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Civil Aviation Safety Authority

Safety Management Systems **for aviation:** a practical guide

SMS 6
Human factors and human performance

3rd Edition

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image: Civil Aviation Safety Authority

SMS and human factors

Your organisation's safety performance is significantly affected by how you personally view your responsibilities towards safety and how that view interacts with others. In managing safety, you need to understand and address how people contribute to organisational safety.

Over the past 100 years or so, we have discovered that relatively few accidents result purely from technical failures. In around 70–80 per cent of cases, deficiencies in human performance contributed directly to the outcome. Consequently, the greatest potential for reducing aviation accidents lies in understanding the human contribution to safety performance.

Human factors and human performance is, as a result, an integral part of safety management and is necessary in order to understand, identify and mitigate risks as well as optimise the human contribution to safety.

Historically, the human contribution to aviation safety was largely focused on the errors and violations of individuals that adversely affect safety. More recently, there has been a focus on the positive contribution to safety, resilience, and efficiency made by individuals. An individual's ability to adapt is often the reason that the system is successful despite interruptions and disturbances, such as storms, mechanical emergencies, and economic downturns. Current human performance focus recognises the value in assessing and understanding human factors, not only when things go wrong, but also when things go right.

image: Civil Aviation Safety Authority

Throughout aviation people are both the source of risks and an integral part of identifying and managing risks.

Consideration of human factors and human performance is important in safety management as people can be both a source and solution to safety risks through:

- contributing to an incident or accident through variable performance due to human limitations
- anticipating and taking appropriate actions to avoid hazardous situations
- solving problems, making decisions, and taking actions to mitigate risks.

Integrating human factors into your SMS gives you a framework to ensure you systematically identify and analyse any human factor issues and resolve them. Assessing risks associated with human performance can be more complex than assessing the risk factors associated with technology or the environment because:

- human performance is highly variable, with a wide range of interacting influences, internal and external to the individual
- interactions between these variable influences are difficult or impossible to predict
- the consequences of variable human performance will differ according to the task being performed and the context.

No matter the difficulties, managing human factor aspects within your organisation has a positive impact on safety management by reducing errors and improving communication, reducing work related injuries, increasing employee satisfaction, and ensuring balanced workloads. Human factor safety management integration aims to ensure that work procedures and policies within your organisation are compatible with human capabilities, training is sufficient, the workforce is competent, and there is enough spare capacity to deal with emergency situations.

Understanding human factors

The terms human factors, human performance, non-technical skills, and ergonomics are sometimes confused and regularly used interchangeably. This is not surprising as they are closely linked, however they can be distinguished as follows:

- **Human factors** is the application of what we know about human beings including their abilities, characteristics, and limitations, the design of procedures and equipment people use, and the environment in which they function and the tasks they perform.
- **Human performance** is how people perform tasks and represents the human contribution to safety performance.
- **Non-technical skills** relate to behavioural skills or techniques that ensure individuals can function successfully as team members to diminish threats and errors within the operating environment.
- **Ergonomics** is considered a subset of human factors that focuses specifically on designing technical systems, products, and equipment to meet the physical needs of the user.

The study of human factors involves applying scientific knowledge about the human body and mind. This enables a better understanding of human capabilities and limitations so there is the best possible fit between people and the systems in which they operate. Human factors includes social and personal skills, for example communication and decision making, which complement technical skills and are important for safe and efficient aviation.

There are both upsides and a downside to human factors and human performance. The downside is the capacity to make errors or mistakes. However, the equally important upside is our human capacity to be flexible and adaptable when solving complex problems, and often resolving situations with limited information.

Although humans will always make errors there is clear evidence from accident statistics, line observations and research studies, of the benefit of human factors-based mitigation measures. Aircraft systems and equipment, documentation, procedures, and training which have had human factors inputs have been successful in limiting the number and effect of errors. This results in your entire system being more resilient.

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

Human performance principles

There are five key human performance principles that identify how individuals' performance is influenced by different factors. These are:

- people's performance is shaped by their capabilities and limitations
- people interpret situations differently and perform in ways that makes sense to them
- people adapt to meet the demands of complex and dynamic work environments
- people assess risks and make trade-offs
- people's performance is influenced by working with other people, technology, and the environment within which they work.

These principles interact and overlap and do not represent unconnected human performance building blocks. Instead, they provide different insights and perspectives to provide a multi-dimensional picture of human performance. Having awareness of these principles can help to shape, improve, and maximise the performance of your SMS. The human performance principles apply generally to all humans involved in your organisation, across the individual, the team, and at organisational levels.

Human performance limitations

As identified in the first human performance principle, people's performance is shaped by their capabilities and limitations. All human beings have limitations, including both physical and cognitive limitations, which cannot simply be overcome through motivation, sheer will or having a positive safety behaviour mindset. However, for all their limitations, when well supported, people can manage novel situations, adapting their skills to safely manage the operation.

Human performance limitations are often known as personal or individual factors which influence performance and are potential error producing or error promoting conditions. When these individual factors are present, they can interact with other situational and organisational factors, increasing the likelihood of human error. These factors however if proactively evaluated and addressed can be optimised to improve performance and reduce human error risks.

Some well-known human performance limitations include:

- stress
- fatigue impairment
- alcohol and other drug impairment
- physical health
- mental wellbeing and psychological conditions
- sensory capacity (visual and auditory)
- information processing capacity
- attention and vigilance
- memory

Some of these limitations are physiology and we easily recognise or understand them. For example, people cannot function well without adequate sleep and nutrition. They cannot lift very heavy weights, cannot see in the dark, and are subject to involuntary responses under stress. We need to however be aware that these physiological limitations can be aggravated in aviation when flying at altitude or working in highly complex environments. Such as when inflight, with decreased oxygen delivery to organs, including sensory organs, can result in problems with night vision or impaired decision-making.

Other limitations are cognitive and can be harder to recognise. For example, people cannot always remember what they were told. Nor can they always immediately solve complex calculations in their heads, or maintain attentiveness when they are stressed, bored, fatigued, or cognitively overloaded.

While sensory and information processing limitations can lead to perceptual illusions, and to the failure to notice subtle changes in the environment, especially when attention is focused elsewhere or when experiencing spatial disorientation.

Furthermore, people's performance is highly variable. No one can perform at the same level all the time, and the level at which people can perform certain types of tasks changes throughout the day. For example, people's overall performance deteriorates when they are ill, bored, stressed, or fatigued.

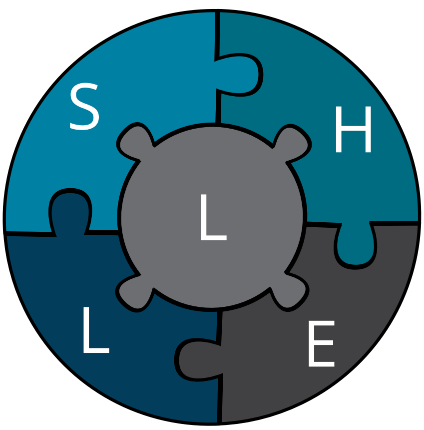
The performance limitation of fatigue impairment is recognised as a specific safety issue in aviation. It should be addressed within your SMS as a distinct human performance risk accordingly, regardless of any fatigue management regulations for certain groups of aviation professionals. This enhanced awareness of fatigue risk in aviation is because of the insidious nature of fatigue and its well-known impacts on safety performance. When identifying, assessing, and managing fatigue risks organisations must consider the basic scientific principles relating to fatigue impairment and how they will manage these to ensure personal are not performing safety critical tasks while impaired by fatigue. These basic scientific principles include:

- the need for sleep
- sleep loss and recovery
- circadian effects on sleep and performance, and
- the influence of workload.

The SHELL model

Several models have been developed to support the understanding and assessment of human factors on safety performance. The SHELL model is well-known and used by the International Civil Aviation Organization (ICAO). The model illustrates the impact and interaction of the different system components on humans and emphasises the need to consider human factors as an integrated part of safety risk management.

The model illustrates the relationship between the human at the centre of the model surrounded by workplace or organisational components.



The outer letters, SHEL, represent four satellite components:

S = software: the procedures, training and other support aspects of tasks or work design.

H = hardware: the equipment, tools and technology used in work.

E = environment: the environmental conditions in which work occurs, including the organisational and national cultures influencing interaction.

L = liveware: the interrelationships between humans at work.

Which are surrounding the main component of:

L = liveware: the human operating within the system.

The SHELL model represents the way the whole system influences how individuals behave. Any breakdown, disconnect or absence between components can lead to human performance problems.

For example, an accident where communication breaks down between pilots in the cockpit, or engineers at shift handover, would be characterised by the model as a liveware-liveware breakdown. Situations where pilots or engineers disregarded a rule or do not follow a standard operating procedure would be characterised as a liveware-software breakdown.

An analysis of these interactions can assist your organisation in both the development of processes and procedures or introduction of new systems and also in a reactive sense during an investigation of an incident, for example.

Case study

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

Controlled flight into terrain

This case study illustrates some key human factors issues arising from the controlled flight into terrain accident at Lockhart River, Queensland, in 2005.

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

At 11:43:39 (AEST), 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 were 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 the result of controlled flight into terrain. This means that an airworthy aircraft under the control of the flight crew was flown unintentionally into terrain, possibly 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 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 operator's operations manual
- during the approach, the aircraft descended below the segment minimum safe altitude for its position on the approach

ATSB Transport Safety Investigation Report 200501977: 'Collision with terrain; 11km NW Lockhart River Aerodrome'.

- the aircraft's high rate of descent, and the descent below the segment minimum safe altitude, were not detected or corrected by the crew before the aircraft collided with the terrain
- the crew probably experienced a very high workload during the approach
- the crew possibly 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 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.

If we now apply the SHELL model to the Lockhart River accident, we can see that there was a poor fit between several different components in the SHELL model.

What led to the accident goes far beyond the actions of the PIC alone:

- **Software–liveware:** 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:** the aircraft was not fitted with any terrain awareness and warning system, such as an enhanced ground proximity warning system.
- **Environment (culture)–liveware:** 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 a 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:** the PIC 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'. This analysis enables a deeper and more directed review of causal factors of the accident which ultimately leads to better organisational safety in the future.

Understanding errors and error management

Human error is a normal and natural part of everyday life as it is generally accepted that we will make errors every day. 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 many errors, the good news is that the vast majority have no serious consequences because they are automatically self-corrected. In most cases somebody or something reminds us of 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 reminds us of where we were going, or you continue the wrong route wasting your 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 can be discovered by a dual inspection. The term 'near-misses' describes errors that occur but are corrected before any damage or harm is caused.

Some people refer to the terms *human factors* and *human error* as if they are the same. However, human error is really the *outcome* or consequence of our human performance limitations, the human factor.

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.

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

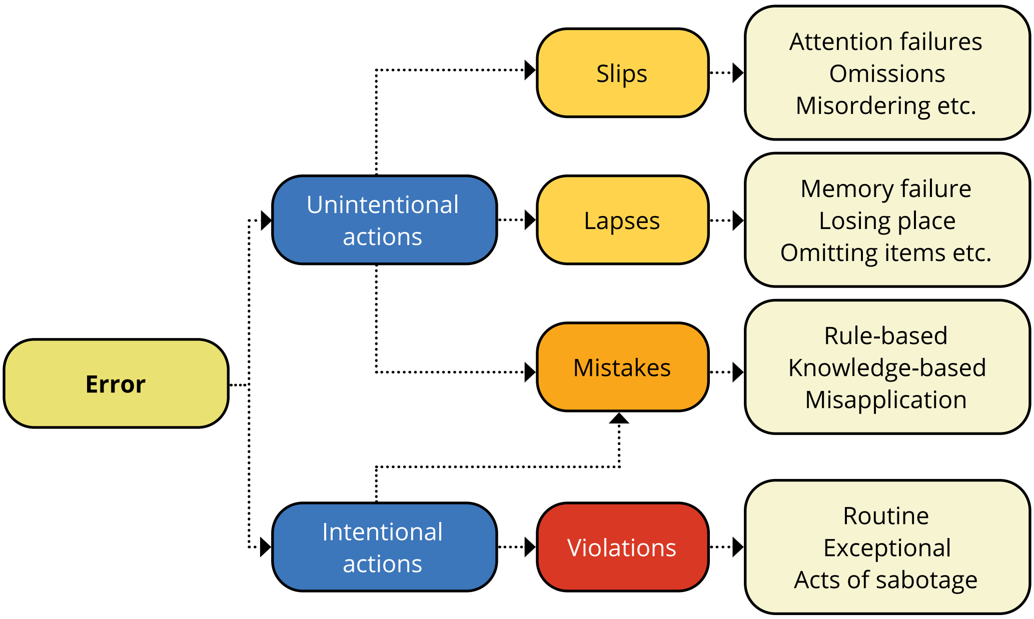
image: Civil Aviation Safety Authority

Unintentional errors, violations, and unsafe acts

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

- **Intentional actions:** 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:



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

Unintentional actions

Unintentional actions are those that are identified as acceptable human errors. They provide your organisation with a learning opportunity and because of this response helps to promote a positive safety culture. These acts should not result in punitive actions and should instead lead to an analysis of the contributing factors that led to the slip, lapse or mistake. The analysis should identify any mitigating actions your organisation can take to reduce the potential for reoccurrence.

Error type	Description
Slips	Are errors made when you don't pay attention, or your plan is incorrectly carried out. For example, you intend to drive to the shops, but turn the way you usually do to go to work.
Lapses	Occur because you fail to carry out an intended action, usually due to a memory failure. For example, you forget to buy something at the shops or forgetting to check that the undercarriage locking pins are in place.
Mistakes	Occur when you plan to do something, and carry out your plan accordingly, but it does not produce the outcome you wanted. For example, the shop you went to 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. This type of error is at times identified as an intentional action error because often the actions taken are intentional. However, when a mistake occurs due to inadequate knowledge or inappropriate rule application the outcome is identified as being unintentional and falls into an overarching unintentional category of errors.

Case study

image: iStockphoto

Forgetting to latch fan cowl door

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 Number 1 engine and struck the aircraft. The doors were destroyed, and localised damage resulted to the engine and its pylon, the left wing, the left flaps and slats, the fuselage, and the fin.

An investigation identified that although the doors were likely closed following maintenance, they were not securely latched resulting in the accident. When the doors are closed, there are no conspicuous alerting cues to indicate they are unlatched and no indication on the flight deck.

Similar incidents have occurred on at least seven other occasions worldwide. It was identified during the investigation that the engineers had been called away during performing the maintenance task on the engine. When they returned to complete the task, including locking the fan cowl, they returned to the incorrect aircraft on the bay next to the aircraft in question. This resulted in a failure to identify that the task had not been completed, although they believed they had.

(Ref. UK AAIB Bulletin 7/2000)

Intentional actions

Unlike unintentional actions, intentional actions or violations involve deliberately, and consciously, departing from known and established rules or procedures. For example, choosing to skip a step in a standard operating procedure so you can complete a task faster.

Within your SMS these are the types of actions that may, depending on their contributing factors, result in some degree of punitive action along with organisational learnings to prevent reoccurrence. The table below explains the different violation types and their main causes.

Violation type	Main causes
Routine: result when a violation becomes what is normally done i.e., the norm within the workplace or for an individual. Routine violations are often short cuts taken to help get the job done quickly, more easily, or perhaps more efficiently and become part of the routine for that task. They are frequent, known and often become condoned. Unless you monitor and control this behaviour, it can lead to a culture that tolerates violations and ultimately degrades your safety culture. Given many processes and procedures are learnt 'on the job', new employees often accept routine violations as 'normal' procedure as they know no different.	• We think the rules are unnecessary or too rigid. • We are poorly supervised.
Situational: occur when there is a gap between what the rules or procedures require and what resources are available or possible to be able to complete the task. When there is a lack of local resources, or a failure to understand real working conditions, this may increase pressure on individuals to ignore procedures or break the rules to get the job done and achieve targets. Situational violations represent individuals adapting to problems in the workplace to still achieve their tasks.	• 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.

Violation type	Main causes
Optimising (personal or organisational): involve individuals doing something for personal goals (self before safety), or simply for the associated thrills, or for kicks. For example, performing only a cursory examination of the aircraft to get out of the cold weather quickly and return inside faster. Where there are incentives, such as a bonus for meeting production targets or increased on time performance, this may encourage organisational optimising violations. For example, individuals not following all the required procedural steps for expedient turnarounds in aircraft where teams are rewarded for faster on time performance. Identifying organisational optimising violations can assist in improving both productivity and safety goals if brought out into the open, communicated and discussed.	• We break a rule because it is more convenient for us personally. • We are bored, or the job is monotonous. • We want to please the customer or get the job done for the boss or organisation.
Exceptional: these are rare, one-off acts in novel or unfamiliar situations, or actions individuals might take to deal with an unusual situation. For example, ignoring the pre-landing checklist on final approach to take evasive action due to traffic conflict.	• There is a lack of a thorough, risk-based approach to training in the anticipation of safety-critical scenarios. • We are under extreme pressure to perform.
Act of sabotage involves malevolent behaviour and intentional actions to cause damage or harm. For example, not tightening a bolt to cause intentional structural failure.	• An individual fully intends to cause harm to life or property.

Managing error

If you want to find actual solutions for the problems human errors cause, you often need substantial integrated systemic changes. For example, you might have to modify your 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 your system thus 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. Error tolerant systems are an example of effective human factors integration and systems thinking to achieve enhanced safety performance.

As individuals we are amazingly error tolerant, even when we are injured or unwell. 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 as the same properties that give human beings such robustness and creativity can also produce errors or result in optimising or exceptional violations.

Our natural tendency to interpret partial or missing information can also 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 i.e., installing multiple layers of defences, is more likely to prevent accidents that result from human errors and violations.

Some organisational strategies to contain and prevent errors, reduce the potential for catastrophic consequences, or methods for avoiding the error in the first place, are in the tables following.

image: Civil Aviation Safety Authority

Error containment strategies

Error containment	Sample strategies
Formalise acknowledgement that errors are 'normal'	• policy signed by the CEO stating the importance of reporting errors • acknowledgement from senior management that errors occur and encouragement of a just culture to identify and manage errors • safety investigation procedures acknowledging the 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 the risk of potential errors through normal operations behavioural observation programs	• independent peer-on-peer confidential observation program • safety mentoring and coaching programs 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 and practical applications prior to roll out • ensure critical job roles have backup to avoid over-reliance on specific individuals (redundancy)
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 human factors training • focus on good examples of error capture at shift handover at regular toolbox talks and safety chats • 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

Error prevention strategies

Error prevention	Sample strategies
Reinforce the stringent use of checklists to combat memory limitations	• establish a 'non-negotiable' operational policy and safety standard stating checklists, not memory, are always to be used • provide a mechanism for staff to report any failings or difficulties with using checklists or standard operating procedures so they can be reviewed and updated if needed • 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 impairment 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 a formal policy statement e.g. 'a failure to report is a violation' and that reporting occurrences of genuine human errors will not result in punitive actions • regular feedback to staff via a newsletter or safety meetings of near-miss examples reported
Decrease reliance on personal vigilance via the strategic use of automation and technology	• regular industry benchmarking to identify 'smart technology' to complement the 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), designing human-centred equipment (alarms and warning devices) 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 or procedures before implementation.

Managing violations firstly involves finding their root causes or contributing factors. Automatically punishing a violator is not 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 routine or situational violations. Any person in the same scenario might have found it difficult not to commit a violation, this is known as the substitution test.

The substitution test involves asking yourself and the individual's peers: 'Given the circumstances (including organisational, situational and environmental factors) at the time of the event, could you be sure you would not have committed the same, or a similar, unsafe act?'

Some examples of organisational strategies for managing error and violation types to enhance safety performance are shown in the table following.

image: Civil Aviation Safety Authority

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 workflow through planning and scheduling
Rule-based mistakes (poor use of rules)	• conduct routine question and answer discussion 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 an analysis of why the rules were wrongly used or not followed and do not simply end when it has been identified that an individual did not correctly follow a rule or procedure
Knowledge-based mistakes (unfamiliarity or poor knowledge)	• staff have access to appropriate training and procedures, including recurrent training • ensure staff do not have too much information, data, or paperwork as this can cause an information overload resulting in selective attentional focus (or tunnel vision). Practical checklist style summaries or workflow diagrams are best.

Management strategies by violation type

Violation type	Management tools
Routine	• regularly rationalise or simplify rules e.g. do we really need it? And if so, why? • reward compliance with procedures, e.g. identified in employee performance reviews or promoted via safety standards awards across teams
Situational	• make procedures realistic for the task • involve staff in developing rules • improve the level of supervision and resources • in instances where resources are reduced or lacking allow for extended time for task completion
Organisational optimising violation	• make rules easier to follow through simplification
Personal optimising violation	• consider discipline through 'a 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.

SMS human factors integration

To create a robust and resilient SMS you need to consider human factors and how this influences overall safety performance. Human factors and human performance principles have consequences for safety management and actions, meaning human factors should be integrated and embedded into your SMS.

Historically many organisations have understood human factors integration to mean having personnel complete human factors or non-technical skills training. While training personnel in human factors and non-technical skills is an element of SMS integration there is much more involved than just this. Consideration of human factors and human performance influences needs to be taken across all aspects of your organisation's SMS.

The following are some common ways in which safety management processes consider human factors:

- senior management is committed to creating a working environment that optimises human performance and encourages personnel to actively engage in and contribute to the organisation's safety management processes. This can be achieved by a clear policy statement and just reporting processes
- responsibilities of personnel with respect to safety management are constantly clarified to ensure common understanding and expectations
- personnel are provided with information and training by your organisation that:
  - describes the expected behaviours in respect to the organisation's processes and procedures
  - describes what actions will be taken by the organisation in response to individual behaviours
- human resourcing levels are monitored and adjusted to ensure there are enough individuals to meet operational demands
- policies, processes, and procedures are established to encourage hazard and safety reporting
- safety data and safety information are analysed to allow consideration of those risks related to variable human performance and human limitations. Particular attention to any associated organisational and operational factors can be made during the analysis
- policies, processes, and procedures are developed that are clear, concise, and workable, with the aim of:
  - optimising human performance
  - preventing inadvertent errors
  - reducing the unwanted consequences of variable human performance
  - continually monitoring the effectiveness of these during normal operations
- ongoing monitoring of normal operations including assessments of whether processes and procedures are followed and, when they are not followed, investigations are carried out to determine the underlying causes
- safety investigations include the assessment of contributing human factors, examining not only behaviours but reasons for such behaviours (context), with the understanding that in most cases individuals are doing their best to get the job done
- management of change processes include consideration of the evolving tasks and roles of the human in the system
- personnel are trained to ensure they are competent to perform their duties, the effectiveness of training is reviewed, and training programs are adapted to meet changing needs.

It is unlikely that your SMS will achieve its full potential for improving safety performance without a full understanding and application of human factors principles by all personnel to support a positive safety culture.

You can use the following human factors SMS integration checklist on this page as a starting point for assessing how well you have integrated human factors and human performance considerations into your SMS.

You can also demonstrate integration of human factors in your SMS by including considerations within each of the following elements:

- safety culture and management commitment
- safety reporting and data analysis
- hazard identification, risk assessment and mitigation
- incident and accident investigation
- management of change
- design of systems and equipment
- training of operational staff
- job and task design.

Human factors SMS integration checklist

- [ ] Human performance safety data is being collected, analysed, and acted upon to improve safety performance of the system.
- [ ] There is a process in place that encourages safety reporting. Which enables identification of human performance issues, resulting in lessons learned and sharing lessons across the organisation.
- [ ] There is a process in place for informing personnel of actions taken when things did not go to plan to reduce the likelihood of reoccurrence.
- [ ] There is a process for managing safety risks associated with individuals' fitness for duty, including a process for returning individuals to duty after an absence related to being unfit.
- [ ] Training programs include addressing individual responsibilities, organisational processes and procedures, and their rationale.
- [ ] The change management process includes appropriate human performance considerations in changes including human performance training relevant to changing roles and responsibilities.

Safety culture and management commitment

Of all the human factors influencing individuals' behaviour, one of the most powerful is your organisation's safety culture. An organisation's safety culture has been shown to be a key predictor of safety performance. It influences how effectively an organisation manages its safety risks and how your managers and employees behave and interact.

The effectiveness of safety management depends largely on the degree of senior support and management commitment to create a working environment that optimises human performance and encourages personnel to actively engage in and contribute to your organisation's safety management processes.

To address the way that your organisation influences human performance there must be senior level support to implement effective safety management. This includes management commitment to create the right working environment and the right safety culture to address human factors. This will ultimately influence the attitudes and behaviours of everyone in your organisation.

For example, a workplace with a positive safety culture is where safe and professional practices are not only expected normal behaviours but are routinely reinforced and supported by management, even when there are considerable time and customer pressures present. In this type of organisation, personnel will tend to 'do it by the book' and take the time to ensure appropriate work practises, inspections, cross-checks, and signoffs are carried out. The organisation's positive safety culture has influenced human performance. If, however, management overlooks routine shortcuts and workarounds taking place to enable quicker turnarounds and faster task completion, a 'near enough is good enough' attitude will prevail. This could ultimately result in the acceptance of lower standards of work and degraded safety performance.

The standard set and displayed by management regarding safety culture has been shown to have a significant influence on human performance through both attitudes and actions of personnel. Your organisation's culture affects how safety is perceived, valued, and prioritised by both managers and personnel.

Underpinning this is a sound 'just culture' that recognises personnel will make mistakes and errors and they should not be punished for doing so. While accepting that human errors are likely to be made there also needs to be a clear understanding of what is deemed appropriate and inappropriate safety behaviours. Wilful or negligent actions degrading safety need to be followed up and may result in some level of individual performance management, which is different to the treatment of unintentional lapses, errors, or mistakes.

A documented safety policy that identifies and promotes positive safety behaviours is only the first step to human factors integration within your safety culture. Your management team must also be committed to demonstrate your safety culture values in their own actions and support personnel when they also demonstrate positive safety behaviours. This is the second step. This is the 'walking the talk' human factors influence of safety culture.

> Punishing an individual for making an error undermines safety culture and can prevent the development of effective safety risk mitigations.

Safety reporting systems and data analysis

People ultimately create safety, either directly via their actions or indirectly via design of processes, equipment, and systems. Therefore, the need to collect and analyse human performance data is central to safety management. This type of information can be collected in various types of data sources, including mandatory and voluntary hazard reports and accident or incident investigations. When analysing human performance data, it is important to look at both what went wrong and what went right.

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. Analysing safety data represents an important opportunity to examine the interactions between the human and other system components.

Generally, the same decision-making, communication breakdown and distraction problems you see in a serious accident you will also 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. Your voluntary hazard and safety reports are enhanced through a positive safety culture where people feel empowered and supported to report when errors, lapses or mistakes have been made without fear of retribution.

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 because 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 personnel 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 author of the report (Within 48 hours? Within 72 hours?)
- ☐ Is there an option for personnel to submit confidential reports if the issue is particularly sensitive?
- ☐ Do managers' meetings with personnel 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?
- ☐ Do you give personnel a template representing the level of detail and provide reference points or examples that make your 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?

image: Civil Aviation Safety Authority

Case study

Human factors and hazard management

A simple example of considering human factors issues in the hazard management process is outlined in this 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. It is also identified that there are no visual cues to indicate when the wheel brakes have been activated, meaning when standing back from the stairs it is difficult to tell if the brakes are on or not.

Simple human factors solutions would include installing a sign prompting operators to secure the wheel brake, have the backside of the brake mechanism coated in a reflective hi-vis tint that can only be seen when in the upright locked position, and to ensure that all airport staff are regularly reminded of the danger of unsecured stairs.

Hazard identification

Your hazard identification program can reveal potential or actual errors and their underlying causes. This requires looking beyond the error itself and instead identifying the underlying contributing factors that have caused an error to occur.

The table below gives examples of questions to ask in relation to hazard management and human factors influence.

Human factors and hazard management checklist

- ☐ Do you consider human factors and human performance issues in general risk assessments where hazards are identified?
- ☐ Are the human factors issues involved with hazards understood?
- ☐ Are different error types associated 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 your reporting process prompt users to consider human factors and human performance issues? What errors might result if the hazard is not managed well?
- ☐ Have you identified the human factors issues with the greatest implications for safety or performance?
- ☐ Is there a standard process to investigate and analyse human factors issues?
- ☐ Do you include human factors risks on your risk register?
- ☐ Do you keep clear records of how you have resolved these human factors risks?

image: iStockphoto | vaeenma

Operator error is rarely the root cause of an occurrence. Usually, some underlying systemic issue is hiding behind it.

Incident and accident investigation

Make sure your investigation procedures detail 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 the PEAR model, the SHELL model, or James Reason's accident causation 'Swiss cheese' model or some other investigation framework and consider human error, both at the individual and organisational levels.

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

Investigators and analysts need to recognise that identifying an event simply as human error offers little insight. To gain further insight, analysis of safety occurrences includes an in-depth evaluation that requires a thorough understanding of the context in which the error occurred, including organisational, situational, and environmental factors.

The following checklist may be useful to assist you in assessing how well you have considered human factors in your safety investigation system.

Human factors and incident/accident investigation checklist

- [ ] Do you use a systemic investigation model (e.g. Reason model) to investigate occurrences that goes beyond just identifying what happened and asks why it happened i.e. it identifies the contributing factors.
- [ ] Is the investigation process clearly defined via supporting procedures and checklists, which identifies the need to consider human factors contributions?
- [ ] Do those who investigate incidents and 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 at job, individual and organisational levels?
- [ ] Are your recommendations and corrective actions accepted and effective in addressing immediate and underlying or contributing factors of the occurrence?
- [ ] Do you review recommendations and corrective actions to ensure they have been effective in preventing recurrence of or reducing the risk?
- [ ] Do you provide feedback to those affected by the occurrence or recommendations?
- [ ] Do you use information from the incident management system to update and review risk assessments?

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, organisational structure, or work processes are all likely to affect performance and cause distractions.

When an organisation makes any significant changes to its business practices, operating procedures or operating environment, the implications for human performance risks should be the focus of performance monitoring during and after implementing the change.

You must 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.

Some simple questions to consider during change management to keep human performance challenges front of mind are:

- Does the change alter tasks performed by your personnel or how they interact with others within your organisation?
- Does the change imply processing of new information, require new knowledge, or new skill sets by those involved in the new process?
- Does the change involve new technology or automation?
- Does the change take place in parallel with other changes?

If you answer yes to any of the questions, then additional human performance risk mitigations or controls need to be included in your change risk assessment to address these areas.

Case study

image: iStockphoto

Aircraft fleet retirement

A low-capacity air transport operator decides to retire its existing fleet of nine aircraft as part of its expansion program. Some of the flight crews are made redundant and are not offered positions on the new aircraft type. The CEO of the operator 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 are distracted by their job uncertainty but are having to continue to operate as effective crew members for some time
- retained flight crew are distracted by the new aircraft type
- both types of flight crew are 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
- regularly communicates identified human factors hazards and associated risk controls to personnel
- provides affected staff with weekly summaries of the change process to keep them informed.

The following checklist may be useful to assist you in assessing how well you have considered human factors in your change management process.

Human factors and management of change checklist

- ☐ Is there a clear policy and procedure prompting consideration of human factors 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 human factors risks and opportunities resulting from the change (where you want to get to)? Do you assess human factors 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 the 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 personnel. You should always ensure that there is a good fit between the equipment and those using it. As discussed above in this booklet, good ergonomics is a key factor in the liveware to hardware relationship.

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 organisational safety reporting or via incident investigation.

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 error tolerant rather than relying on the human to adapt to the new system
- [ ] 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


image: Adobe Stock | Gorodenkoff

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 your personnel's' capabilities, limitations, and personal needs.

Human factors and job and task design

- ☐ identify safety-critical tasks, those who perform them and the environment in which the tasks will be performed (the context)
- ☐ design the task objectives, sequences, and actions to be performed
- ☐ structure the task so it supports safe performance by the individual and 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 human performance risks
- ☐ evaluate human performance and safety performance against the stated objectives

Case study

image: Civil Aviation Safety Authority

Aircraft normal checklist

A regional airline found recurring problems with a version of their aircraft's 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.

The operator designed a new checklist with the help of flight crew with the following features and implemented it across the operation:

- specific checklist usage rules
- changed checklist responses to reflect the systems configuration more accurately
- tactile (feel) checks associated with some checklist responses
- additional checklist items at transition (pressurisation) to ensure more effective memory prompting.

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

Human factors training

Human factors training while not being the sole source of human factors safety management integration is a key aspect of integration. It is important that your personnel understand that human factors and human performance principles apply to them and to everybody else. It is also important for your personnel to understand that being aware of the consequences of the human performance principles does not make a person immune to them.

It is common in various parts of the aviation industry to talk about 'human factors training' when referring to specific training topics such as threat and error management (TEM), crew resource management (CRM) and non-technical skills (NTS). However, human factors and NTS are different training elements.

Your organisation should ensure your training program for safety-critical personnel covers both fundamental human factors principles as well as non-technical skills elements. The differentiation between the two are:

- human factors principles are directed towards meeting human performance knowledge requirements focusing on understanding human performance limitations and influences when working within a broader system
- non-technical skills relate to applied human performance competencies via behavioural skills or techniques that ensure individuals can function effectively as team members to mitigate threats and errors within the operating environment.

Human factors training should focus on providing aviation safety-critical personnel with an understanding of human factors principles and non-technical skills to manage the prevention and consequences of human error. This implies that making errors is normal and expected. The consequences of error are just as important as the causes. Knowledge and awareness of human factors principles help shape, improve, and maximise human performance within the aviation system.

Human factors principles training should include:

- safety culture
- human performance principle basics
- stress and stress management
- fatigue and fatigue management
- workload management.

Consider identifying examples of desired behaviours as well as undesired behaviours when developing training and educational materials.

While the initial emphasis should be upon knowledge and comprehension of human factors principles, you should also include appropriate operational behaviours and skills training. This is the NTS element of your training program. NTS are applied specific human competencies which may minimise human error in aviation. These include but are not limited to:

- communication
- teamwork
- situational awareness
- decision making
- threat and error management
- human information processing.

Non-technical skills can be considered as the decision making and social skills which complement technical skills. For example, inspecting an aircraft engine using a borescope is a technical skill performed by an engineer. 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.

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

Wherever practicable your human factors training should be incorporated into your already existing training systems. Human factors training forms a part of your SMS and should also be integrated across all aspects of safety and personnel training. Human factors training is directed at preventing and managing risks in dynamic operational contexts. It therefore has relevance, not just for meeting technical training requirements, but for meeting organisational safety management responsibilities.

You should continue to develop your safety-critical personnel's human performance knowledge and non-technical skills as a priority. It makes sense as non-technical skills are one of your primary defences in reducing errors.

For more information on human factors and safety behaviours see the following CASA guides:

Safety behaviours: human factors for pilots | Civil Aviation Safety Authority (casa.gov.au)

Safety behaviours: human factors for engineers resource kit | Civil Aviation Safety Authority (casa.gov.au)

casa.gov.au