Australian Government
Civil Aviation Safety Authority

SMS 6

SMS FOR AVIATION–A PRACTICAL GUIDE | 2ND EDITION

Human factors

Contents

For further information visit **www.casa.gov.au/sms**

The case studies featuring 'Bush Aviation and Training' and 'Outback Maintenance Services' are entirely fictitious. Any resemblance to actual organisations and/or persons is purely coincidental.

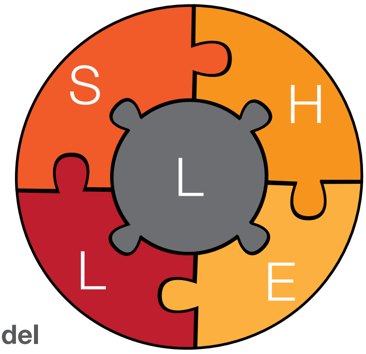
Understanding human factors

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

The term human factors can mean many things to many people, and trying to understand all its implications can be daunting. Perhaps because the term is often used following human error of some type, it is easy to think of it negatively. However, there are two sides to human performance: the downside is the capacity to make mistakes, but the equally important upside is our human capacity to be flexible and adaptable when solvng complex problems, and often to resolve situations with limited information. So human factors also includes all the positive aspects of human performance: the unique things human beings do well.

The primary focus of any human factors initiative is to improve safety and efficiency by reducing and managing human error made by individuals and organisations.

Human factors is about understanding humans—our behaviour and performance. Then, from an operational perspective, we apply that human factors knowledge to optimise the fit between people and the systems in which they work, to improve safety and performance.



The SHELL model

ICAO uses the SHELL model to represent the main components of human factors. The letters SHELL stand for:

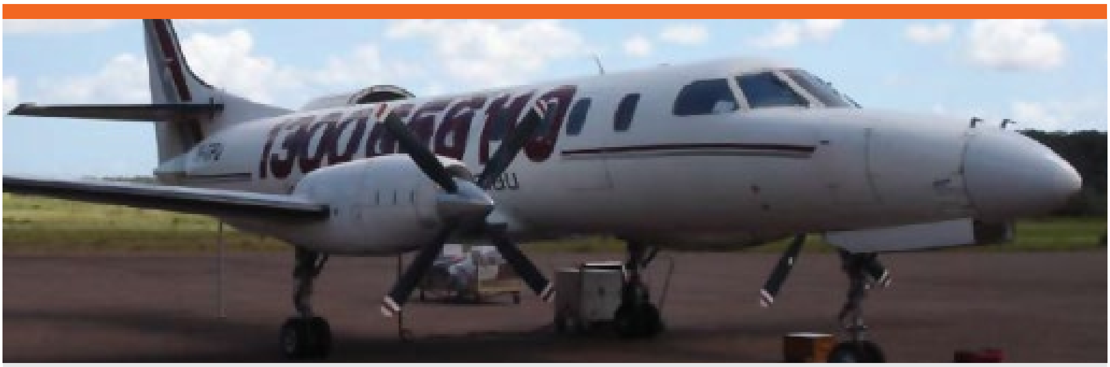
- **S = software:** the procedures and other aspects of work design
- **H = hardware:** the equipment, tools and technology used in work
- **E = environment:** the environmental conditions in which work occurs, including the organizational and national cultures influencing interaction
- **L = liveware:** the human aspects of the system of work
- **L = liveware:** the interrelationships between humans at work

The SHELL model emphasises that the whole system shapes how individuals behave. Any breakdown or mismatch between two or more components can lead to human performance problems.

The ICAO SHELL model is a conceptual framework proposed in ICAO Circular 216-AN31. Edwards developed the concept in 1972, with an extra L-liveware added in 1975 to the centre 'L'—culture etc. (The name SHELL comes from the first letter of each of the components.)

For example, an accident where communication breaks down between pilots in the cockpit, or engineers at shift handover, would be characterised by the SHELL model as a liveware-liveware problem. Situations where pilots or engineers disregarded a rule would be characterised as liveware-software.

A case study illustrating some of the key human factors issues arising from the controlled flight into terrain accident at Lockhart River, Queensland, in 2005 is on page 2.



Controlled flight into terrain | case study

On 7 May 2005, a Fairchild Aircraft Inc. SA227-DC Metro 23 aircraft, registered VH-TFU, with two pilots and 13 passengers, was being operated by Transair on an IFR regular public transport service from Bamaga to Cairns, with an intermediate stop at Lockhart River, Queensland.

At 11:43:39 Eastern Standard Time, the aircraft crashed in the Iron Range National Park on the north-western slope of South Pap, a heavily timbered ridge, approximately 11km north-west of the Lockhart River Aerodrome. At the time of the accident, the crew was conducting an area navigation global navigation satellite system (RNAV [GNSS]) non-precision approach to runway 12. The aircraft was destroyed by the impact forces and an intense, fuel-fed, post-impact fire. There were no survivors.

According to the Australian Transport Safety Bureau (ATSB) investigation report, the accident was almost certainly the result of controlled flight into terrain; that is, an airworthy aircraft under the control of the flight crew was flown unintentionally into terrain, probably with the crew unaware how close the aircraft was to the ground.

The investigation report identified a range of contributing and other human factors safety issues relating to the crew of the aircraft, including:

- The crew commenced the Lockhart River runway 12 approach, even though they were aware that the co-pilot did not have the appropriate endorsement and had limited experience of conducting this type of instrument approach.
- The descent speed, approach speed and rate of descent were greater than those specified for the aircraft in the Transair operations manual.
- During the approach, the aircraft descended below the segment minimum safe altitude for its position on the approach.
- The aircraft's high rate of descent, and the descent below the segment minimum safe altitude, were not detected and/or corrected by the crew before the aircraft collided with terrain.
- The crew probably experienced a very high workload during the approach.
- The crew probably lost situational awareness of the aircraft's position along the approach.
- The pilot in command (PIC) had a previous history of conducting RNAV (GNSS) approaches with crew without appropriate endorsements, and operating the aircraft at speeds higher than those specified in the Transair operations manual.
- The co-pilot had no formal training and limited experience to act effectively as a crew member during the type of approach conducted into Lockhart River.

ATSB Transport Safety Investigation Report 2005 019.77: 'Collision with terrain; 11km, Lockhart River Aerodrome'.

above: VH-TFU at Bamaga Aerodrome on a previous flight (Photo courtesy of ATSB)

If we apply the SHELL model to the Lockhart River accident, we can quickly see that there is a poor fit between a number of the different components in the SHELL model.

What led to the accident goes far beyond the actions of the pilot in command alone:

» **Software–liveware mismatch:** there were contradictory and unclear procedures for conducting instrument approaches. The company operations manual did not provide clear guidance on approach speeds, or when to select aircraft configuration changes during an approach. It also had no clear criteria for a stabilised approach, nor standardised phraseology for crew members to challenge others' safety-critical decisions.

» **Hardware–liveware mismatch:** the aircraft was not fitted with any terrain awareness and warning system, such as an enhanced ground proximity warning system.

» **Environment/culture–liveware mismatch:** there were significant limitations in the operator's flight crew training program, such as the superficial or incomplete ground-based instruction, no formal training for new pilots in the operational use of GPS, no structured training on minimising the risk of controlled flight into terrain, and no structured training in crew resource management in a multi-crew environment. There was also a lack of independent evaluation of training and checking, and a culture suggesting disincentives and restricted opportunities to report safety concerns about management decisions.

» **Environment–liveware:** the crew experienced a very high workload during the approach. The lack of visibility and poor weather also contributed to their poor situational awareness.

» **Liveware–liveware mismatch:** the pilot in command did not detect and correct the aircraft's high rate of descent, and the descent below the segment minimum safe altitude before the aircraft crashed. The co-pilot did not have the appropriate endorsement and had limited experience of this type of instrument approach.

This example illustrates how important it is to understand the human contribution to an accident in context, rather than simply labelling what somebody did as 'operator error'.

Human factors training

If you are an airline operator (CAO 82.3 or 82.5) or an approved maintenance organisation (Part 145), you must provide regular human factors skill-based training programs. ICAO requires human factors training to skilled level for pilots, cabin crew, and other safety-critical personnel. Human factors training for maintenance personnel is also required up to the skilled level. These human factors training programs are often referred to as crew resource management (CRM) training for aircrew, and maintenance error resource management (MRM) programs for maintenance personnel.

Human factors training should focus squarely on providing aviation safety-critical personnel with the *non-technical skills* to manage the prevention/consequences of human error. This implies that making errors is normal and expected. The consequences of error are just as important as the cause/s.

Non-technical skills are the decision making and social skills that complement technical skills. For example, inspecting an aircraft engine using a borescope is a technical skill performed by a licensed maintenance engineer (LAME). However, maintaining situational awareness (attention to the surrounding environment) during the inspection of a wing, to avoid tripping over hazards, is a non-technical skill.

In 2009, CASA produced a comprehensive resource guide and accompanying DVD on this topic called *Safety Behaviours: Human Factors for Pilots*. The non-technical skills covered in that resource guide are outlined on page 4. A corresponding HF resource guide for engineers *Safety Behaviours: Human Factors for Engineers* was released in 2013.

(For more information go to **www.casa.gov.au/hf**)

Main categories and elements of non-technical skills

Non-technical skill categories	Elements
Managing fatigue	Identifying symptoms of fatigue Recognising effects of fatigue Implementing fatigue-coping strategies
Managing stress	Identifying symptoms of stress Recognising effects of stress Implementing stress-coping strategies
Alcohol and other drugs (AOD)	Recognising the effects of AOD use Identifying risk factors and symptoms of AOD use Implementing strategies to maintain fitness for duty Awareness of AOD testing
Team-based cooperation and coordination	Supporting others Solving conflicts Exchanging information Coordinating activities
Decision making	Defining the problem Considering options Selecting and implementing options Reviewing the outcome
Situational awareness	Gathering information Interpreting information Anticipating future states (Or simply, asking: ‘what has happened?’; ‘what is happening?’; ‘what might happen?’)
Communication	Sending information clearly and concisely Including context and intent during information exchange Receiving information, especially by listening Identifying and addressing barriers to communication
Leadership and followership	Using authority Maintaining standards Planning and prioritising Managing workload and resources

Safety Behaviours: Human Factors for Pilots. Civil Aviation Safety Authority, Australia (2009).

Two important strategies underpin these non-technical skills.

1. Error management strategies and performance criteria

Error management strategies	Performance criteria
Threat and error management	Recognise and manage errors Recognise and manage threats Recognise and manage undesired aircraft states
Airmanship	Maintain effective lookout Maintain situational awareness Assess situations and make decisions Set priorities and manage tasks Maintain effective communication and interpersonal relationships

Safety Behaviours: Human Factors for Pilots. Civil Aviation Safety Authority, Australia (2009).

2. Error management strategies and performance criteria

Error management strategies	Performance criteria
Error management	Identify and eliminate error-promoting conditions Recognise and manage errors
Professionalism	Maintain discipline–follow approved procedures to perform a given task Assess situations–know what's going on around you Make decisions–take decisive actions Set priorities and manage tasks–prioritise safety above personal concerns Maintain effective communication and interpersonal relationships Expert knowledge–maintain currency

Safety Behaviours: Human Factors for Engineers. Civil Aviation Safety Authority, Australia (2013).

You should continue to develop your staff's non-technical skills as a priority. It makes sense: non-technical skills are one of your primary defences in reducing errors.

The crucial role non-technical skills play in aviation safety is illustrated in the following maintenance case study.

The O-rings case study on page 6 illustrates how routine violations of procedures can creep into any organisation, and ultimately, trigger an accident. A systematic and thorough approach to human factors should therefore be a core part of any SMS.

Missing O-rings | case study

Soon after departing Sydney on an international flight, the crew of a Boeing 747-400 noticed that the oil levels on the No.1 and 2 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 No. 1 and 2 engines in preparation, but the tool that enabled the engines to be turned by the starter drive was lost. The starter motors for engines 3 and 4 were not removed, and all the engines were turned by another method. Because there were not enough spares, the O-rings were not replaced when the starter motors were refitted. This time, however, a mechanic had followed the documented procedures and removed the O-rings from the No. 1 and 2 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' O-rings would have been removed from all four engines, with potentially fatal consequences.

Errors and error management

> **'Making errors is about as normal as breathing oxygen.'**
>
> James Reason

Error is a normal and natural part of everyday life—it is generally accepted that we will make errors daily. In fact, research suggests that we make between three to six errors every waking hour, regardless of the task being performed.

While this may appear to be a large number of errors, the good news is that the vast majority have no serious consequences, because they are automatically self-corrected: somebody or something reminds us what we should be doing, or the errors we make do not involve a potential safety hazard.

Imagine that you drive the wrong way to the local shops. As you leave home, you turn down the wrong street and realising this, you alter your course (self-correction), or the passenger in your car says something (passenger reminds us where we were going), or you continue on the wrong route (wasting time). Similarly, a pilot forgetting to perform a checklist can be picked up by another crew member, or a warning system on the aircraft; likewise a maintenance error by a dual inspection The term 'near-misses' describes errors that occur, but are corrected before any damage is caused.

Some people refer to the terms *human factors* and *human error* as if they are the same. Human factors is a field of scientific knowledge drawing from established disciplines such as ergonomics, physiology, psychology and engineering. Human error is really the *outcome* or consequence of our human performance limitations.

Therefore human error involves all those situations where what you planned to do did not happen. For example, forgetting to set the parking brake in your car, or hitting the brakes in wet and slippery road conditions.

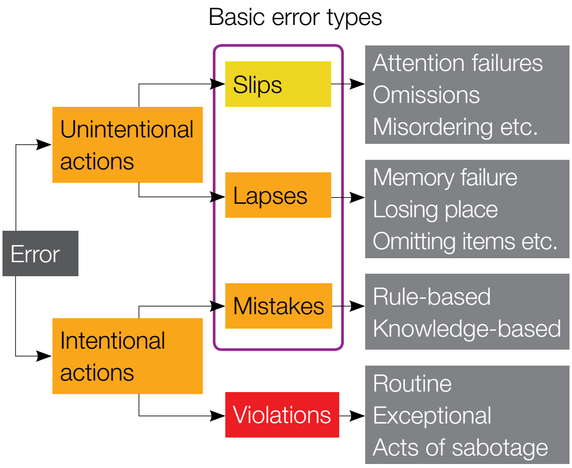
Unintentional errors, violations and unsafe acts

Human error can be divided into either intentional or unintentional actions.

- **Intentional actions**—those actions that involve conscious choices. These actions are largely due to judgement or motivational processes.
- **Unintentional actions**—those in which the right intention or plan is incorrectly carried out, or where there is a failure to carry out an action. These actions typically occur due to attention or memory failures.

The figure below illustrates the difference between unintentional and intentional actions:

Unintentional and intentional actions



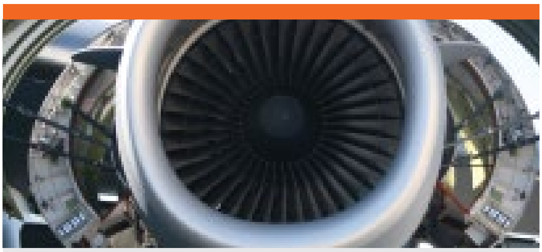
Adapted from *Human Error*, J. Reason, Cambridge University Press, Cambridge (1992).

Slips are errors made when you don’t pay attention, or your plan is incorrectly carried out (e.g. you intend to drive to the shops, but turn the way you usually do to go to work).

Slip on ladder | case study

A maintenance engineer was supervising aileron repair work when he lost his balance as he attempted to climb down a ladder. The engineer’s foot slipped as he stepped on the top rung of the ladder, trapping his foot between the platform and ladder rung. His leg then acted as an anchor as he fell, taking the full force of the fall. A workmate standing beside the engineer managed to rescue him before he could fall to the ground below. The engineer was wearing safety footwear and the platform surface was in a dry and clean condition. The platform had no handhold to assist a person ascending or descending the ladder, and the guard rails were not erected correctly. The engineer was distracted by the presence of another worker nearby and was not paying attention to where he placed his foot on the ladder rung.

Lapses occur as a result of you failing to carry out an intended action, usually due to a memory failure (you forget to buy something at the shop). For example, you forget to check that the undercarriage locking pins are in place.



Forgetting to latch fan cowl door | case study

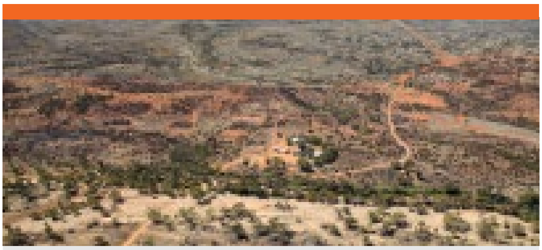
On 20 January 2000, as an Airbus A-320 aircraft rotated on take-off from London's Gatwick Airport, both fan cowl doors detached from the No. 1 engine and struck the aircraft. The doors were destroyed and localised damage resulted to the No. 1 engine and its pylon, the left wing, the left flaps and slats, the fuselage and the fin.

It is likely that the doors had been closed following maintenance, but not securely latched before the accident. When the doors are closed, there are no conspicuous cues to indicate they are unlatched and no indication on the flight deck. Similar incidents have occurred on at least seven other occasions worldwide.

(Ref. UK AAIB Bulletin 7/2000)

Mistakes occur when you plan to do something, and carry out your plan accordingly, but it does not produce the outcome you wanted (the shop does not sell the item you are looking for). This is often because your knowledge was inadequate, or the rules you applied in deciding what to do were inappropriate.

Violations involve deliberately (and consciously) departing from known and established rules or procedures (you speed on the way to the shops to get there more quickly).



Lost? Just land and ask directions | case study

A pilot of a Cherokee Six became lost on a flight from Uluru to Alice Springs. He decided to land on a gravel road to ask passing traffic where he was. On final approach, it became evident the area of road selected was unsuitable, but the pilot persisted with the landing. After touching down, the aircraft struck trees on the side of the road and crashed.

The aircraft was damaged beyond repair but the six occupants escaped unhurt. There was no pressing reason why the pilot had to land so hastily - the weather was good, the day was young and he had at least three hours of fuel remaining. The pilot could have climbed to a higher altitude to help him establish his position, or used the road as a navigation aid.

The table below provides examples of different violation types and describes their main causes.

Different types of violation and main causes

VIOLATION TYPE	DEFINITION	MAIN CAUSES
Routine For example, relying on memory to perform a checklist	Frequent, known and often condoned	» We think the rules are unnecessary or too rigid » We are poorly supervised
Situational For example, not using the proper work stand or light during wing inspection, as wing stand is broken and time is short	Adapting to the problems in the workplace	» We don't have enough help to do the job, or there is not enough time due to poor planning » We find that the procedures are too complicated or onerous
Optimising (personal or organisational)	Self before safety (personal)	» We break a rule because it is more convenient for us
» personal – for example, doing a cursory examination of the aircraft to get out of the cold weather	Thrill-seeking (personal)	» We are bored, or the job is monotonous so we look for things to do
» organisational – not following all the required procedural steps for expediency turnaround in aircraft	Trying to achieve production goals (organisational)	» We want to please the customer or get the job done for the boss or organisation
Exceptional For example, ignoring the pre-landing checklist on final approach to take evasive action due to traffic conflict	Rare, one-off acts in novel or unfamiliar situations	» There is a lack of a thorough, risk-based approach to training anticipating safety-critical scenarios » We are under extreme pressure to perform
Act of sabotage For example, not tightening a bolt so as to cause structural failure	Malevolent behaviour	» We fully intend to cause harm to life and/or property

Adapted from Safety Wise Solutions *Incident Cause Analysis Method (ICAM) Pocket Guide* (Issue 5, October 2010). Earth Graphics, Melbourne.

Routine violations—result when a violation becomes what is normally done (the norm) within your workplace, or for you as an individual. Routine violations are often short cuts taken to help you get the job done more quickly, more easily, or perhaps more efficiently. Unless you monitor and control this behaviour, it can lead to a culture that tolerates violations.

Routine short cuts | case study

During maintenance of a Lockheed L-1011 aircraft, aircraft maintenance engineers failed to fit O-ring seals on the master chip detector assemblies. This led to loss of oil and consequent engine failure during the aircraft's flight from Miami, USA, to Nassau, Bahamas, on 5 May 1983. The captain decided to return to Miami, and the aircraft landed safely with only one engine working. Investigation showed that the AMEs had been used to receiving the master chip detectors with O-ring seals already fitted and that informal procedures were in use regarding fitment of the chip detectors. This problem had occurred before, but no appropriate action had been taken to prevent a reccurrence.

(Ref. NTSB/AAR 84/04)

Situational violations—occur when there is a gap between what the rules or procedures require and what you think is available or possible. When there is a lack of local resources, or a failure to understand real working conditions, this may increase pressure on you to ignore procedures or break the rules to get the job done and achieve targets.

Situational violation | case study

On 2 November 1996, a Boeing 747's 4L door handle moved to the 'open' position during the climb after take-off. The captain elected to jettison fuel and return to Gatwick, and the aircraft landed safely. An investigation revealed that the door torque tube had been incorrectly drilled/fitted. The maintenance manual required a drill jig to be used when fitting the new undrilled torque tube, but no jig was available. The licensed aircraft maintenance engineer and fleet technical liaison engineer elected to drill the tube in the workshop without a jig, due to time constraints and the operational requirement for the aircraft. The problem with the door resulted from incorrectly positioned drill holes for the fasteners in the door torque tube.

(Ref. UK AAIB Bulletin 5/97)

Optimising violations—(personal or organisational) involve you doing something for *personal* goals, or simply for the associated thrills (for 'kicks'). However, where there are incentives, such as a bonus for meeting production targets, this may encourage *organisational* optimising violations. Identifying organisational optimising violations can assist in improving both productivity and safety goals within your organisation, if brought out into the open, communicated and discussed.


© Airbus Helicopters

Personal optimising violation | case study

In Athlone, Ireland, on 9 May 2008, a pilot landed his helicopter on the top of a multi-storey car park because he wanted to have keys cut at a nearby shopping centre.

The attendant at the Athlone car park, who claimed he had waved the small aircraft away from the empty roof when it tried to land in the previous July, said he was forced to take refuge behind a door to protect himself.

But he said he was injured when the downwash caused by the main rotor blew the door closed on his hand. The Air Accident Investigation Unit found the pilot, who believed he had permission to land, displayed poor airmanship and broke Irish air law.

'The shopping centre was open for business at the time and for obvious safety reasons the area should have been completely avoided.'

The investigation report noted the landing was contrary to the rules of the air and that the area was congested and should have been avoided.

Exceptional violations—these are one-off actions you might take to deal with an unusual situation, such as speeding to hospital rather than waiting for an ambulance, or jumping into a runaway vehicle to stop it hitting someone.

Exceptional violations | case study

A third-party contract worker, hired by the local aero club, was using a grinder with a frayed electric cord that was plugged into an improvised power outlet not rated for outdoor use. He was not wearing any personal protective equipment, did not have a fire extinguisher available while conducting the hot work, and was working while perched on a ladder without a safety observer.

Managing error

If you want to find actual solutions for the problems human errors cause, you often need large systemic changes. For example, you might have to modify maintenance rostering to combat fatigue, or revise your flight manuals to make them easier to interpret.

Another way is for you to build error tolerance into the system—limiting the consequences of errors when they do occur. This involves adopting a broad organisational approach to error management, rather than focusing solely on the individuals making the errors.

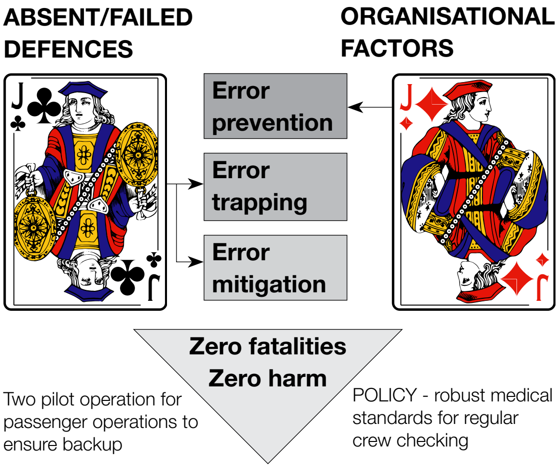
Error tolerance refers to the ability of a system to function even after an error has occurred. In other words, an error-tolerant system is one in which the results of making errors are relatively harmless. An example of building error tolerance is a scheduled aircraft maintenance program. Regular inspections will allow multiple opportunities for catching a fatigue crack in a wing before it reaches a critical length.

As individuals we are amazingly error tolerant, even when physically damaged. We are extremely flexible, robust, creative, and skilled at finding explanations, meanings and solutions, even in the most ambiguous situations. However, there is a downside: the same properties that give human beings such robustness and creativity can also produce errors.

Our natural tendency to interpret partial/missing information can cause us to misjudge situations in such a believable way that the misinterpretation can be difficult for us to discover. Therefore, designing systems that predict and capture error—in other words installing multiple layers of defences—is more likely to prevent accidents that result from human error.

Consider the following strategies to manage the risk of pilot incapacitation in-flight:

Error-tolerant solutions for pilot incapacitation



Two pilot operation for passenger operations to ensure backup

POLICY - robust medical standards for regular crew checking

TRAINING - Regular education on healthy lifestyle for crew

POLICY – AOD monitoring program

Adapted from Safety Wise Solutions *Incident Cause Analysis Method (ICAM) Pocket Guide* (Issue 5, October 2010)., Earth Graphics, Melbourne

This example shows that the best way to reduce the likelihood of pilot incapacitation is to implement good risk management (organisational factors in the Reason model) such as robust medical standards, regular crew education on healthy lifestyle choices and an alcohol and other drugs (AOD) monitoring program. However, to minimise the consequences of pilot incapacitation, you should also put effective controls (absent/failed defences in the Reason model) in place, such as a competent and trained second flight crew member.

Managing error - maintenance

Shift handover is a prime time for error in maintenance, so multiple defences to capture and prevent such errors are important. To minimise miscommunication because of the previous shift wanting to get away, a possible defence could be to have shift times overlap to allow for a more thorough handover; improved checklists and training/safety communication.

Some general organisational strategies to contain errors (reducing their potential for catastrophic consequences) and prevent errors (trying to avoid them occurring in the first place) are in the table below:

Error containment strategies

ERROR CONTAINMENT	SAMPLE STRATEGIES
Formalise acknowledgement that errors are 'normal'	» Policy signed by the CEO stating the importance of reporting errors » Safety investigation procedures acknowledging difference between intentional and unintentional errors
Conduct regular systemic analysis to identify common errors and build stronger defences	» Periodic staff discussion groups to identify errors and ways to manage them » Task analysis to identify error potential and effectiveness of current controls
Identify risk of potential errors through normal operations behavioural observation programs	» Independent peer-on-peer confidential observation program » Safety mentoring and coaching program to identify task-specific potential errors
Identify potential single-point failures (high risk) and build stronger defences	» Road testing of procedures to identify ease of comprehension prior to roll out » Ensure critical job roles have backup to avoid over-reliance on individuals
Include the concept of shared mental models in team-based training initiatives	» Focus on good operational examples of situational awareness and threat and error management in recurrent CRM training » Focus on good examples of error capture at shift handover at regular toolbox talks. » Use shift handover as an opportunity for team problem solving, where the incoming shift, with fresh eyes, may help to resolve any issues which have occurred during the outgoing shift.

Adapted from *Human Factors and Error Management training manual* (September, 2010). Leading Edge Safety Systems, in conjunction with IIR Executive Development, Sydney.

Error prevention strategies

ERROR PREVENTION	SAMPLE STRATEGIES
Reinforce the stringent use of checklists to combat memory limitations	» Establish 'non-negotiable' policy that states checklists, not memory, always to be used » Regular use of industry-based examples via safety alerts demonstrating the perishable nature of memory and potential outcomes
Standardise and simplify procedures	» Establish a technical committee that meets regularly to identify opportunities to rationalise procedures » Ensure corrective actions from safety investigations do not always rely on procedural changes
Identify jobs and tasks that are at risk of fatigue and introduce fatigue proofing strategies	» Focused fatigue countermeasures (e.g. breaks, staff backup, supervisor monitoring etc.) on those jobs that are safety-critical » Proactively identify fatigue-producing rosters through staff feedback
Use hazard or near-miss reporting systems to identify error management lessons	» Establish formal policy statement: 'a failure to report is a violation' » Regular feedback to staff via newsletter o r safety meetings of near-miss examples reported
Decrease reliance on personal vigilance via the strategic use of automation/technology	» Regular industry benchmarking to identify 'smart technology' to complement human operator

Adapted from *Human Factors and Error Management training manual* (September, 2010). Leading Edge Safety Systems, in conjunction with IIR Executive Development, Sydney.

These error management strategies are broad safety management goals. More specific error management initiatives can then be put in place based on different error types.

For example, the most common types of errors (slips and lapses) involve attention, vigilance and memory problems. Therefore, developing procedures (checklists that act as memory aids), designing human-centred equipment (alarms and warning devices if operationally critical items are forgotten) and training programs to raise awareness of human factors issues, are all common tools.

To reduce mistakes, getting your people to better understand the rules and ensuring an adequate transition time when rules are changed are useful strategies. You should also consider question and answer sessions, or trialling new rules before implementation.

Managing violations firstly involves finding their root causes. Punishing a violator is not always productive because the violation may be committed because of factors beyond the individual's control. While you should never tolerate dangerous and reckless behaviour, poor work planning or insufficient allocation of resources may have led to some individuals' routine or situational violations. Any person in the same situation might have found it difficult not to commit a violation (the substitution test).

Substitution test

Ask the individual's peers:

'Given the circumstances at the time of the event, could you be sure you would not have committed the same, or a similar, unsafe act?'

Practical strategies for managing violations are shown below.

Management strategies by error type

ERROR TYPE	SAMPLE STRATEGIES
Slips and lapses (attention & memory)	» Avoid 'over supervision' » Reduce the likelihood of interruptions or distractions that disrupt the work flow through planning and scheduling
Rule-based mistakes (poor use of rules)	» Conduct routine Q & A sessions on the rules so they are understood, not just followed blindly » Outline new rules when changing work activities so the rationale (why another change?) is clear » Regularly check on those leading the task – are they passing on bad habits? » Safety investigations include analysis of why the rules were wrongly used/ not followed
Knowledge-based mistakes (unfamiliarity or poor knowledge)	» Staff have access to appropriate training and procedures » Ensure staff do not have too much information, data or paperwork as this can cause selective attention. Practical checklist style summaries or work flow diagrams are best.

Adapted from *Human Factors and Error Management training manual* (September, 2010). Leading Edge Safety Systems, in conjunction with IIR Executive Development, Sydney.

Management strategies by violation type

VIOLATION TYPE	MANAGEMENT TOOLS
Routine	» Regularly rationalise/simplify rules e.g. do we really need it? » Reward compliance with procedures
Situational	» Make procedures realistic for the task » Involve employees in developing rules » Improve the level of supervision and resources
Organisational optimising violation	» Make rules easier to follow through aggressive simplification
Personal optimising violation	» Consider discipline through 'fair and just culture 'program
Exceptional	» Train employees for the unexpected, to avoid surprises » Regular training about what 'good' situational awareness and critical decision-making skills look like
Act of sabotage	» Performance management » Disciplinary action » Prosecution
All violations	» 'Fair and just culture' program

Adapted from *Safety Wise Solutions Incident Cause Analysis Method (ICAM) Pocket Guide* (Issue 5, October 2010). Earth Graphics, Melbourne.

Note: The concept of a 'fair and just culture' is discussed in Booklet 1 SMS Basics.

Relationship between human factors and SMS

Integrating human factors into your SMS is important: without a good HF program, safety management becomes difficult. It is unlikely that your SMS will achieve its full potential for improving safety performance without a full understanding and application of HF principles by all your staff to support a positive safety culture.

While the Australian aviation industry has achieved significant improvements in safety performance recently, this improvement has largely been driven by the development of government regulations and of effective safety management systems by industry operators.

The challenge now is to continue this improvement towards the next level of performance, where a concept of zero harm or a ‘nobody gets hurt’ culture is ingrained. Good safety behaviour contributes to productivity, and therefore safety improvement strategies must be seen as valuable and integral to all business processes. Regulations and safety management systems are merely mechanical unless organisations understand and value safety behaviour.

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Reasons to integrate human factors into an SMS

Avoid having a standalone human factors policy that gathers dust on a shelf. Such a standalone document does not recognise that human factors must be considered as routinely as other important SMS activities such as cost, risk and resources.

You can demonstrate integration of HF in your safety management system by including consideration of the following (as a minimum):

- Hazard identification, and risk assessment and mitigation
- Management of change
- Design of systems and equipment
- Training of operational staff
- Job and task design
- Safety reporting and data analysis
- Incident/accident investigation.

Integrating human factors into hazard identification and reduction

Your hazard identification program can reveal potential or actual errors and their underlying causes.

A simple example of considering human factors issues in the hazard management process is outlined opposite.

Human factors and hazard management checklist

☐ Do you consider HF issues in general risk assessments where hazards are identified?

☐ Are the HF issues involved with hazards understood?

☐ Are different error types with hazards recognised? Are the workplace factors that increase the error potential for hazards, such as high workload, distractions or inadequate equipment availability or design, considered?

☐ Do you consider human performance issues in regular staff workshops identifying potential safety hazards?

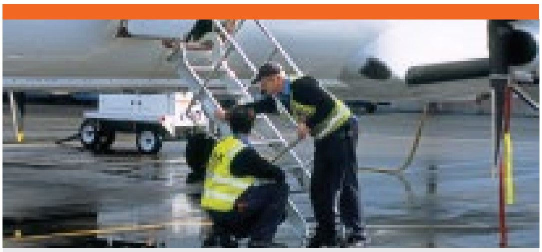
☐ Is your hazard reporting process user-friendly? Does it prompt users to consider HF issues? What errors might result if the hazard is not managed well?

☐ Have you identified the HF issues with the greatest implications for safety or performance?

☐ Is there a standard process to investigate and analyse HF issues?

☐ Do you note HF issues on your risk register?

☐ Do you keep clear records of how you have resolved these HF issues?



Human factors and hazard management | case study

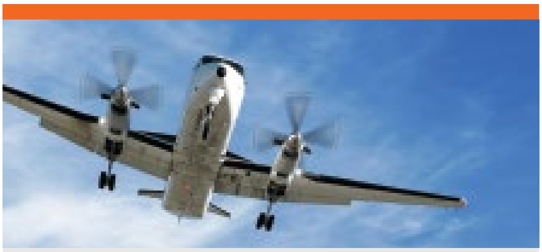
A pilot notices the mobile aircraft stairs being left unsecured, and the potential for the stairs to hit the aircraft, particularly in strong wind. The pilot reports this concern via the company hazard reporting process. The company safety manager considers the human factors issues involved, and, in talking with ramp staff, finds out that sometimes people forget (memory lapse) to secure the wheel brake properly. On inspecting the stairs, the safety manager finds that there are no signs on them to remind operators to activate the wheel brake. Simple human factors solutions would be to install a sign prompting operators to secure the wheel brake, and to ensure that all airport staff are regularly reminded of the danger of unsecured stairs.

Further solutions could be identified at a toolbox briefing.

Management of change

Any major change within your organisation has the potential to introduce or increase human factors issues. For example, changes in machinery, equipment, technology, procedures, work organisation or work processes are all likely to affect performance and cause distractions.

Carefully consider the magnitude of change: how safety-critical is it? What is its potential impact on human performance? Consider human factors issues especially during the transition period of the change.



Aircraft fleet retirement | case study

A low-capacity RPT operator decides to retire its existing fleet of nine Beech 1900 aircraft as part of its expansion program. Some of the flight crew are made redundant and are not offered positions on the new aircraft type. The CEO of the airline determines that a structured change management program is required to minimise disruption to operations and ensure a smooth transition.

There are significant human factors issues associated with this change process, such as:

- Redundant flight crew distracted by job uncertainty, but having to continue to operate as effective crew members for some time.
- Retained flight crew distracted by new aircraft type.
- Both types of flight crew still having to perform as a coordinated team during flight operations.

To manage human factors issues during the transition period, the operator:

- offers confidential counselling and financial advice to those affected.
- uses a normal (LOSA-like) operations flight crew observation program to identify human factors issues.
- provides affected staff with weekly summaries of the change process to keep them informed.

Human factors and management of change checklist

☐ Is there a clear policy and procedure prompting consideration of HF issues as part of the change management process?

☐ Do you plan and stagger these changes carefully, to avoid too many simultaneous changes?

☐ Do you assess HF risks and opportunities resulting from the change (where you want to get to), as well as HF risks arising from the process of change (how you get there) during the planning process?

☐ Do you explain the need for change, and consult or involve employees in the change process? Are the planned changes clear to all those affected?

☐ Do you actively consult with key personnel (and contractors) before, during and after the change?

☐ Are there enough people to carry out everyday work and respond to any unplanned, unusual or emergency situations during the transition and change periods?

☐ Do you take employee morale into account before, during and after the change?

☐ Do managers ask if the changes are working, or whether there are any problems?

☐ Has the company made changes in a way that employees can easily adapt to and cope with? Although some changes are small, their effects can be cumulative and suddenly create a problem.

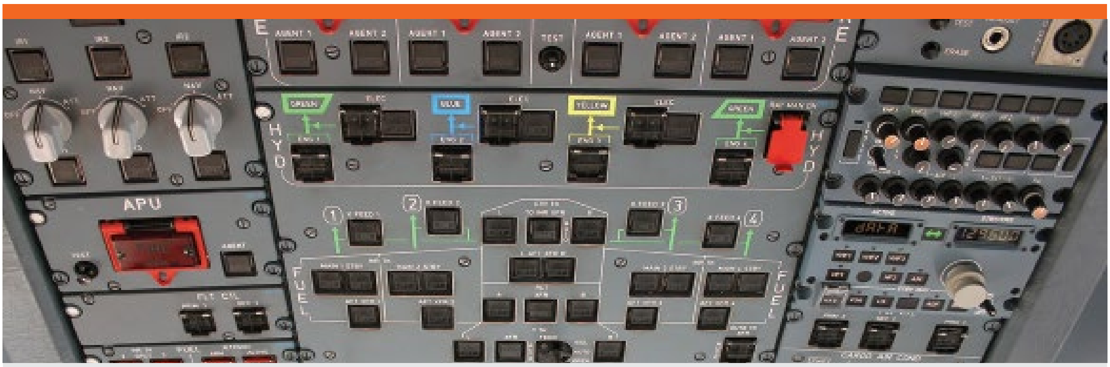
☐ Do you carry out a full review prior to going live with changes to systems to double check that you have addressed any potential for error?

Design of systems and equipment

Poorly thought-out equipment design can have a major impact on the performance of your staff, and you should ensure that there is a good fit between the equipment and those using it.

The design of equipment such as displays and control systems, alarm systems, signals and warnings, as well as automated systems, may involve significant human factors risks. These days, aircraft manufacturers spend a lot of time ensuring that human factors criteria influence the design of aircraft controls, displays and other equipment on board.

However, occasionally a human factors issue is missed, coming to light through an incident investigation, as the case study on page 20 illustrates.



A-340 overhead switch layout | case study

In December 1996, a Singapore Airlines A-340 was operating an RPT service from Singapore to Sydney. When it was over Bourke, NSW, the flight crew noticed a minor fuel imbalance problem. The flight manual procedure requires the crew to open the four fuel cross-feed valves, located on the centre overhead panel, thus enabling fuel transfer to occur. These switches are activated frequently in flight to maintain optimal aircraft weight and balance.

Adjacent to these switches, and 3 cm directly above them, are four engine-driven hydraulic pump switches, which control the state of the hydraulics and, if switched off, result in the hydraulic pressure dropping. These switches are rarely (if ever) used in flight.

The pilot monitoring initially placed his finger on the fuel cross-feed switch, but was distracted by a message on the engine condition and monitoring instrument panel. While the pilot was observing the panel, his finger moved slightly, repositioning itself over the hydraulics switch.

The pilot continued with the cross-feed, looked up to his finger, and then pressed the (incorrect) switch. He then depressed the remaining three switches, believing them to be the fuel switches. Immediately, hydraulic pressure dropped and the nose of the aircraft pitched correspondingly. The flight crew noticed the problem before complete control was lost, and corrected it by activating the side stick to keep the nose down. The resulting large pitch change caused some passengers, and one cabin crew member, to be flung up towards the cabin ceiling. The cabin crew member sustained significant neck injuries, requiring medical treatment.

The ATSB investigation of this incident determined that:

- The hydraulic switches were not guarded and were of very similar appearance to the fuel cross-feed switches
- The switches were activated by the same push-button switching action and used the same white illumination to indicate activation
- The hydraulic switches were located immediately above, and almost aligned with, the fuel cross-feed switches

The A-340 incident demonstrates a number of lessons about equipment design:

- Different controls should be easy to distinguish
- Function of controls should be clear
- Means of activation should conform to expectations
- Accidental activation/selection should be unlikely
- Actions should be reversible.

These issues do not apply only to aircraft controls, but also to equipment used around an aircraft, such as the aerobridge, mobile stairs, maintenance tools and equipment, baggage trolleys etc. Before committing funds to buying new equipment, test it out with the actual users first. They will soon tell you what they think about it.

Human factors and systems design and equipment checklist

- ☐ Always refer to international standards for user-centred design
- ☐ Where possible, design systems and equipment to be tolerant of operator error
- ☐ Identify all the ways in which people can potentially interact with the system
- ☐ Assess any risks associated with those interactions
- ☐ Ensure you have management strategies for any identified risks
- ☐ Continually review equipment design and how you use it to identify any human performance issues

Training of operational staff

Before training operational staff in non-technical skills, do a training needs analysis, so that you know which error management measures to target to which groups—individuals and/or teams.

Training requirements to consider are included in the following checklist:

Human factors and training checklist

- ☐ Understanding the role of human performance in accident prevention and causation
- ☐ Safety culture, safety accountability and the role of a safety reporting culture
- ☐ The responsibilities of management and employees in developing, implementing, operating and maintaining an SMS
- ☐ Crisis management and emergency response planning
- ☐ Safety promotion
- ☐ Communication skills
- ☐ Specialised training or familiarisation in, for example, crew resource management (CRM), maintenance error management (MEM), threat and error management (TEM), fatigue risk management systems (FRMS) and line operations safety audit (LOSA)

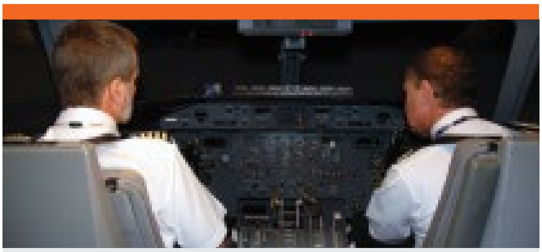
Task and job design

Task and job design can significantly affect human performance. Tasks involving excessive time pressure, a complex sequence of operations, relying overly on memory, or that are physically or mentally fatiguing, are likely to negatively affect performance.

Task design is essentially about task matching – make sure that tasks and activities are appropriate and suited to a person's capabilities, limitations and personal needs.

Human factors and job and task design

- Identify safety-critical tasks, and those who perform them
- Design the task objectives, sequences and actions to be performed
- Structure the task so it supports safe performance by the individual or team
- Consider the working environment so it supports safe performance of the task
- Assess the potential risks associated with non-compliance, human capabilities and limitations
- Implement risk management strategies to manage identified risks
- Evaluate safety performance against the stated objectives



Dash-8 normal checklist | case study

A major Australian regional airline operating Dash 8s found recurring problems with the 1996 version of the Dash 8 normal checklist. Flight crew found that the design of the checklist resulted in overly wordy, 'scripted' briefings with unnecessary talking, and some of the checklist items were technically outdated and too long. The operator found this could lead to human performance issues such as: inappropriate checklist item responses, conditioned or automatic responses, and missed items.

With flight crew input, they designed a new checklist with the following features, and implemented it across the operation:

- Specific checklist usage rules
- Changed checklist responses to reflect systems configuration more accurately
- Tactile (feel) checks associated with some checklist responses
- Additional checklist item at transition – 'pressurisation' – to ensure more effective memory prompt

The new checklist formed part of dedicated training modules in the operator's cyclic program and a line maintenance training program was also implemented.

Safety reporting systems and data analysis

The main objective of any safety data collection and analysis system is to make events, hazards, safety trends and their contributing factors visible and understandable so that you can take effective corrective action.

Generally, the same decision-making, communication breakdown and distraction problems you see in a serious accident you will also tend to see in minor occurrences.

Your safety reporting system should not only collect information about notifiable occurrences and incidents, but also hazards, near-misses and errors that otherwise might have gone unnoticed.

Ensure your staff are aware of, and know how to report, even the most minor events to help avert more serious incidents. Systems to encourage open reporting based on trust, acceptance and motivation include:

- Non-punitive, confidential hazard and incident reporting systems
- Formal and informal meetings to discuss safety concerns
- Feedback from management about action taken as a result of hazard and incident reports or safety meetings.

The following checklist shows the key human factors issues to consider in safety reporting and data analysis:

✓ Human factors and safety reporting and data analysis checklist

Safety reporting

☐ Do the procedures for reporting hazards, near misses and safety occurrences encourage staff to report errors and violations?

☐ Is there a clear non-punitive safety reporting policy signed by the CEO?

☐ Is there a simple, user-friendly system for reporting occurrences?

☐ Does the organisation have a policy of a strict timeframe for feedback to the person who submitted the report (Within 48 hours? Within 72 hours?)

☐ Is there an option for people to submit confidential reports if the issue is particularly sensitive?

☐ Do managers' meetings with employees regularly explain why it is important to obtain feedback on errors and events? Do you describe management expectations and discuss how information will be used?

☐ Do you provide examples of hypothetical reports? Give people a template representing the level of detail and facility reference points that makes expectations clear?

☐ Do you have a designated event report coordinator who is seen as credible and trustworthy?

Data analysis

☐ Do you use an error classification system to at least identify the difference between errors and violations?

☐ Do you periodically inform people of the significance of their reporting, and how the data is being used?

☐ Do you track and trend errors from the reporting system? Do you use this information to identify areas of high risk where corrective actions can be taken to reduce error?

☐ Do you use data from the reports in ongoing training and lessons learned?

Incident/accident investigation

Make sure your investigation procedures detail clearly how human factors considerations are included. The main purpose of investigating an accident or incident is to understand what happened, how it happened, and why it happened, to prevent similar events in future. Use a model (such as Reason's model) or framework for investigations and consider human error, both at the individual and organisational levels.

Your investigators need to be trained in basic human factors concepts and design procedures to be able to establish which human performance factors might have contributed to the event.

The following check questions may be useful to assist you in assessing how well you have considered HF issues in your internal safety investigation system.

Human factors and incident/accident investigation checklist

☐ Do you use a systemic investigation model (e.g. Reason model) to investigate occurrences?

☐ Is the investigation process clearly defined via supporting procedures and checklists?

☐ Do those who investigate incidents/accidents have human factors training, specifically in relation to the application of error identification, capture and management?

☐ Does your investigation methodology encourage investigators to determine why human failures occur?

☐ Do you identify immediate causes (active failures) and contributing factors (latent conditions) at job, individual and organisational levels?

☐ Are your recommendations/corrective actions accepted and effective in addressing immediate and underlying/latent factors of the occurrence?

☐ Do you review recommendations/corrective actions to ensure they have been effective in preventing recurrence of/reducing risk?

☐ Do you provide feedback to those affected by the occurrence or recommendations?

☐ Do you use information from the incident management system to update/review risk assessments?

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