Threat and error management (TEM)

What is threat and error management (TEM)?

TEM is the process of detecting and responding to threats (such as powerlines or faulty equipment) and errors (such as selecting the wrong radio frequency, or missing a checklist item), to prevent safety being compromised.

Left unmanaged, these threats and errors can lead to 'undesired aircraft states'- the last opportunity to avoid a serious incident or accident. TEM can be considered an extension to airmanship, providing a structured way to help people maintain safety margins during everyday operations.

TEM was derived from observations on flight decks during Line Operation Safety Audits (LOSA). Developed by the University of Texas, TEM was originally based on how flight crews responded to external threats and internal errors that could have led to undesired aircraft states during flight.

The obvious safety benefit of recognising and managing threats, errors and undesired states before they lead to a serious incident or accident is of course not just limited to flight crews. TEM is equally applicable and relevant to cabin crew, air traffic control (ATC) and maintenance operations.

Why is TEM important?

Without TEM, what is the worst that can happen?

TEM complements risk management processes within safety management systems and can assist in maintaining the safety of the operation and ultimately keep people safe.

There are numerous examples of fatal accidents that have occurred due to decision-making errors, such as continuing a visual flight into deteriorating weather conditions, which could have been prevented by thorough preflight planning (Refer CAA Safety Investigation Report 13/5710 and CAA Safety Investigation Report 15/1129). Air accidents have also occurred due to errors made in the maintenance hangar – leading to catastrophic consequences in flight – which could have been identified before the aircraft ever left the ground (refer ATSB Safety Report AO-2017-078).

Furthermore, one of the worst aviation disasters occurred on the ground at Tenerife, where the flight crew of a KLM Boeing 747-200 misunderstood the departure clearance issued. Due to reduced visibility and use of non-standard phraseology by the flight crew, ATC did not detect the aircraft commencing its take-off roll, while a Pan Am Boeing 747-100 was backtracking on the same runway. The resulting collision, and post-impact fire cost the lives of 583 people.[1]

After an accident it is, of course, important to understand why the errors occurred and how the threats went undetected, but what is equally as important is preventing these threats and errors from developing into adverse outcomes, such as described above.

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[1] https://www.skybrary.aero/index.php/B742_/_B741,_Tenerife_Canary_Islands_Spain,_1977

TEM supports situational awareness

People can manage only what they are aware of. Actively detecting and recognising emerging threats and errors supports our ability to maintain situational awareness.

People maintain situational awareness through their understanding of the current situation or system, their appreciation of 'what is going on' and their ability to anticipate future changes and/or developments.[2,3,4]

Our ability to gather information relating to the current situation and task is influenced by our mental model. A mental model can be described as a representation of the 'world' based on our knowledge and experiences, and is built by our ability to detect or determine changes in our environment through our sensory channels (i.e., visual and auditory, etc.) and the meaning we ascribe to those changes, see Figure 1.
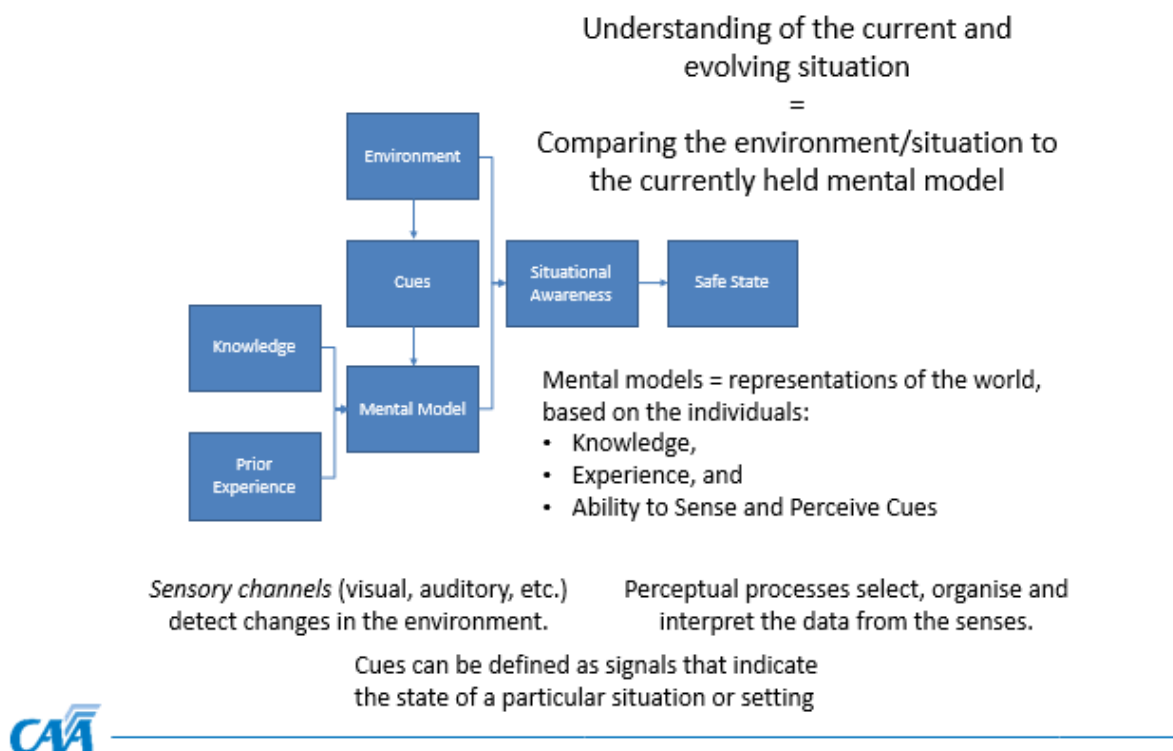
Figure 1 - A representation of the processes underpinning situational awareness

TEM provides a defence against our own limitations

Everyone has limitations, whether they are physical or cognitive. While sitting in a seat most people could not reach a switch positioned two metres away (the physical length of your arm being the limitation), and how many times have we forgotten to pick up the milk on the way home (the failure of prospective memory)?

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[2] https://www.skybrary.aero/index.php/Situational_Awareness_(OGHFA_BN), section 4, Issues and Factors Involved. Accessed 01/08/2020

[3] Endsley, M. R. (1995). A taxonomy of situation awareness errors. Aldershot, England: Avebury Aviation, Ashgate

[4] Endsley, M. R. (1995). Towards a theory of situation awareness in dynamic systems. Human Factors, 37, 32-64

The way people process information (detect threats and errors) and make decisions (respond to these threats and errors), in certain situation can also be subject to systematic flaws, known as heuristics and biases.[5]

Heuristics and biases can be broadly defined as a type of judgement relying on cognitive short-cuts or 'rules of thumb'. While these automatic or subconscious strategies help reduce the burden of information-processing and judgement in situations of uncertainty, they can lead us to miss vital visual stimuli or cues, or make incorrect judgements if there is a mismatch between what is sensed, and the meaning ascribed to it.

TEM applied effectively may therefore help identify times when we may be more susceptible to these heuristics and biases. For example, during 'push back', you hear the controller give a landing clearance to an aircraft with a similar call sign. You should determine how you are going to manage the potential confusion/misinterpretation, that might occur with both aircraft being given taxi instructions at a similar time.

What are threats, errors, and undesired states?

Threats

Threats can be defined as a situation or event that has the potential to have a negative effect on safety. Threats can be classified as internal and external.

Internal threats are related to the individual.

Examples of internal threats are:

- fatigue
- experience
- attitude
- lack of recency and proficiency
- health and wellbeing.

External threats can relate to the context of the operation and therefore can be different depending on the situation.

Examples of external threats within different operational context are:

Pilot-related threats	Cabin crew-related threats
• adverse weather	• unanticipated turbulence
• high terrain or obstacles (wire, etc.)	• unruly passengers
• night operations	• smoke in cabin
• other traffic	• equipment faults
• equipment faults	• Interruption/distraction
• remote strips/landing sites	• lithium battery (PED, etc.) fire
• weight and balance.	• sudden depressurisation.

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[5] Tversky, A. & Kahneman, D. (1974). Judgment under Uncertainty: Heuristics and Biases. Science, New Series, 185(4157), 1124-1131.

ATC-related threats	Maintenance-related threats
• airspace design	• shift handover
• airport layout	• uncontrolled tooling
• co-ordination	• environment, lighting, etc.
• communication failure	• night shifts
• navigation aids	• poor documentation
• traffic	• lack of tooling
• visibility/weather.	• time pressure.

Threats can also be categorised as anticipated, unanticipated, and latent threats, and all three can reduce safety margins.

Anticipated threats are those that can be predicted, such as thunderstorms, congested airports, and complex or physically demanding tasks. Unanticipated threats are those that occur unexpectedly, such as unforeseen turbulence or unexpected equipment malfunctions.

Latent threats, however, are those that may not be directly obvious or observable and may need to be discovered through formal safety analysis. These may include sociopsychology and/or organisational factors such as organisational culture, operational pressures and normalised behaviours.

Errors

As humans we are fallible, and errors are to be expected. Even the most experienced and well-trained person can make an error. Errors can be defined as actions or inactions which can lead to:

- a deviation from individual or organisational intentions or expectations
- reduced safety margins
- increased probability of undesirable events on the ground and/or during flight.

Errors can be classified as slips, lapses, or mistakes, and are generally always considered unintentional.

Slips are actions that do not go as planned, or where we find ourselves doing something we never mean to do. For example, selecting flap instead of landing gear.

Lapses are memory failures or leaving out a step that we intended to carry out. For example, forgetting to check the aircraft was sufficiently refuelled after the tanks were drained.

Mistakes are when we carry out the actions as planned, but what we had planned to do was not right for the situation. For example, fuel calculations were performed, but the fuel burn figure used was for the de-rated engine, which had much lower fuel burn compared with the actual engine fitted.

When the action is an intentional or deliberate deviation from rules or procedures, it is classified as an intentional non-compliance (or violation).

Violations can occur when we try to complete the task in the most efficient way, and they often involve shortcuts or workarounds. For example, cutting across the apron to get to the

aircraft, as this is the most direct route, even though the rules require the designated walkways be followed.

Typical errors may include:

- incorrect calculations or input errors
- inaccurate planning or scheduling
- non-standard communications or handovers
- mishandling the aircraft/equipment
- incorrect systems operation or management, i.e., selecting the wrong switch
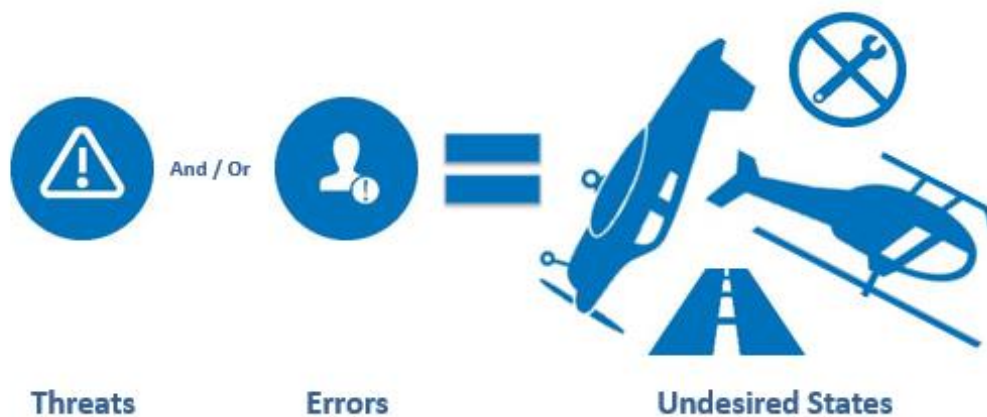- procedure or checklist errors.

Figure 2 – Threat and/or errors can lead to undesired states

Undesired states

Threats and/or errors not detected and/or not managed correctly can lead to an 'undesired state'. Undesired states are generally defined as an unintended situation resulting in a reduction in safety margins. They are usually transient in nature, only existing for a limited time until the state is either recovered or becomes an adverse outcome, such as an incident or accident. Examples of undesired states for pilots, cabin crew, ATC and maintenance are provided below.

Pilot-related undesired states

- aircraft unstable on approach due to a failure to observe the wind direction changing to a tailwind on approach
- loss of external load inflight due to ground crew not having the equipment, training, or experience for the type of operation
- aircraft enters an unusual attitude after an evasive manoeuvre to avoid an inflight collision due to inappropriate or ineffective scan
- aircraft running low on fuel due to diversion around adverse weather not identified during preflight planning.

Cabin crew-related undesired states

- uncontained fire in passenger seat aisle due to personal electronic device being trapped in seat mechanism not identified and being damaged by the seat mechanism.

- passengers evacuating the aircraft when unsafe to do so, such as exiting when the aircraft engine(s) are operating due to miss communication
- inflatable slide deploys on stand due to the door not being disarmed before opening.

ATC-related undesired states

- aircraft entering the runway when it should not; aircraft vacating the runway at the position where it should not
- aircraft climbing/descending to another flight level/altitude than it should; aircraft not climbing or descending to the flight level/altitude where it should
- aircraft entering a taxiway that it should not use; aircraft not entering a taxiway that it should use.

Maintenance-related undesired states

- the incorrect screws are installed in a windscreen, leading to the windscreen departing the aircraft during flight
- a socket is left in the engine inlet and is ingested, leading to an engine failure on take-off and a forced landing.
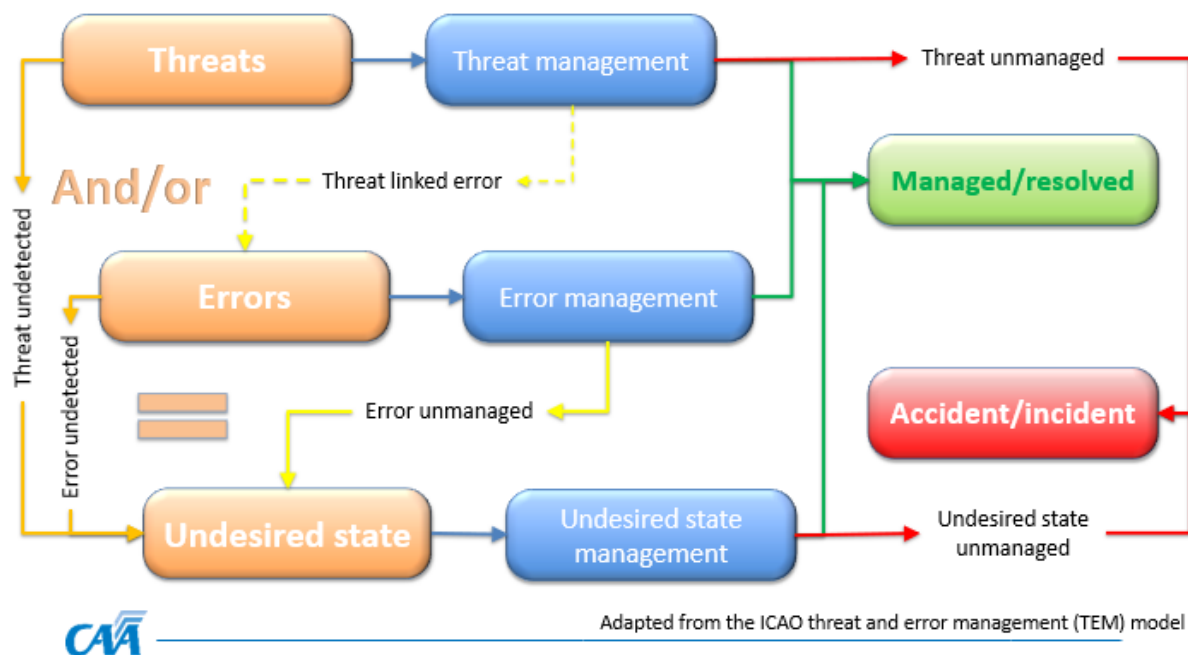
Applying TEM and countermeasures

Figure 3 – CAANZ threat and error management (TEM) model. Adapted from the International Civil Aviation Organization (ICAO) model.

How well threats and errors are managed is determined by the individual's ability to detect them in time. If threats and/or errors go undetected, they can lead to undesired states, and if left unmanaged can lead to an accident or incident, refer Figure 3.

Error is an unavoidable part of being human, but certain threats, such as fatigue, can affect an individual's decision-making ability, increasing the likelihood of errors. When managing a threat such as poor environmental conditions, individuals can become distracted, leading to additional errors being made, these can be considered 'threat-linked errors' (Figure 3).

If an undesired state is encountered, it is important to apply the correct solutions to manage/resolve the situation, restoring the safety margins.

Using TEM, individuals can plan and apply appropriate countermeasures to identify and then manage threats and errors, to prevent them leading to an undesired state compromising the safety margins. Therefore, responding quickly and applying the appropriate actions to manage and/or resolve the threat and/or error ensures safety is maintained.

Countermeasures used in TEM include many standard aviation practices and may be categorised as follows:

- Planning countermeasures:
    o briefings
    o handovers
    o planning and mental simulation
    o contingency planning.
- Execution countermeasures:
    o Monitoring (including self-regulation)
    o Checklist discipline
    o Cross/rechecks
    o Duplicate checks
    o Maintaining situational awareness
    o Information management
    o Task/workload management.
- Review countermeasures:
    o Evaluating and modifying plans
    o Inquiry and questioning.

TEM is therefore a continuous process; the practice of ongoing planning, appreciating, and controlling the progress of events to ensure a safe outcome.