How MEDA provides a structured framework for documenting contributing factors to errors and for recommending error prevention strategies.

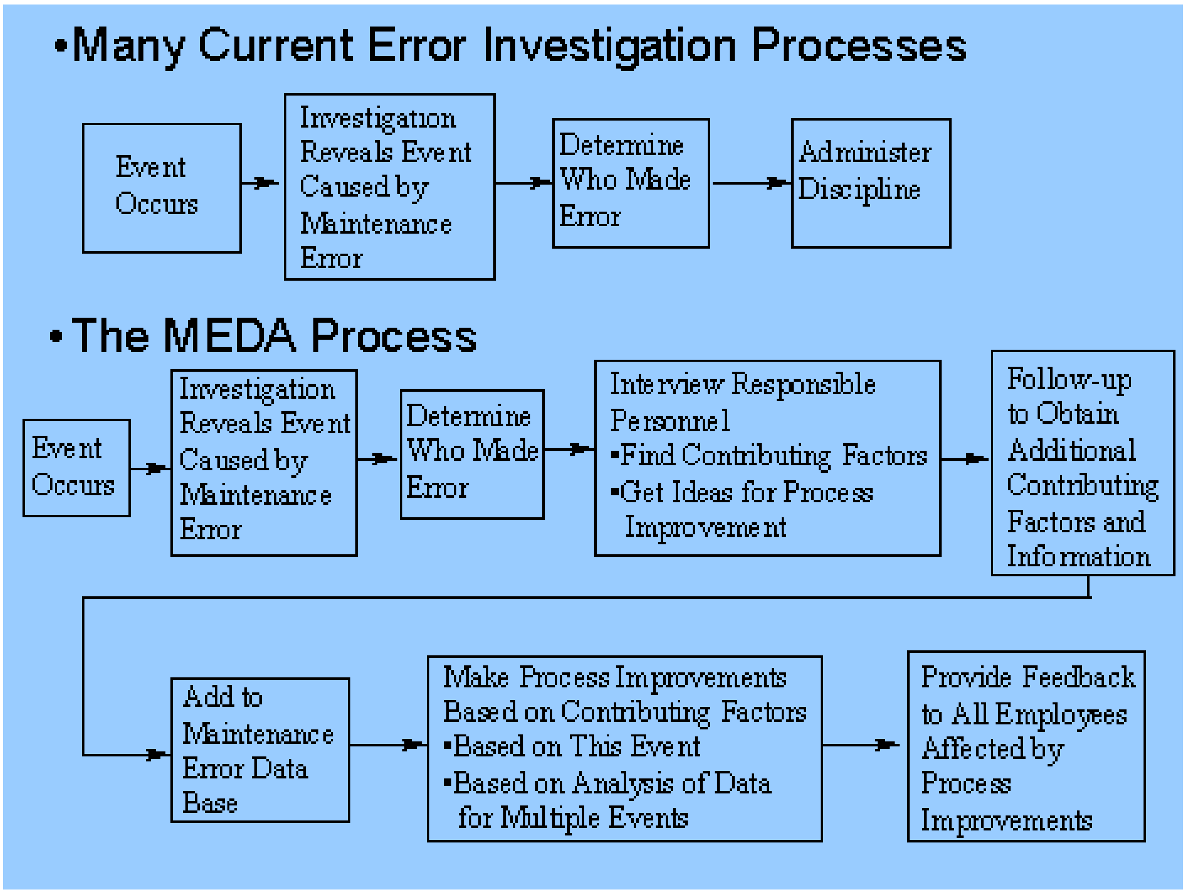
MEDA Philosophy

The fundamental philosophy behind MEDA is:

- Maintenance errors are not made on purpose.
- Most maintenance errors result from a series of contributing factors.
- Many of these contributing factors are part of an airline process, and, therefore, can be managed.

MEDA Process

MEDA is a process that helps airline maintenance organizations reduce errors by giving them a tool to identify factors that contribute to the errors. The following is a comparison of how the MEDA process is different from many current error investigation processes:



•Many Current Error Investigation Processes
Event Occurs
Investigation Reveals Event Caused by Maintenance Error
Determine Who Made Error
Administer Discipline
•The MEDA Process
Event Occurs
Investigation Reveals Event Caused by Maintenance Error
Determine Who Made Error
Interview Responsible Personnel
•Find Contributing Factors
•Get Ideas for Process Improvement
Follow-up to Obtain Additional Contributing Factors and Information
Add to Maintenance Error Data Base
Make Process Improvements Based on Contributing Factors
•Based on This Event
•Based on Analysis of Data for Multiple Events
Provide Feedback to All Employees Affected by Process Improvements

Instructions on Using the MEDA Form

Use the MEDA Results Form to collect data associated with a maintenance error. Each section of the form, as shown in Figure 1, captures specific data. The end product will contain information about what happened (the incident), why (contributing factors), system barriers that failed to prevent the error and recommendations for prevention strategies to prevent the error from occurring again. What follows are detailed instructions on how to fill in each section.

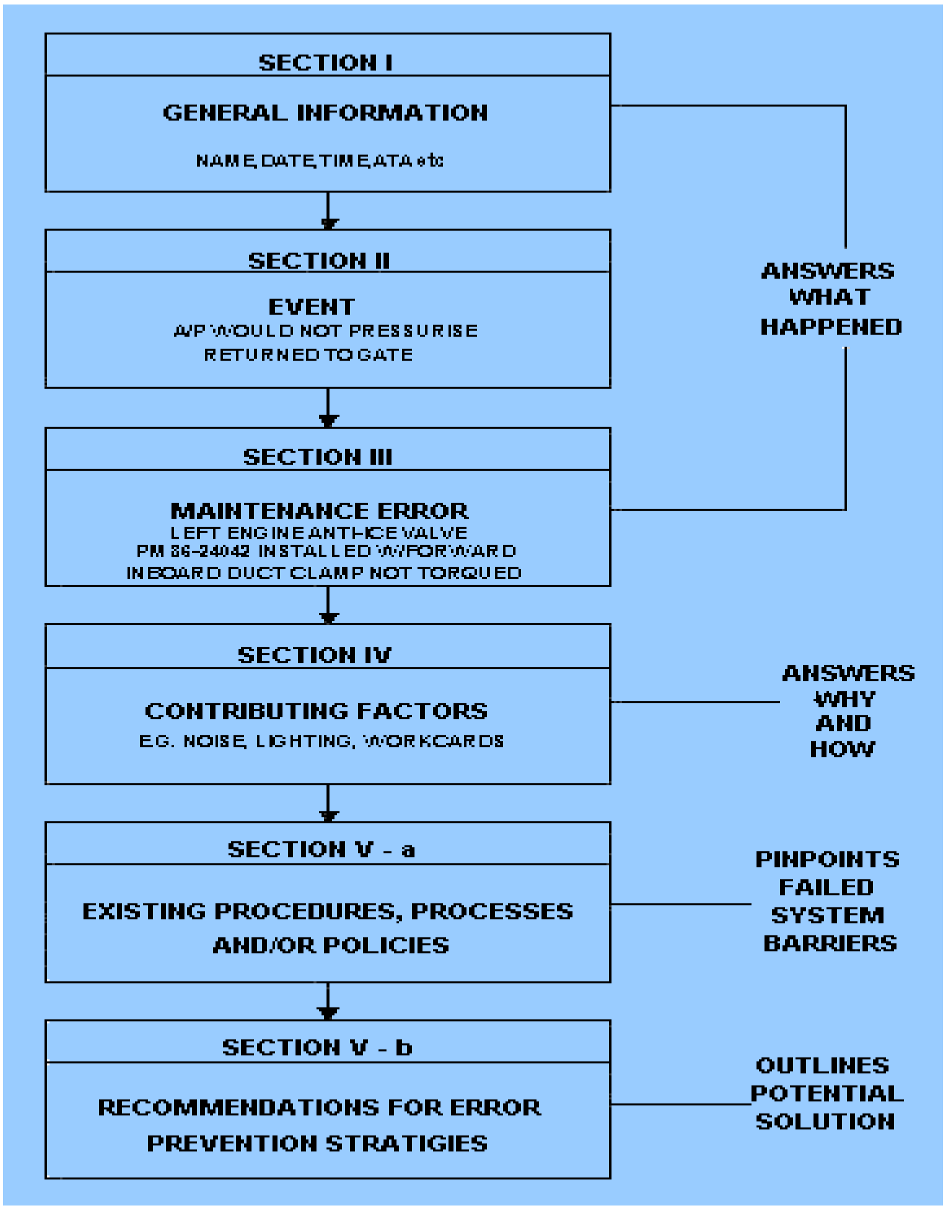


Figure 1 - MEDA Results Form Flow Chart

MEDA Form Section 1 General

REFERENCE # (Optional)

Two letter airline designator plus three sequential numbers (e.g., BA001, BA002, etc.)

AIRLINE

Two or three letter airline designator

STATION OF ERROR

Station where the error occurred NOT where it is being reported (if different)

AIRCRAFT TYPE

Manufacturer and model (e.g., B747-400, DC10-30, L1011-100, A320-200)

ENGINE TYPE

PW4000, RB211-524, CF6-80A, etc.

REG. #

Airplane registration number

FLEET NUMBER

Letter or number designator

ATA #

ATA chapter (e.g., 30-10) most closely related to the error under investigation

AIRCRAFT ZONE (Optional)

e.g., 210, 130, etc.

REF # OF PREVIOUS RELATED EVENT (IF APPLICABLE)

If this investigation is a repeat of a similar event, use this field to reference to the previous investigation's data

ANALYST NAME / ANALYST TELEPHONE #

This information is required in case the MEDA focal in your organization needs clarification or more detailed data

DATE OF INVESTIGATION

Date the investigation starts

DATE OF EVENT

Date the event occurred

TIME OF EVENT

Time of the event, if known

SHIFT OF ERROR

Shift during which the error occurred, if known

TYPE OF MAINTENANCE

Indicate whether the error occurred during line or base maintenance, and what type of check or maintenance was being performed (e.g., turnaround, A-Check, overhaul, etc.)

DATE CHANGES IMPLEMENTED

Date that recommended and approved prevention strategies were implemented and documented.

An event is an unexpected, unintended, or undesirable occurrence that interrupts normal operating procedures and may cause an incident or accident.

Note: This part will not apply in cases where the maintenance error was discovered before an incident occurred.

MEDA Form Section 2 Event

STEP 1

Check as many of the event identifiers that apply:

A. P LEASE CHECK THE EVENT

( ) Flight Delay ___days___hrs.___min.

( ) Flight Cancellation

( ) Gate Return

( ) In-Flight Shut Down

( ) Air turn-back

( ) Aircraft Damage

( ) Injury

( ) Diversion

( ) Rework

( ) Other

STEP 2

DESCRIBE THE INCIDENT/DEGRADATION/FAILURE (E.G., COULD NOT PRESSURIZE) THAT CAUSED THE EVENT.

If there was no event enter N/A.

Example:

During take off, an off-wing escape slide inadvertently deployed hitting and damaging the side and the tail of the airplane.

MEDA Form Section 3 Maintenance Error

A maintenance error is an action or inaction within the maintenance organization that leads to an aircraft problem.

STEP 1

A. PLEASE CHECK THE TYPE OF MAINTENANCE ERROR (CHECK ONLY ONE):

Check ONE error and identify its contributing factors and error prevention strategies in Sections IV and V, respectively.

NOTE: Sometimes several errors combine to cause an incident. Investigation results are less confusing when Sections IV and V describe contributing factors and error prevention strategies for a single error at a time. Therefore, it is important that only ONE error be identified in this section. If two or more errors combined to cause the incident, use Sections III, IV and V on separate forms and staple them to the back of the first.

STEP 2

DESCRIBE THE SPECIFIC MAINTENANCE ERROR (E.G., AUTO PRESSURE CONTROLLER INSTALLED IN WRONG LOCATION).

Enter a brief written description of the maintenance error.

Example:

It appears the maintenance technician failed to secure the escape slide carrier pin and one or both door latches.

MEDA Form Section 4 Contributing Factors Checklist

This checklist will help the analyst identify the contributing factors that contributed to the error. If several errors combined to cause the event, it is important to remember that you are identifying only those factors contributing to **one error at a time**. Use Sections III, IV and V on separate forms for multiple errors.

STEP 1

Check all the applicable contributing factors for the error identified in Section III. See the Contributing Factors Checklist Examples section for additional information on each factor.

STEP 2

If a contributing factor on the list was not involved, check N/A. The purpose of this step is to ensure that each contributing factor is considered during the analysis.

STEP 3

For each factor identified, give a written description of how it contributed to the error.

A. **WHAT CURRENT EXISTING PROCEDURES, PROCESSES, AND/OR POLICIES IN YOUR ORGANIZATION ARE INTENDED TO PREVENT THE INCIDENT, BUT DIDN'T?**

This section highlights organizational barriers that were in place but failed to prevent the error from occurring.

Check and describe as many items as are related to the error identified in Section III.

B. LIST RECOMMENDATIONS FOR ERROR PREVENTION STRATEGIES.

List all proposed changes or actions that are recommended to prevent the error from occurring again. This may include changes based on analysis of the contributing factors for this error, and also process or system improvements based on the analysis of data across several errors.

Contributing Factors Checklist Examples

The following paragraphs and lists contain additional data about each contributing factor from Section IV of the MEDA Results Form. Each lettered section heading corresponds to a lettered block on the Results Form, and each numbered item beneath that heading corresponds to a numbered item on the Results Form. Use this supplemental material during your error analysis to assist you in filling out the checklist.

Information refers to the written or computerised source data that a maintenance technician needs to carry out a task or job. It includes workcards, maintenance manual procedures, service bulletins or engineering orders, maintenance tips, illustrated parts catalogues and other manufacturer supplied or internal resources. To determine that information was a contributing factor to the maintenance error, either the information itself must be problematical (e.g., hard to understand, not complete, conflicting), or the information should have been used but was not (e.g., it was not available, it was ignored). If it is expected that the maintenance technician has this information memorised, then refer to the Technical Knowledge/Skills section.

Examples to look for:

1. Not understandable
    - Unfamiliar words or acronyms
    - Unusual or non-standard format
    - Poor or insufficient illustrations
    - Not enough detail or missing steps
    - Poorly written procedures

2. Unavailable/Inaccessible
    - Procedure does not exist
    - Not located in correct or usual place
    - Not located near worksite

3. Incorrect
    - Missing pages or revisions
    - Does not match airplane configuration
    - Transferred from source document incorrectly
    - Steps out of sequence
    - Not the most current revision
    - Procedure does not work
4. Too much/conflicting information
    - Similar procedures in different resources do not agree (e.g. MM versus task card)
    - Too many references to other documents
    - Configurations shown in different resources do not agree
5. Update process is too long/complicated
    - Requested revisions have not been incorporated yet
    - Configurations changed by Service Bulletins or Engineering Orders have not been updated in applicable maintenance procedures
    - Document change requests are not submitted, lost, or incorrectly filled out
6. Incorrectly modified manufacturer's MM/SB
    - Intent of manufacturer's procedure is not met
    - Non-standard practices or steps are added
    - Format does not match rest of procedure or other procedures
7. Information not used
    - Procedure available but ignored
    - Technician too familiar with procedure
8. Other
    - ☐ Operator cannot use digital information

Equipment/Tools

Equipment, tools and parts are the tools and materials necessary for performance of a maintenance task. **Equipment and tools** refer to things such as non-destructive test equipment, work stands, calibrated torque wrenches, screwdrivers, test boxes, and special tools called out in maintenance procedures.

Unsafe equipment and tools may cause a maintenance technician to become distracted from the task due to concern for personal safety. If equipment or tools are not available or are inaccessible, the maintenance technician may use other equipment or tools that are not fully suited for the job. Other factors that can contribute to error include mis-calibrated instruments, use of unreliable equipment, or equipment or tools with no instructions for use.

Incorrectly labelled parts can contribute to improper installation or repair. Parts that are unavailable can contribute to error by the maintenance technician who uses a substitute part.

Examples to look for:

1. Unsafe
   - Platform moves and is unstable
   - Brakes or safety devices inoperative
   - Non-skid material worn or missing
   - A lock-out mechanism is missing or faulty
   - Placards (warnings or cautions) are missing or faded
   - Sharp edges are exposed or personal protective devices are missing
   - Power sources are not labelled or protected

2. Unreliable
   - Intermittent or fluctuating readings on dials or indicators
   - Damaged or worn out
   - Expired use limits
   - Part with history of defects

3. Poor layout of controls or displays
   - Easy to read wrong display or use wrong control
   - Awkward locations, hard to reach
   - Too small to read or control
   - Directional control of knobs or dials is not clear

4. Mis-calibrated
   - Tool out of calibration from the start of use
   - Wrong specifications used during calibration procedure

5. Unavailable
   - Is not owned or in stock
   - Not available for procurement

6. Inappropriate for the task
   - Standard hand tools used for leverage
   - Not capable of handling weights, forces, or pressures required for the task
   - Wrong or outdated (part) dash numbers
   - Connections or grips not the right size

7. Can't use in intended environment
   - Not enough space to operate tool or install part
   - Requires level surface where one is not available

8. No instructions
   - Instructional placards missing or faded
   - Directional markings missing
   - Tool usage instructions not available

9. Too complicated
   - Tool usage requires too many simultaneous movements and/or readings
   - Fault isolation or testing is too complex
   - Installation of part requires too much time

10. Incorrectly labelled
    - Hand marked labelling or operating instructions are incorrect
    - Wrong part number on tool
    - Illegible labels

11. Not used
    - Equipment/tool/part is available but not used
    - Not all parts installed during multiple installation

12. Other
    - System protection devices on tools/equipment not available
    - Parts are fragile, damaged during installation

Aircraft Design/Configuration/Parts

An airplane should be designed/configured so that parts and systems are accessible for maintenance. The maintenance technician should be able to reach a part, should be able to remove it from a reach and strength standpoint, and should be able to easily replace the part in the correct orientation. When reviewing accessibility as a contributor to maintenance error, it must be seen as a real contributor to the error and not just as an inconvenience to the maintenance technician.

Good designs also incorporate feedback that helps the maintenance technician know that something has been performed correctly. For example, an electrical connector that has a ratchet effect provides feedback to the maintenance technician when the installation is correct. If this ratchet effect is included in some connectors and not others, this could contribute to error. If a maintenance technician goes from a ratchet connector to a non-ratchet connector, the technician may over-tighten the second connector looking for the ratchet.

Configuration variability between models and airplanes can contribute to error when there are small differences between the configurations that require maintenance tasks to be carried out differently or require slightly different parts.

Parts refer to airplane parts that are to be replaced.

<u>Examples to look for:</u>

1. Complex
    - Fault isolation on the system or component is difficult
    - Installation of components is confusing, long, or error prone
    - Multiple similar connections exist on the system or component (electrical, hydraulic, pneumatic, etc.)
    - Installation tests for the component are extensive and confusing
    - Different sized fasteners can be installed in multiple locations

2. Inaccessible
    - Components or area to be maintained is surrounded by structure
    - No access doors exist in the maintenance area
    - Area lacks footing space or hand-holds
    - Small or odd-shaped area

3. Configuration variability between models/airplanes
    - Similar parts on different models are installed differently
    - Airplane modifications have changed installation or other maintenance procedures between airplanes

4. Parts unavailable
    - Is not owned or in stock
    - Not available for procurement

5. Parts incorrectly labelled
    - Hand marked labelling or operating instructions are incorrect
    - Wrong part number on part
    - Illegible labels

6. Easy to install incorrectly
    - Lack of feedback provided by component or system
    - Can be easily installed with wrong orientation
    - Direction of flow indicators do not exist

7. Other

- Components are too heavy for easy removal/installation

Job/Task

A maintenance technician's job/task can logically be separated into a series of tasks. Under certain circumstances, when the tasks are poorly planned and/or combined, the work can become quickly become unmanageable. If the investigator feels the task was a contributing factor, the investigator should analyse the combination or sequence of tasks. The investigator, when examining the task sequencing, should also determine whether written information was being used and what technical skills and knowledge were expected of the maintenance technician.

Examples to look for:

1. Repetitive/monotonous

- Similar steps are performed over and over (opening and closing circuit breakers during a long test)
- The same task performed many times in multiple locations (removing seats)

2. Complex/confusing

- Multiple other tasks are required during this task
- Multiple steps required at the same time by different maintenance technicians
- Long procedure with step sequences critical
- System interacts with other systems during testing or fault isolation
- Multiple electrical checks are required
- Task requires exceptional mental or physical effort

3. New task or task change

- New maintenance requirement or component
- Revision to a procedure
- Engineering modification to existing fleet
- New airplane model

4. Different from other similar tasks

- Same procedure on different models is slightly different
- Recent change to airplane configuration has slightly changed task
- Same job at different worksites is performed slightly different

5. Other

- The workgroup performs the task differently than called out in the source data (or written information)

Technical Knowledge/Skills

1. Inadequate skills

Technical skills (sometimes also referred to as abilities) refer to tasks or subtasks that maintenance technicians are expected to perform without having to refer to other information. Technical skills include such things as being able to lock wire, use a torque wrench, and remove common parts from an airplane. For (lack of) technical skills to be a contributing factor to error, the technician must not have skill that was generally expected of him/her.

- History of frequently made similar errors
- Poorly installed or serviced items when procedures were available and straightforward
- History of poor performance after extensive training in tasks, airline processes, and airplane systems
- Trouble with memory items or poor decision making

2. Inadequate task knowledge

Technical knowledge refers to the understanding of a body of information that is applied directly to performing a task. Technical knowledge, in order to be a contributing factor to error, is knowledge that is supposed to be known (memorised) by the maintenance technician. Three broad categories of knowledge are required of a technician: airline process knowledge, airplane systems knowledge, and maintenance task knowledge. These are discussed in more detail below.

- Slow task completion
- Technician change of maintenance responsibilities
- Task performed by maintenance technician for the first time
- Task performed in wrong sequence

3. Inadequate task planning

- Frequent work interruptions to get tools or parts
- Failure to perform preparation tasks first
- Too many tasks scheduled for limited time period
- Tasks necessary for safety not performed first

4. Inadequate airline process knowledge

Airline process knowledge refers to knowledge of the processes and practices of the airline or repair station in which the maintenance technician works. Examples include shift turnover procedures, parts tagging requirements, and sign off requirements. While this knowledge is generally acquired through general maintenance operating procedures and on-the-job discussion with peers, it may also be acquired from other sources such as employee bulletins and special training.

- Failure to acquire parts on time
- Technician new to airline or to type of work (from line to hangar, etc.)
- Airline processes not documented or stressed in training

5. Inadequate aircraft system knowledge

Aircraft system knowledge refers to knowledge of the physical aircraft systems and equipment. Examples include location and function of hydraulic pumps and rework options for corroded or fatigued parts. While this knowledge is generally acquired from the airplane design characteristics, training, maintenance manuals, and on-the-job discussion with peers, it may also be acquired from other sources such as trade journals and maintenance tips.

- Technician changes airplane types or major systems
- Fault isolation takes too much time or is incomplete

6. Other

- Technician performance/skills not accurately tracked/measured

Factors Affecting Individual Performance

Factors affecting individual performance vary from person to person and include factors brought to the job by individuals (e.g., body size/strength, health, and personal events) and those caused by outside factors (e.g., peer pressure, time constraints, and fatigue caused by the job itself). These factors may help explain errors made by maintenance technicians who are usually top performers.

1. Physical health includes the acuity of human senses as well as physical conditions and physical illnesses. human senses, especially vision, hearing, and touch, play an important role in maintenance. Technicians are frequently required to perform tasks that are at or near the limits of their sensory capabilities. For example, some tasks require good vision and/or touch, such as visual inspection for cracks or finger inspection for burrs. Good hearing is also required in order to hear instructions or feedback before and during a maintenance task.

Physical conditions, such headaches and chronic pain, also have been shown to relate to errors. Alcohol/drug use, as well as side effects of various prescription and over-the-counter medicines, can negatively affect the senses. Physical illness, such as having a cold or the flu, can also negatively affect the senses and the ability to concentrate. Illnesses can also lead to less energy, which can affect fatigue.

- Sensory acuity (e.g. vision loss, hearing loss, touch)
- Failure to wear corrective lenses
- Failure to use hearing aids or ear plugs
- Restricted field of vision due to protective eye equipment
- Pre-existing disease
- Personal injury
- Chronic pain limiting range of movement
- Nutritional factors (missed meals, poor diet)
- Adverse affects of medication
- Drug or alcohol use
- Complaints of frequent muscle/soft tissue injury
- Chronic joint pain in hands/arms/knees

2. Fatigue has been defined as a depletion of body energy reserves, leading to below-par performance. Fatigue may be emotional or physical in origin. Acute fatigue may be caused by emotional stress, depletion of physical energy, lack of sleep, lack of food, poor physical health, or over excitement. Fatigue may also be caused by the work situation itself. The time of the day, the length one has been working, and complex mental tasks or very physical tasks can cause fatigue.

- Lack of sleep
- Emotional stress (e.g. tension, anxiety, depression)
- Judgment errors
- Inadequate vigilance, attention span, alertness
- Inability to concentrate
- Slow reaction time
- Significant increase in work hours or change in conditions
- Excessive length of work day
- Excessive time spent on one task
- Chronic overloading
- Task saturation (e.g., inspecting rows of rivets)

3. Time constraints or time "pressure" are common to the maintenance technician. The need to finish a maintenance task so an airplane can be released from the gate or to finish a heavy maintenance task so an airplane can be put back into service often cause technicians to feel pressure to get their tasks done. Studies have linked both too little time and too much time with increased error. There is a well known speed/accuracy trade-off, in that the faster one tries to finish a task the more likely an error is to happen. This trade-off also holds for speed and safety. However, when things are done too slowly, boredom can set in and also increase the chance of errors.

- Constant fast-paced environment
- Multiple tasks to be performed by one person in a limited time
- Increase in workload without an increase in staff
- Too much emphasis on schedule without proper planning
- Perceived pressure to finish a task more quickly than needed in order to release the airplane from the gate

4. Peer pressure can also influence a maintenance technician's performance. For example, there may be peer pressure not to use maintenance manuals because it is seen as a sign of lack of technical knowledge. Peer pressure may also influence a technician's safety-related behaviour.

- Unwillingness to use written information because it is seen as a lack of technical skills/knowledge
- Lack of individual confidence
- Not questioning other's processes
- Not following safe operating procedures because others don't follow them

5. Boredom/complacency

- Under use of maintenance technicians (low workload)
- Failure to vary maintenance technician assignments
- Under use of maintenance technician skills

6. Body size and strength are two obvious factors that affect a maintenance technician's ability to perform a task. If someone is too small to reach a plug or if someone is unable to let down an LRU from an upper rack, this can contribute to error.

- Abnormal reach, unusual fit, or unusual strength required for the task
- Inability to access confined spaces

7. Personal event

- Death of a family member
- Marital difficulties
- Change in health of a family member
- Change in work responsibilities/assignment
- Change in living conditions

8. Workplace distractions/interruptions during task performance

- Confusion or disorientation about where one is in a task
- Missed steps in a multi-step task
- Not completing a task
- Working environment is too dynamic

9. Other

- Absenteeism
- Vacations
- Medical leave
- Hazardous attitudes (anti-authority, invulnerability, resignation)
- Risk-taking behaviour

Environment/Facilities

The working environment/facilities can contribute to error. For example, temperature extremes (either too hot or too cold), high noise levels, inadequate lighting (reflection/glare, etc.), unusual vibrations, and dirty work surfaces could all potentially lead to maintenance errors. Concerns about health and safety issues could also contribute to maintenance technician errors.

Examples to look for:

1. High noise levels
   - High noise impacts the communication necessary to perform a task
   - Extended exposure to noise reduces ability to concentrate and makes one tired
   - Noise covers up system feedback during a test

2. Hot
   - Work area is too hot so the task is carried out too quickly
   - Extremely high temperatures cause fatigue
   - Long exposure to direct sunlight
   - Exterior components or structure too hot for maintenance technicians to physically handle or work on

3. Cold
   - Work area is too cold so the task is carried out too quickly
   - Long exposure to low temperature decreases sense of touch
   - Extremely low ambient temperature creates difficult maintenance environment

4. Humidity
   - High humidity creates moisture on airplane, part and tool surfaces
   - Humidity contributes to fatigue

5. Rain
   - Causes obscured visibility
   - Causes slippery or unsafe conditions

6. Snow
   - Causes obscured visibility
   - Causes slippery or unsafe conditions
   - Protective gear makes grasping, movement difficult
   -

7. Lighting
    - Insufficient for reading instructions, placards, etc.
    - Insufficient for visual inspections
    - Insufficient for general maintenance activity
    - Excessive, creates glare, reflection, or eye spotting
8. Wind
    - Interferes with ability to hear and communicate
    - Moves stands and other equipment (creates instability)
    - Blows debris into eyes, ears, nose or throat
    - Makes using written material difficult

9. Vibrations
    - Use of power tools fatigues hands and arms
    - Makes standing on surfaces difficult
    - Makes instrument reading difficult

10. Cleanliness
    - Loss of footing/grip due to dirt, grease or fluids on parts/surfaces
    - Clutter reduces available/usable work space
    - Inhibits ability to perform visual inspection tasks

11. Hazardous/toxic substances
    - Reduces sensory acuity (e.g. smell, vision)
    - Exposure causes headaches, nausea, dizziness
    - Exposure causes burning, itching, general pain
    - Personal protective equipment limits motion or reach
    - Causes general or sudden fatigue
    - Causes general concern about long term effect on health

12. Power sources
    - Not labelled with caution or warning
    - Guarding devices missing or damaged
    - Power left on inappropriately
    - Circuit protection devices not utilized or damaged
    - Cords chafed, split, or frayed

13. Inadequate ventilation

- Strong odour present
- Burning or itching eyes
- Shortness of breath
- Sudden fatigue

14. Other

- Area(s) not organized efficiently (difficult to find parts, work cards, etc.)
- Area too crowded with maintenance technicians and/or other personnel

Organisational Factors

The organisational culture can have a great impact on maintenance error. Factors such as internal communication with support organizations, trust level between management and maintenance technicians, management goals and technician awareness and buy-in of those goals, union activities and attitudes, morale, etc., all affect productivity and quality of work. The amount of ownership the technician has of his/her work environment and the ability to change/improve processes and systems is of key importance to technician morale and self esteem, which in turn, affects the quality of task performance.

Examples to look for:

1. Quality of support from technical organisations

- Inconsistent quality of support information
- Late or missing support information
- Poor or unrealistic maintenance plans
- Lack of feedback on change requests
- Reluctance to make technical decisions
- Frequent changes in company procedures and maintenance programmes

2. Company policies

- Unfair or inconsistent application of company policies
- Standard policies do not exist or are not emphasised
- Lack of ability to change or update policies
- Policies inhibit reporting of errors and therefore inhibit process improvements

3. Company work processes

- Standard error prevention strategies don't exist or are not applied
- Inflexibility in considering special circumstances

4. Union action

- Contract negotiations create distractions
- Historical management/labour relations are not good
- Positive or negative communication from union leadership
- Strike, work slowdown, or other labour action creates a disruption

5. Corporate change/ restructuring

- Layoffs are occurring
- Early retirement programs drain experience
- Reorganisations, consolidations and transfers cause more people to be in new jobs
- Demotions and pay cuts
- Frequent management changes

6. Other

- Work previously accomplished in-house is contracted out
- Overall inadequate staffing levels

Leadership/Supervision

Even though supervisors normally do not perform the tasks, they still contribute to maintenance error by poor planning, prioritising, and organising of job tasks. Delegation of tasks is a very important supervisory skill and if not done properly, can result in poor work quality. Also, there is a direct link between the management/supervisory attitudes and expectations of the maintenance technician and the quality of the work that is performed.

Also, supervisors and higher-level management must also provide leadership. That is, they should have a vision of where the maintenance function should be headed and how it will get there. In addition, leadership is exhibited by management "walking the talk," that is, showing the same type of behaviour expected of others.

Examples to look for:

1. Poor planning/organisation of tasks

- Excessive downtime between tasks
- Not enough time between tasks
- Paperwork is disorganised
- Tasks are not in a logical sequence
- Airplane configurations are changed too frequently during the maintenance visit

2. Inadequate prioritisation of work
    - Technicians not told which tasks to carry out first
    - Important or safety related tasks are scheduled last
    - Fault isolation is not performed with the most likely causes checked first

3. Inadequate delegation/assignment of tasks
    - Assigning the wrong person to carry out a task
    - Inconsistency or lack of processes for delegating tasks
    - Giving the same task to the same person consistently
    - Wide variance in workload among maintenance technicians or departments

4. Unrealistic attitude/expectations
    - Frequent dissatisfaction, anger, and arguments between a supervisor and a technician about how to do a task or how quickly a task should be finished
    - Pressure on maintenance technicians to finish tasks sooner than possible or reasonable
    - Berating individuals, especially in front of others
    - Zero tolerance for errors
    - No overall performance expectations of maintenance staff based on management vision

5. Amount of supervision
    - "Look over the shoulder" management style
    - Frequent questioning of decisions made
    - Failure to involve employees in decision making

6. Other
    - Not enough supervision
    - Meetings do not have purpose or agendas
    - Supervisor does not have confidence in group's abilities
    - Management doesn't "walk the talk" and thereby sets poor work standards for maintenance staff

<u>Communication</u>

Communication issues refer to breakdowns in communication that prevent the maintenance technician from getting the correct information in a timely manner regarding a maintenance task. The types of communication include both written and verbal.

Examples to look for:

1. Between departments

- Written communication incomplete or vague
- Information not routed to the correct groups
- Department responsibilities not clearly defined or communicated
- Personality conflicts create barriers to communication between departments
- Information not provided at all or not in time to use

2. Between people (peers)

- Failure to communicate important information
- Misinterpretation of words, intent or tone of voice
- Language barriers
- Use of slang or unfamiliar terms
- Use of unfamiliar acronyms
- Failure to question actions when necessary
- Failure to offer ideas or process improvement proposals
- Personality differences

3. Between shifts

- Work turnover not accomplished or done poorly or quickly
- Inadequate record of work accomplished
- Processes not documented for all shifts to use
- Job boards or check-off lists not kept up to date

4. Between crew and lead

- Lead fails to communicate important information to crew
- Poor verbal turnover or job assignment at the beginning of a shift
- Unclear roles and responsibilities
- Lead does not provide feedback to crew on performance
- Crew fails to report problems and opportunities for improvement to lead
- Communication tools (written, phones, radios, etc.) not used

5. Between lead and management

- Little or no communication exists
- Goals and plans not discussed regularly
- No feedback from management to lead on performance
- Lead does not report problems and opportunities for improvement to management

- Management fails to communicate important information to lead

6. Other

- Computer or network malfunctions lead to loss of information
- E-mail not used or ignored

Types of Error Prevention Strategies

There are four broad categories for error prevention strategies. These are as follows:

Error Reduction/Error Elimination

The most often used, and most readily available, error prevention strategies are those that directly reduce or eliminate the contributing factors to the error. Examples include increasing lighting to improve inspection reliability and using Simplified English procedures to reduce the potential for mis-interpretation. These error prevention strategies try to improve task reliability by eliminating any adverse conditions that have increased the risk of maintenance error.

Often, the individual error investigation does not yield contributing factors with strong linkages to the error under investigation. Sometimes the effect of certain contributing factors is not fully understood until a number of events are investigated with the same contributing factor(s) related to them. The difficulty for the front-line manager performing an investigation is the pressure to take action resulting from a single event investigation. The dilemma, however, is how to decide on a prevention strategy when you do not have any strong identifiable contributing factors leading to the error. What if the error had safety implications? Somehow, the error must be addressed. Two additional types of error management strategies are available to address error.

Error Capturing

Error capturing refers to tasks that are performed specifically to catch an error made during a maintenance task. Examples include a post task inspection, an operational or functional test, or a verification step added to the end of a long procedure. Error capturing is different than error reduction in that it does not directly serve to reduce the "human error." For example, adding a leak check does little to reduce the probability of a mis-installed chip detector. It does, however, reduce the probability that an airplane will be dispatched with a mis-installed chip detector. This is why most regulatory authorities require a subsequent inspection of any maintenance task that could endanger safe operation of the airplane if performed improperly.

While error capturing is an important part of error management, new views point to a general over-confidence in the error capturing strategy to manage maintenance error. In theory, adding a post-task inspection will require two human errors to occur in order for a maintenance-induced discrepancy to make it onto a revenue flight. In recent years, however, there has been a growing view that the additional inspection to ensure the integrity of an installation will adversely impact the reliability of the basic task. That is, humans consciously or subconsciously relax when it is known that a subsequent task has been scheduled to "capture" any errors made during the primary task. It is not unusual to hear an airline manager say that the addition of an inspection did little to reduce the in-service experience of the error. For example, several major carriers are pulling inspections out of scheduled line-maintenance tasks, in the hopes of improving quality.

Error Tolerance

Error tolerance refers to the ability of a system to remain functional even after a maintenance error. The classic illustration of this is the 1983 Eastern Airlines loss of all three engines due to mis-installed chip detectors. As a strategy to prevent the loss of multiple engines, most regulatory authorities granting ETOPS (extended twin operations) approval prohibit the application of the same maintenance task on both engines prior to the same flight. The theory is that even if a human error is made, it will be limited to only one engine.

This was not the case in the Eastern loss of all three engines. One series of human errors, the same incorrect application of a task applied to all three engines, nearly caused an airplane to be lost.

Another example of building error tolerance into the maintenance operation is the scheduled maintenance program for damage tolerant structures (allowing multiple opportunities for catching a fatigue crack before it reaches critical length).

Error tolerance, as a prevention strategy, is often limited to areas outside the control of the first line investigator. However, it is important for the first line supervisor or investigator to be aware of this type of prevention strategy, and consider it when it may be the best way to effectively deal with the error.

Audit Programs

Audit programs refer to an approach that actually chooses not to directly address the error. In other words, by not directly trying to reduce/eliminate the error, or increase the tolerance for the error, the organisation chooses to do something else. What this can include is a high-level search of the organisation, to see if something can be done that will serve as a prevention strategy. Examples of these types of strategies are independent audit programs and special investigation training. Airlines typically implement audit projects or programmes as a quick fix in response to errors. Yet, these programmes are rarely effective over the long-term in reducing error because the short-term awareness that results from them wears off, and the organisation is not able to achieve any long-term change.