Only human

As long as humans are working in aviation there will be human error.

Human factors expert Patrick Hudson explains how these errors can be managed and minimised in maintenance operations.

SOON AFTER DEPARTING Sydney on an international flight, the crew of a Boeing 747-400 noticed that the oil levels on the number one and two engines were falling.

Fortunately the aircraft was close enough to its departure point to land without needing to shut down any engines during the flight. On the ground, oil was seen leaking from the engines.

The problem? Missing O-rings. During overnight maintenance, engineers had carried out borescope inspections on all four engines. This usually involved removing and refitting each starter motor. The starter motors were removed from the number one and two engines in preparation. But the tool that enabled the engines to be turned by the starter drive was lost.

The starter motors for engines three and four were not removed and all engines were turned by another method.

Because there were not enough spares, O-rings were not replaced when starter motors were refitted. This time, however, a mechanic had followed the documented procedures and removed the O-rings from the number one and two starters, anticipating O-ring replacement.

But the workers who refitted the starters assumed the situation was normal and did not notice that the O-rings were missing. Had the job proceeded as planned, the starter motors would have been removed from all four engines, with potentially fatal consequences.

This true story illustrates how routine violations of maintenance procedures can trigger accidents. In this case, the problem was prevented from becoming serious thanks only to an alert flight crew.

Human errors and deliberate violations are implicated in many accidents and incidents. As the reliability of technology increases, the proportion of causes contributed by humans will increase.

Human error is not the end of the story, despite a long history of investigations that stop there. In aviation, human error has often been termed pilot error and provides a convenient excuse to look no further.

Australian investigations into aviation incidents have shown how weaknesses in maintenance operations can create potentially catastrophic situations inherited by the flight deck.

A 1997 study by Australia's Bureau of Air Safety Investigation showed that omissions were the most frequent type of maintenance error, accounting for 48 per cent of the total, followed by errors of commission (27 per cent), substitutions (12 per cent) and mistimed actions (3 per cent).

Preventive maintenance Modern safety management replaces the "if it ain't broke, don't fix it" breakdown maintenance mentality with preventive, or condition-based,maintenance.

Condition-based maintenance is heavy on inspection, often non-destructive inspection, and this requires closer management.

Components must be taken apart and reassembled, opening the process up to failure. Removal, dismantling and replacement can make a system that was perfect before maintenance hazardous after it.

In contrast to traffic violations, which are often due to bad attitude, industrial violations generally happen because people want to do their best. When on-time departures are seen as imperative, people will do just about anything to meet deadlines. Violations are intentional, but when things suddenly go awry, the outcomes are not intended.

The simplest errors, slips and lapses happen when someone fails to do what they had originally intended. They had a good plan but failed to perform it correctly. Mistakes,meanwhile,involve executing a bad plan.

Slips Slips involve performing the wrong action instead of the intended, right one. Examples are:

• pressing the wrong switch – the emergency oxygen in a Boeing 777, for example,causing all the face-masks to descend, rather than activating the single emergency oxygen supply for a heart patient.

• selecting a switch, but getting an unexpected result, like engine start, because you turned the wrong switch.

Lapses Lapses are actions, such as a check or step in a sequence, not performed. Examples are:

• forgetting to insert or check that the undercarriage locking pins are in place

• missing a step in a checklist due to interruptions.

Mistakes Mistakes involve unintentionally doing the wrong thing. You choose an erroneous plan or action to achieve your goal. Examples are:

• believing all the wheels on a 747 are down and locked because you have three greens. However 747 classics have five greens on the engineer's panel so you would be heading for a nose wheel up landing.

> "The two main reasons for error are that as creatures of habit we do what worked last time and we skip steps when we are in a hurry."

• believing you are on the correct runway and, armed with a clearance, attempting to take off from a runway under construction.

Oops Most slips are quickly spotted and are usually benign. Your brain is prepared for what comes next, and if there is a sudden inconsistency, you get an "oops" message.

Lapses are clear when you know what you forgot to do, but you might be oblivious until things go wrong, so lapses can be more dangerous than slips. Many people have a nagging feeling that they have forgotten something, even when they are not immediately sure what it is, however.

Mistakes are more complicated. People do what they intended but regret the intentions. While slips and lapses are failures to carry out a good plan, mistakes involve carrying out a bad plan. It can take a long time before the gap between what should be happening and what is happening becomes noticeable.

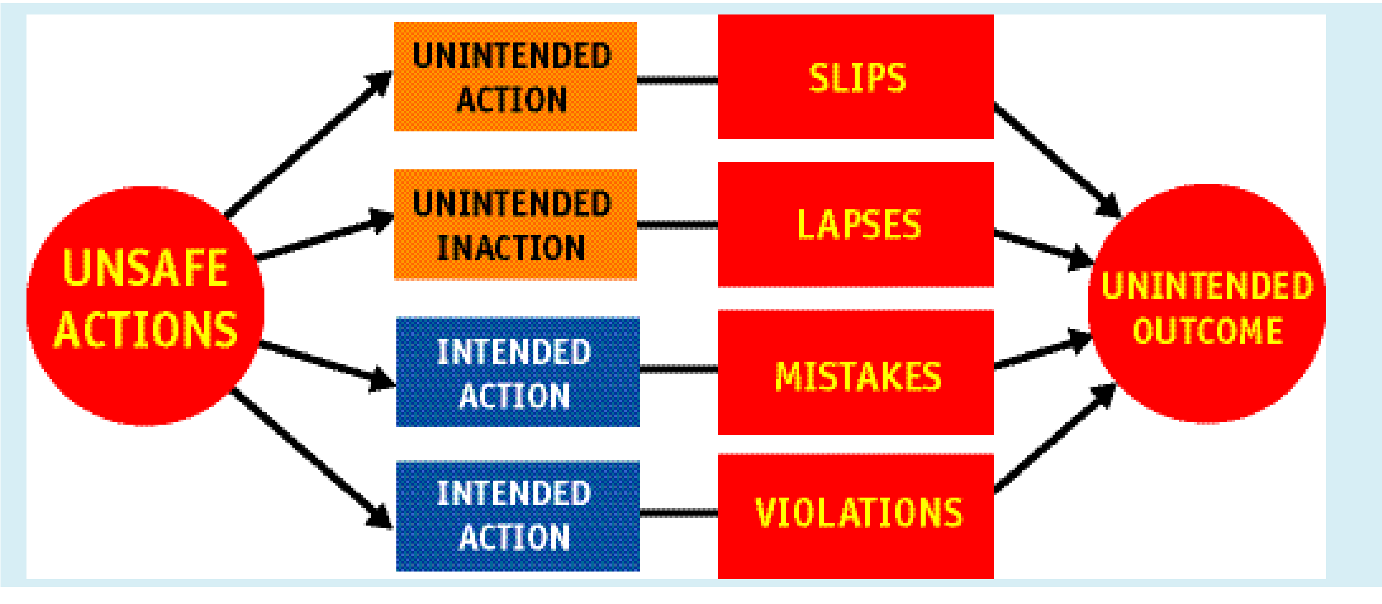
Causes Why do people make errors? Human error is the consequence of what makes us so successful. Our species is very clever, far smarter than machines. We are flexible enough to cope with a world in flux. This flexibility enables us to do more than one thing at once and to solve problems before we have all the information to hand. The downside is that occasionally we do the wrong thing. We fail to juggle several simultaneous tasks, and we draw the wrong conclusions from limited data.

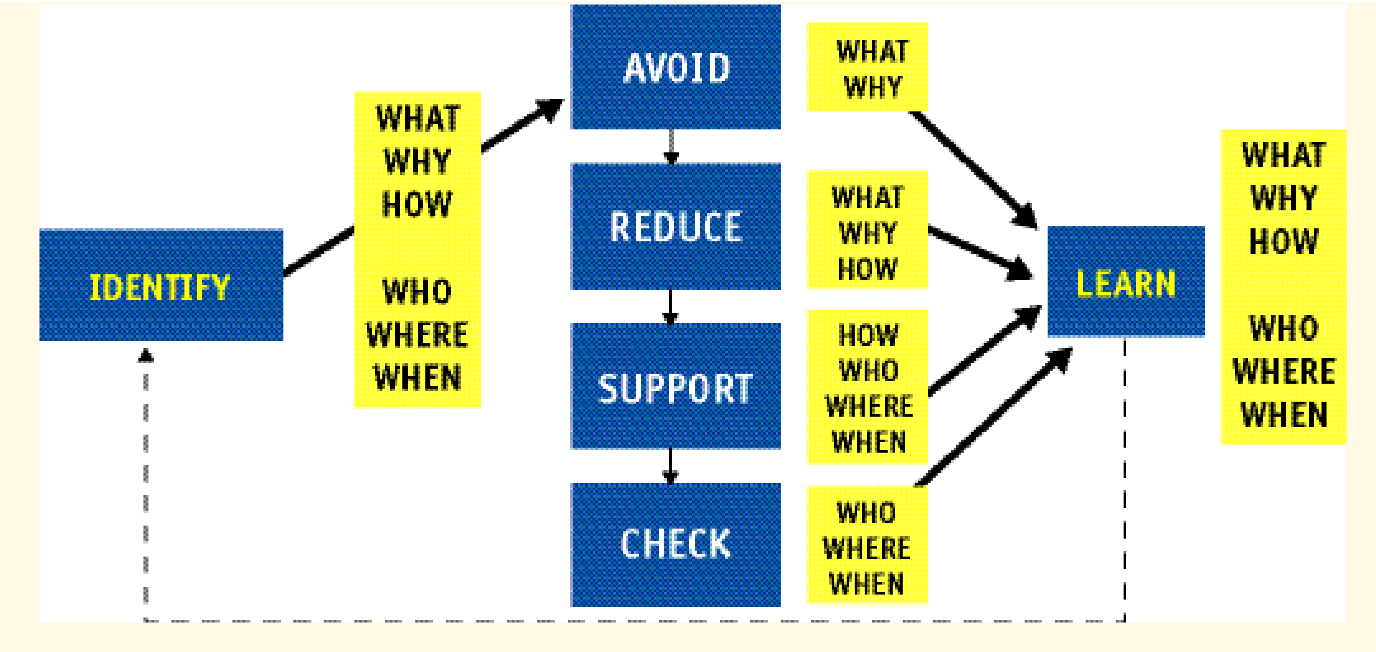
Is there anything we can do about this? We can never eliminate error completely, but we can understand what makes errors more or less likely – the error producing conditions – and design our machines and practices to survive the occasional one. We need to identify the conditions that make errors likely, and systematically fix them.

The two main reasons for error are that, as creatures of habit, we do what worked last time and we skip steps when we are in a hurry. This explains why we slip, lapse and make mistakes. Add a desire to please, and we get violations as well.

Habit, reduced attention and triggering conditions – situations in which conditions are misleadingly familiar – can lead to slips.

Most actions require attention to ensure they are progressing properly, after which they can be left to run to a natural close.





However, if the workload is too high, problems arise. When they are pressured by too much work, people shed their load by letting familiar tasks run without checks, concentrating on areas that seem to need it. Poor or non-existent task planning can often lead to a workload that creates the conditions for slips.

Over-attention also is a problem because it diverts attention from other tasks. And if people don't have enough to do, they can be insufficiently aroused to carry out the necessary checks on their actions.

Triggering conditions can be related to the design, equipment or tools. When people are easily confused or misled by what they think they see – a cockpit display, for example – they might do what they usually do, and this could be the wrong action under the circumstances.

Many of the causes of lapses are the same as those of slips, with a memory component added. Often one person's lapse is another's slip. As soon as someone has to remember something, whether it is an action, a check or just tallying how often an action has been performed, the possibility of forgetting arises.

We must remember why we want to perform an action. Intention memory is a concept easily recognised by anyone who's ever found themselves in front of an open refrigerator, wondering why. And once we have started a sequence of actions, we have to remember where we are in the sequence. When actions are repeated, we have to keep count.

Lapses are caused by factors affecting memory. Solutions may be palliative, helping failing memory, rather than eliminating the problem.

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Mistakes happen for many reasons. People can become fixated on a solution, overlooking alternatives, or they can take too much into consideration. Both too narrow and too wide a focus can trigger mistakes. The solution lies in training people to take systematic approaches to problem recognition and solution.

People must possess all the information necessary to solve a problem, but they might be unaware they lack the necessary data.

Rule-based mistakes involve the nature of the rules themselves. Too many rules, especially if they have slightly different applications, can confuse and make it difficult to apply the relevant rule. We tend to recognise new problems as old ones, overlooking small but important differences that dictate which rule applies.

One approach to error is to forbid it. This is ineffective because most errors are unintentional. Even violations are rarely intended to create harm. They are sometimes a response to the need to get the job done in impossible circumstances.

The second approach is to remove the reasons, such as haste, lack of knowledge and difficulty, for the error. In today's commercial environment, maintenance will, at times, be performed under time pressures, however.

The third approach is to recognise that human error is part of being human, and devise solutions to manage it.

Managing errors

1. Identify:

• the type of technical problem (O-rings omitted, lockwires left off, avionics systems miscalibrated, thrust reversers damaged)

• the type of human errors associated with the problem (slip, lapse)

• the immediate and organisational causes of the errors

• the sort of people making the errors – experienced (violations) or inexperienced (competency and adequacy checking)

• when the problem is happening – during major maintenance, short-term work, at a certain time of the day or year.

2. Examine the equipment and task to see if problems should arise at all. Regulatory requirements for preventive maintenance often mean that avoidance is not the preferred solution, but you might set avoidance as a longer term goal once you have examined the consequences of the problem in detail.

3. Reduce the problem. Avoidance means managing a problem away but reduction can be the first approach to managing around a problem.

There are two basic reduction strategies. One involves lowering the probability of failure by reducing error-enforcing conditions. Many slips and lapses are caused by high work-tempo requirements, incorrect placement of components or reliance on memory.

Many mistakes are caused by unclear or conflicting procedures, or by too many procedures. Systemic solutions are the most effective. They do not eliminate error, but mitigate the cause or consequences.

4. Support the process by acknowledging the error and tackling it head-on. Support requires a good understanding of the type of error and of the immediate conditions that make it more likely. Although reduction might help by easing work stress enabling tighter focus on a problem area, support might involve setting up conditions to arrest wandering attention.

5. Check each other's work systematically. Checking and inspection should reduce the chances of an error. However, this is a limited measure because so many problems are built in. The check has to take place before the problem is hidden.

A missing O-ring is hard to see, but a system ensuring that the old and new components are accounted for would make the problem obvious.

6. Learn what the problems are, where they are concentrated and how they are best managed. Taking on problems one at a time as they are identified and dealt with is a good tactical approach. It is also essential to take a strategic line by examining the wider picture of organisational and systemic issues.

Spread the word A crucial final step is sharing information with manufacturers,airlines and regulators to improve designs, practices and regulation.

Managing lapses Omissions are the most frequent errors in aircraft maintenance,and memory aids can help. Checklists are among the main aids but are not always the solution, as many failures are attributed to checklists that were skipped.

Stencilling simple checklists at the location of an assembly task makes it easy to do the right things in the right order. Another technique involves using a container to separate old and new parts. When the work is finished, the container of new parts should be empty and the container of old parts,full. Painting tool outlines on a board makes it easy to see which tools are out.

Counts are crucial in many situations. Are all the lockwires in? Have all the bolts been torqued?

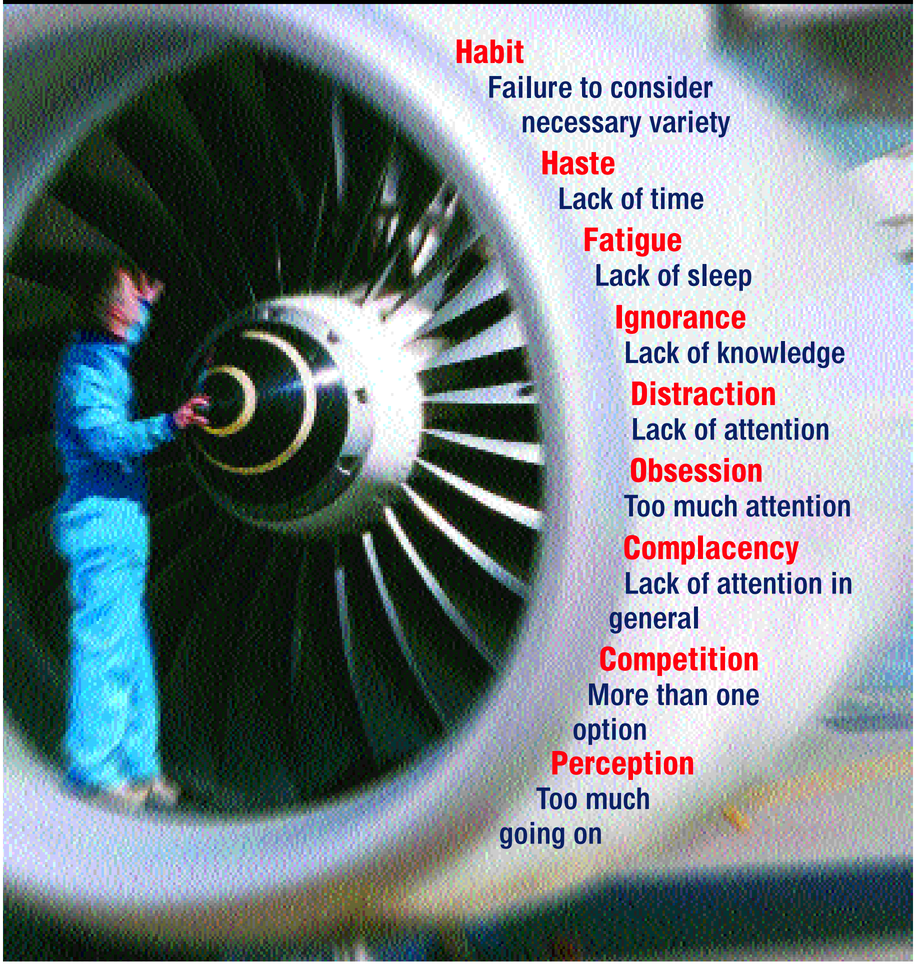
Solutions can be found when memory is replaced by perception. For instance, when replacing lockwires, one approach requires the mechanic to remember, while another, more effective one, uses a storage bag. When the bag is empty, nothing has been forgotten.

Managing error is a complex and time-consuming process.

But half the fight is recognising that errors will happen, and using experience to devise practices that are less error-prone.

Adapted from Patrick Hudson's Managing Errors and Violations, soon to be published by CASA

Error enforcing conditions



How to mitigate errors

Identifying – Find out where maintenance problems occur, discover what types of error are being made and identify the immediate causes.

Avoiding – Is it possible to avoid the problem completely? Areas that continually give rise to maintenance errors need to be identified and redesign considered.

Reducing – Are there measures available that will either reduce maintenance needs (lower frequency) or minimise the consequences? Is it possible to make failures more obvious? Are there alternative procedures available that will be less susceptible to error? Can dis-assembly be reduced?

Supporting – Identify the type of errors being made and provide support. Providing checklists, local reminders and prompts can reduce memory problems.

Checking – If all else fails, put in place a procedure that requires another person to check.

Learning – Provide information about what was discovered and how it was managed to other interested parties such as manufacturers, airlines and regulators.