Threat and Error Management

Definitions

Airmanship: The consistent use of good judgement and well developed skills to accomplish flight objectives (International Civil Aviation Organization (ICAO)**.**

Error: Flight crew actions or inactions that:
  • lead to a deviation from crew or organisational intentions or expectations;
  • reduce safety margins; and
  • increase the probability of adverse operational events on the ground and during flight.

Flight environment: The environment internal and external to the aircraft that may affect the outcome of the flight.

  The aircraft's internal environment may include, but is not limited to, aircraft attitude and performance, instruments, observations, flight controls, equipment, warning and alerting devices, trainee members, aircraft position, procedures, publications, checklists and automation.

  The external environment may include, but is not limited to, airspace, meteorological conditions, terrain, obstacles, the regulatory framework, other stakeholders and operating culture**.**

Formative assessment: Formative evaluation monitors learning progress during instruction and provides continuous feedback to both trainee and instructor concerning learning success and failures.

Human factors: Optimising the relationship within systems between people, activities and equipment.

Manage(ment): To plan, direct and control an operation or situation.

Non-technical skills: Specific human factors competencies, sometimes referred to as 'soft skills', such as lookout, situation awareness, decision making, task management and communications.

Situation awareness: Knowing what is going on around you and being able to predict what could happen.

Summative assessment: A summative evaluation is conducted at the end of a course of training and determines if the instructional objectives (competency standards) have been achieved.

Technical skills: The manipulative and knowledge skills a pilot employs when operating an aircraft.

Threat (University of Texas/GAPAN definition for multicrew/LOSA operations):
Events or errors that:
  • occur outside the influence of the flight crew;
  • increase the operational complexity of the flight; and
  • require crew attention and management if safety margins are to be maintained.

Threat and Error Management (TEM): The process of detecting and responding to threats and errors to ensure that the ensuing outcome is inconsequential, i.e. the outcome is not an error, further error or undesired state.

Undesired aircraft state: Pilot induced aircraft position or speed deviations, misapplication of flight controls, or incorrect systems configuration, associated with a reduced margin of safety.

Introduction

Most aircraft accidents are linked to deficiencies in human performance. These deficiencies may involve a variety of factors. The factors include poor lookout, situation awareness (SA), decision-making, task organisation, communication, failure to recognise threats to safety and the commission of errors.

Worldwide statistics indicate that about 75% of aircraft accidents are caused by Human Factors (HF) deficiencies. The application of Threat and Error Management (TEM) practices requires the competent use of HF skills.
The International Civil Aviation Organization (ICAO) has acknowledged the need for this type of instruction and recommends that HF and TEM should be introduced into all pilot training. A major component of TEM is the application of good HF practices.

Traditionally these items have been associated with airmanship or just plain common sense; and knowledge was gained through experience and a process of 'infusion'. The move to link airmanship to HF is in effect, tantamount to bringing science to the often nebulous concept of airmanship**.**
This training must be structured and designed to meet competency standards. Therefore, it is essential that flight training organisations develop techniques and material for teaching HF and those Flight Examiners conducting flight tests have methods and tools to assess competency.

Thus, as a measure of airmanship, if the pilot is maintaining an adequate lookout, they would (for example) see potential forced landing areas. By maintaining SA (for example, wind velocity, visibility, and aircraft performance) the pilot can apply this information for contingency planning and reinforce the decision-making process if an engine failure occurs. These aspects would be observable and assessable.
The purpose of linking HF and airmanship is not to diminish the importance of airmanship, but to make the measurement of it valid and reliable.

Information processing

Pilots are required to continuously process information during flight operations. This function occurs during all phases of flight from the moment planning begins until the pilot signs the Flight Technical Log after a flight. It is necessary for instructors to understand how information is processed so that they can apply the principles involved to assist trainees with lookout, SA, decision-making, task management and communications.

Stimuli are collected by the sensors: eyes, ears, nose, taste buds, skin and muscles (feel), and the vestibular senses (balance mechanism), and then this information is passed to the brain. The information is analysed and interpreted (perception or mental model) and is stored in the sensory memory for a short time (one to five seconds) until it is replaced by new information.

This is the basis of SA. Failure to receive information or analyse it appropriately, may result in poor SA.

Some factors that may limit the construction of an accurate mental model are:
   • **Experience:** lack of experience will lead to the likelihood of not recognising a stimulus;
   • **Stress:** may lead to single task fixation;
   • **Anomalous perception:** illusions, false signals from other people or the balance mechanism; or
   • **Lack of knowledge:** can lead to a false premise.

The acquisition of SA is what all pilots must strive for, and all instructors must teach. The next step to information processing is decision-making.

After the stimuli have been perceived and options developed, a person is in a position to make a decision. A decision is arrived at after the brain determines what to do about the options. This process involves memory to recall stored information that is applicable to the situation. The working or short-term memory holds the information being used at the time and may call on the long-term memory to evaluate new information. The brain is a 'single channel processor' and can only deal with one decision at a time. Therefore, if the decisions are not prioritised correctly (the most critical decision first), the outcome could be unfavourable.

This is a brief explanation of information processing and CAA recommends that instructors review the information contained in other publications that address the subject in greater depth.

Instructors must be aware of the many limitations that affect information processing and decision-making. Understanding these limitations and applying the information judiciously can assist in the development of a trainee's skills in these disciplines.
Some of the limitations are:
   • time limitations;
   • mental overload, task mismanagement;
   • conflicting information;
   • expectations and anticipation;
   • fatigue;
   • insufficient knowledge;
   • forgetting;
   • emotions; confirmation bias (ignoring information that does not support the decision);
   • personality traits;
   • failure to seek or apply feedback;
   • stress; and
   • fixation and destination obsession.
This is not a comprehensive list but it represents some of the factors that an instructor must take into account when dealing with information processing and decision-making.

Teaching an effective lookout
One area of concern is how to maintain an effective lookout. Effective lookout means seeing what is 'out there' and assessing the information that is received before making an appropriate decision. Teaching this skill is the domain of the instructor.

Vision is the primary source of information for a pilot. Whether it is aircraft attitude, position, physical hazards or other traffic, what a pilot sees is processed by the brain and used to build up SA. Therefore, it is important for an instructor to effectively train a pilot how to best utilise vision to maintain safety. In this context, lookout must not be thought of as just scanning the skies to locate other traffic; it also involves the internal and external environment of the aircraft. Inside an aircraft vision is used to interpret flight instruments, flight controls and aircraft systems and externally to observe and interpret weather, terrain, aircraft attitude and position.

Instructors should guide trainees through the multitude of factors that can adversely affect vision and lookout such as the amount of ambient light, window posts, the cleanliness and crazing of windscreens and other physiological and psychological concerns. Failure to address these issues could result in restrictions to visibility.

Workload mis-management can lead to excessive 'head in the cockpit' with less time spent looking outside the aircraft during busy periods. Instructors should warn trainees about all these situations and highlight such incidents when they occur during flight training. For example, instructors should, during flight training, stress the importance of ensuring the windscreen and eyewear is always clean and free of crazing. Trainees must be taught to move their head to see beyond window posts and any other obstructions such as passengers in the adjacent seat.

Seeing and interpreting
Not only is seeing important, but accurately interpreting what is seen is equally vital.

Instructors may assume that a trainee interprets what they see in the same way as the instructor – but this may not always be the case and instructors should spend time explaining the logic of observations.
Examples for consideration are observing and interpreting:
- aircraft attitude;
- indications of adverse weather;
- wind strength and direction from clouds, blowing dust, smoke, trees and water;
- terrain effects on wind;
- other air traffic;
- reduced visibility;

Throughout training instructors must firstly teach and then assess a trainee's ability to observe what is happening around them and to apply that knowledge to ensure safety.

Looking for traffic
A great deal of a pilot's time must be spent looking for and sighting air traffic in order to avoid possible conflict. The concept of see-and-avoid is far from reliable**.** By employing an effective scanning technique and understanding how to enhance visual detection of other traffic, a pilot is more likely to reduce the likelihood of collision.

Size and contrast are the two primary factors that determine the likelihood of detecting other aircraft. Size is the more important parameter in detecting aircraft and as GA aircraft are usually small, the problem of detecting aircraft is exacerbated.

Passengers may also be used to help improve lookout. Trainees should be taught to ask their passengers to advise them if they sight anything that may be a threat or could compromise safety. An instructor must provide and demonstrate an acceptable lookout technique, and ensure that trainees practice and apply the technique and, most importantly, **see all other traffic that is a threat to flight safety.**

Alerted search
An alerted search is visual scanning when air traffic information has been provided and a pilot is, in effect, told where to look. Air traffic services or other pilots could provide this information.

The likelihood of detecting other traffic is greater under these circumstances than during an unalerted scan. Other technologies that provide similar information include transponders, radar (both airborne and ground installations), Traffic Collision Alerting Devices (TCAD) and Traffic Alert and Collision Avoidance Systems (TCAS).

Although this equipment is not usually fitted to general aviation aircraft it demonstrates how technology can assist lookout and pilots must not disregard the benefits of 'alerted searching'; and listening to and interpreting radio transmissions in the circuit area are an ideal opportunity to teach these aspects to a trainee.

A summary of maintaining an effective lookout:
  • threats are external to the aircraft; so
  • the pilot must look outside the aircraft;
  • search the available visual field to detect threats that will probably appear in the peripheral vision;
  • shift vision directly to the threat and if identified as a collision risk, decide on what effective evasive action to take; and
  • manoeuvre the aircraft to mitigate the risk.

Pilots must realise that this process takes time; and HF deficiencies can reduce the chances of a threat being detected and avoided.

The factors affecting lookout are not errors or poor airmanship, but are limitations of the human visual and information processing systems, which are present to various degrees in all humans.

Nonetheless, effective training can improve the effectiveness of a lookout technique.

Assessment in general
Assessment is the process of weighing evidence of an individual's performance against a standard. The evidence used must follow an established set of rules.
These are:
  • **Validity:** it must cover all the performance criteria for the skills and knowledge of the standard being assessed;
  • **Authenticity:** it must be the individual's own work;
  • **Sufficiency:** enough evidence must be collected to judge the individual is competent across:
    ◦ all elements and performance criteria;
    ◦ all dimensions of competency; and

• **Currency:** the individual is competent now and meets the current standard.

Only with evidence which follows these rules can an accurate judgment of an individual's competence be made.

The 'dimensions of competency' referred to in the previous paragraph means that the assessment is not narrowly based on a task, but embraces all aspects of performance and represents an integrated and holistic approach to the assessment. The assessment process must take into account task skills, management and contingency skills, role skills and transfer skills. For example, instead of just assessing a 30° banked turn against the specified standard, it may be more realistic to observe the candidate performing the manoeuvre during a precautionary search (a contingency) where the turn is used to position the aircraft to observe and assess the landing surface (a role).

The skill is being applied to a new circumstance (transfer of skill), while managing a somewhat complex undertaking. This approach combines knowledge, understanding, problem solving, technical skills and application into the assessment.

Assessing lookout
Instructors and Flight Examiners have the task of assessing the ability of trainees to maintain an effective lookout. Their roles are slightly different: an instructor is required to conduct formative assessments during training to determine how well a trainee is learning, but the Flight Examiner must conduct a summative assessment at the conclusion of training to determine if the trainee is competent to be issued a licence.

There are two main elements to effective lookout.
Firstly, to see an 'object' and secondly, to react appropriately to what has been seen. An 'object' could range from a speck in the windscreen that is an aircraft at long range, to a large feature like Mount Cook. The next step would be to determine if the object is a threat, and then take mitigating (more commonly known as avoiding action!). These are the processes the assessor is looking for.

The three performance criteria relevant to maintaining an effective lookout are:
• maintains lookout and traffic separation using a systematic scan technique at a rate determined by traffic density, visibility and terrain;
• maintains radio listening watch and interprets transmissions to determine traffic location and intentions; and
• performs 'airspace cleared' procedure before commencing any manoeuvres.

These three criteria must be achieved for a positive assessment of effective lookout.

The key point is that the trainee covers the field of view from the cockpit, and varies the scan rate to accommodate the threats. Clearly, during periods in congested airspace, extra attention must be paid to other traffic.

Unfortunately airspace congestion is usually encountered during busy stages of a flight, such as departure and approach. These high workload periods often focus a trainee's attention inside the cockpit.

Flight Examiners must watch the trainee during these phases of flight to ensure that tasks are prioritised and managed to ensure a good lookout is maintained. This can be achieved by monitoring head and eye movement, when possible. Additionally the assessor must monitor the candidate to determine whether any traffic information received by radio transmissions is reacted to appropriately.

Pilots must always clear the airspace around them before manoeuvring the aircraft. This 'clearing procedure' must not only be used to locate other aircraft but also any terrain, weather or other hazards that may compromise safety.

Flight Examiners must observe whether the trainee always uses an acceptable procedure and whether when they look, threats are seen and identified.

Finally, assessors must ensure that trainees are aware of the limitations of vision and take these aspects into account when looking out. These include such aspects as blind spots, threshold of acuity, accommodation (focusing on an object), empty field myopia, focal traps, visual field narrowing and cockpit workload.

What is situation awareness?
Simply defined SA is; 'Knowing what is going on around you, and being able to predict what could happen'.

A more colloquial term is 'street smarts'. However, a comprehensive and technical definition proposed by M. R. Endsley in 1988, is; 'The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future'.

The first definition is generic and applies to life in general, and to most occupations. The second definition is more specific to aviation and is often assigned three levels which are:
   • **Level 1:** perception of the current environment;
   • **Level 2:** interpretation of the immediate situation; and
   • **Level 3:** anticipation of the future environment.

Monitoring and gathering information from both within the cockpit and outside the aircraft achieves perception of the current environment.

This information is collected by the senses (Level 1). Next the process of interpretation (Level 2) leads to making conclusions of what is likely to occur (Level 3).

Teaching situation awareness
From the moment training begins, a trainee must be made aware of SA, its importance, and how it will be taught and assessed. In the normal course of flight training, trainees are shown how to monitor flight instruments, aircraft systems and flight attitudes and to manage them appropriately to achieve the desired performance. Instructors need to point out how all this information is applied to develop SA. Additionally, trainees must learn to monitor, gather and interpret appropriate information from both inside and outside the aircraft. This continual monitoring assists perception (mental model) of what is happening and what is likely to happen in the near future, which is the basis of SA. Visual information is the greatest source for building and maintaining SA.

Instructors must also explain to trainees the importance of maintaining a good radio listening watch and, during initial training, explain how interpretation of radio-telephone (R/T) transmissions will enable them to anticipate other traffic and likely air traffic instructions. As training progresses, the instructor must observe the trainee's performance and if necessary develop scenarios to improve, challenge and assess SA.

Observation and questioning are the primary means of making a formative assessment of SA. For example, one of the first senses that can degrade during higher workload is hearing. If a trainee (or instructor) is aware they require ATC to read back clearances more often than normal, and/or they are starting to miss radio calls altogether, this could be the first sign of overload and degraded SA. Questions like "What would you do if…?" can be used to assess a person's SA. This type of assessment must be conducted throughout a pilot's training and the results used to modify the training plan when appropriate.

During training, instructors must include SA as part of every flight. This could be achieved by stressing the importance of continually monitoring the total environment and updating options as situations change.

Trainees must be encouraged to verbalise their observations so that the instructor is also informed and able to make assessments. Therefore, they may need to plan how they will conduct SA instruction and possibly create scenarios to enable the learning to occur, it is likely however that, during the normal course of a flight, situations will evolve that present trainees with the opportunity to apply and demonstrate their SA.

Assessing situation awareness
The most important aspect of assessing SA is to confirm that the pilot's mental model (or perception) of the environment is accurate. Next, find out what options have been generated and whether they are realistic. In other words, the assessor must see if the 'what ifs' complement the mental model and provide a basis for an accurate and timely decision if one is required. There may be no need to proceed to the next step of making a decision, as SA is an ongoing process and further action only needs to be taken if some of the perceived situations compromise flight safety. For example, if there are thunderstorms in the area but they do not conflict with the intended track, and the adverse effects of the storm will not affect the flight, no action would need to be taken.

However, it would indicate a lack of SA if the pilot did not consider the storms and the associated hazards in their planning.

Assessors must determine if SA is being maintained regardless of workload. During periods of high workload it is possible that information may be overlooked. For example, if the trainee is busy during an approach into a very active terminal area, radio transmissions may be missed or instructions forgotten. A possible cause for this reduction in SA is failure to recall the information received (short-term memory breakdown causing faulty perception) which can lead to failure to take appropriate action.

Equally, assessors must continue to monitor the trainee during periods of low arousal or workload (inactivity) to ensure that an appropriate level of SA is maintained. During a long navigation leg that is proceeding according to plan, a trainee may relax and stop thinking about "what is happening and what could happen". It would be appropriate to confirm that

SA is being maintained by the use of questions such as "Where would you divert to now if a passenger became seriously ill?", "If you suffered an engine failure where would you land?" or "What is our endurance now?"

Assessors must also observe the appropriate application or otherwise of knowledge, because SA can be adversely affected by a lack of knowledge. For example, unfamiliarity with air traffic separation rules could result in unsatisfactory descent planning when opposing traffic is present. Deficiencies in aircraft systems knowledge could lead to unsatisfactory outcomes; fuel system mismanagement would be a typical example.

Teaching decision making
By applying SA, a pilot may arrive at a number of options of 'what could happen', and the next step is to make a decision that achieves the optimum outcome. In daily life people are always making decisions - usually sub-consciously. However, in the aviation environment the decisions that sometimes must be made can have tragic consequences if they are incorrect or inappropriate. Therefore, it is important for pilots to understand and be able to apply the decision making process and to be aware of the need to make timely and correct decisions. Instructors must mentor trainee pilots through the decision-making process. For example, applying information sources such as meteorological reports, NOTAMs, radio transmissions, visual observations and knowledge to the situation to make decisions.

Assess Situations and Make Decisions
Trainees must be given the opportunity to decide and, if a decision is flawed, the reasons must be clearly explained. For example, if the weather is marginal before a flight, rather than cancelling the sortie, the instructor should ask the trainee (who probably is very eager to fly) whether or not it would be prudent to undertake the flight.

It is quite normal for an instructor to make decisions during flight, but it may be of more benefit to ask the trainee for their opinions. By doing this it is possible to assess their progress and then to provide training if it is required.

During flight training there will be many occasions to observe, assess and improve a trainee pilot's decision making.
Instructors must be conscious of when there is a requirement for a trainee to make a decision. They must then determine if it is an acceptable decision that has been made in the time available. If the decisions are defective, it may be necessary to go through the reasoning that was used and point out any faults and explain how considerations and logic should be applied to reach an acceptable decision.
Although this may seem to be a laborious procedure, it is an improvement on the traditional method of simply revealing to a person that they had made a wrong judgment, and telling them what they should have done, without analysing why the mistake was made and offering guidance to help them improve their decision-making skills.

The timeliness of decisions is another facet of decision-making that instructors must emphasise. During flight training opportunities will arise to gauge and advise a trainee about timely decisions, but there may be a need to create scenarios for the purpose of demonstration. For example, a mishandled landing may require a quick decision to go around to prevent damage to the aircraft.
However, the decision to divert because of adverse weather or fuel shortage on a navigation flight may have a 'deadline', by which time a decision must be made.

Although the aforementioned decisions must be made in different timeframes, the information process will be the same. That is:
- receive information;
- convert information into reality;
- options are generated;
- options are analysed; and
- a decision is made.

What is also different is that in the second case the situation is dynamic, variable, emotive and subject to bias.
These aspects of decision-making make the process more difficult and susceptible to errors.

The result could be an incorrect or 'non' decision. To give a trainee practice at this type of (more complex) decision-making, instructors may have to develop scenarios for different stages of flight training to provide opportunities to practice (and learn) decision-making. Another example to highlight this process is a simulated engine failure versus partial power loss. The first is a relatively clear outcome that requires well rehearsed decisions, checklists and actions to set up a forced landing.

The latter is more subjective, potentially offers more time and provides the trainee with a larger number of options from which to make a final decision. In itself this latter type of scenario is a richer training environment for decision-making as it leaves the trainee with a number of options that can be discussed in the debrief: why the trainee chose a specific course of action, what were their considerations for reaching this conclusion etc.

Furthermore, with increased experience and exposure to known operating conditions and a specific aircraft type, a number of processes become more automated, which is the natural outcome from a positive transfer of learning. For those that have been driving a car for a number of years you probably don't have to think about what you are doing, your actions are automatic. For others who are learning to drive it is more mechanical and requires much more conscious effort and thought to consider the steps required. This automatic decision making process will occur within flight training as the trainee becomes more familiar with the local operating environment and the training aircraft. This familiarity also translates to an environment in which decision-making may not be fully tested in the latter stages of training as the local operating conditions are so well known and rehearsed that the trainee continues to have large amounts of spare capacity to deal with any simulated scenarios the instructor may wish to impose, many of which have been previously experienced.

Higher cognitive demands are potentially created any time a trainee experiences something new or unknown,. For example, if the trainee has conducted a large part of their training under conditions of clear weather, even with considerable training experience, the first flight in which they are required to deal with marginal weather in the same training area and aircraft could impose significantly increased workload with the potential to result in degraded performance and higher cognitive demands when making decisions.

Instructors should ensure that training sequences consider trainee familiarity and look for opportunities that expose the trainee to new situations with which they may not be as familiar, in order to consolidate and assess their ability to manage the flight, maintain situational awareness and make sound decisions.

Finally, when teaching decision-making, instructors must remember that individuals have different emotional attitudes, learning rates, thought processes, analytical skills, aspirations and cultural backgrounds which may influence how this skill is taught. Therefore, instructors must be flexible, imaginative and innovative in developing ways of passing on decision-making skills to pilots of all experience levels. The bottom line is that pilots must make timely, correct or correctable decisions…if not the consequences could be fatal!

Assessing decision-making
Normal flight training provides ample opportunities for instructors to conduct formative assessments of decision-making skills, though it may be necessary to create scenarios to analyse a trainee's ability to manage complex decision-making. This process may be more difficult for a Flight Examiner to assess on a flight test because of a limited time frame and reduced opportunity.
Nevertheless, a pilot's decision-making must be assessed as competent on a licence or rating flight test.
The pilot must recognise that a decision has to be made. The ongoing process of acquiring SA, if working correctly, will provide the pilot with a perspective from which any number of options can be derived and ultimately the best action to follow. Problems must be identified and the assessor will use observation and questioning to determine the facts. Next, the problems must be analysed and solutions (options) proposed. This procedure will require the pilot to gather and process information. The pilot's actions must be observable, but some questioning may be required to obtain an accurate assessment. Using this information a decision can be made. Assessors must ensure the decision is the optimal one and is implemented effectively in the time available. The pilot then must monitor progress against their plan and re-evaluate as circumstances change, even if it is to confirm the desired outcome.

For an obvious decision such as a 'go around' after a mishandled landing, the action and results will be very evident. In such a case a point worth considering would be to ensure the pilot recognised the mishandled landing soon enough and did not delay the recovery action. However, more complicated decisions may require greater analysis by both the pilot and the assessors. A complex problem may require a decision that does not lead to the optimum result, but could be modified at a later time.
It is acceptable to make a decision on the basis that it may require revision, if the safety of the flight is not compromised and the trainee continues to re-evaluate and update that initial decision. This situation could occur where a decision is made during flight planning, which may have to be modified after the pilot becomes airborne (operational requirements, insufficient information available or weather).

Teaching how to set priorities and manage tasks
The adage 'aviate, navigate and communicate' is the basis of prioritisation and task management.
Task management means completing a job or operation competently in the time available. If the workload is high and many tasks have to be completed, they must be prioritised in a logical and efficient sequence.
The brain is a single-channel processor (linear) and humans can normally only manage one activity at a time. Instruction to ensure competent task management must begin at the commencement of a pilot's flight training. Many things that experienced pilots take for granted must be pointed out and explained to the novice.

For example, when a pilot is first introduced to the cockpit they must be shown how to adjust their harness and seat, and reach and touch controls and switches. Proficiency in these operations will make workload management easier.

During flight training trainees must be encouraged to prioritise tasks to ensure that the important and safety critical actions are dealt with first. Referring to the adage at the beginning of this section 'aviate' or maintaining control of the aircraft must be a pilot's first concern. One of the cornerstones of managing an undesired aircraft state in TEM is timely correction of the undesired state rather than concentrating on why an error may have occurred. This is prioritising correctly. Instructors must alert trainees when they have incorrectly prioritised and offer a more appropriate solution.
A question like "What is more important?" may prompt a pilot to prioritise correctly.

Another practice that instructors must stress is good organisation in the cockpit. This is particularly applicable when navigating. Thoughtful selection and storage of charts, flight plans, computers, publications and writing implements should result in more precise and simpler navigation. In addition, achieving an appropriate work rate is critical during this phase of flight. Instructors must remember that rationalising the workload will ensure more efficient task completion which in turn must result in greater safety.

One of the keys to workload management is the ability to recognise factors that adversely affect a pilot's ability to operate efficiently. A non-comprehensive list of factors that can reduce a pilot's work efficiency follows:
  • **lack of preparation**: (confusion, disorganisation);
  • **fatigue:** (poor decision making, errors);
  • **discomfort**: (distraction, fatigue);
  • **stress**: (inefficiency, distraction);
  • **arousal**: (increased or decreased work cycles);
  • **domestic stress**: (distraction, lack of concentration);
  • **distraction**: (diverted attention);
  • **non-use of automation**: (increased work);
  • **destination or task obsession**: (poor decision making, press-on-itis);
  • **bad health**: (decreased physical and psychological performance); or
  • **overload**: (fixation, tunnel vision, broken work cycles).
Although this is not a comprehensive list, instructors must be aware of these types of factors and look for these deficiencies in their trainees. Once the weaknesses have been identified, instructors must advise trainees of methods of developing and applying countermeasures or strategies to manage these inhibiters to efficient workload management.

A final word on prioritising tasks. Whether it is a minor or major problem that is being encountered it must always be remembered that the first priority is survival.
To survive requires maintaining control of the aircraft and/or the situation. When dealing with a major system malfunction at the same time as Air Traffic Control is requesting information the choice is simple: deal with the malfunction first. Unfortunately, a pilot's response to 'authority' can dominate and time could be wasted with a long communication with ATC. This would be an example of incorrect prioritisation if it happened in a remote area, in bad weather, when uncertain of position, and dealing with a worried or annoyed passenger. This would be an unenviable position - nevertheless the pilot must think 'survival' and prioritise actions accordingly.

During flight training an instructor must develop and use appropriate scenarios to provide valuable and potentially lifesaving guidance.

Assessing prioritisation and task management
An assessor must assemble evidence of competence in setting priorities and managing tasks on a flight test by simply observing a pilot's work pattern and task completion. The danger is that such assessment is prone to subjectivity.
For example, if a pilot is told by ATC to "Expedite takeoff", and does so before completing pre-take-off checks then the pilot could be reasonably deemed as not competent at prioritising tasks.

When assessing task management the Flight Examiner must be looking for competent completion of a task in the time available. In particular, the assessor would be seeking confirmation that the pilot can manage multiple tasks (not an excessive amount) in a logical order. It may be necessary to create scenarios to fulfil this requirement.
The assessment process will require detailed observation, information gathering and questioning because there will be a need to determine how a candidate's mind is functioning while managing tasks. By obtaining this information and combining it with observations it is possible to judge a pilot's ability to competently set priorities and manage tasks.

Teaching effective communications and interpersonal relationships
Communication is a two-way process; it involves the accurate transmission, receipt, and interpretation of information. Communication is not limited to the radiotelephone; it also involves direct verbal and non-verbal exchanges. 'Effective interpersonal relationships' is a topic that may seem to be 'touchy-feely', but involves being able to get a positive or helpful, rather than negative or obstructive, response from individuals or groups that a pilot deals with. A major component of interpersonal relationships is effective communication.

The first requirement for communication is a common language, which is the English language and 'aviation English'. Aviation English is the use of standardised, abbreviated, precise and agreed terminology and phraseology. Pilots are expected to use Aviation English and will gain knowledge and experience in its use as their flight training progresses. There may be a tendency for instructors to take the communication process for granted, without considering some of the deeper implications of not communicating clearly, or failing to consciously train novice pilots to communicate adequately.

Instructors must monitor and develop a pilot's communication skills throughout flight training, pointing out when communications are confusing, ambiguous or out of context. The next step would be to suggest a way to modify and improve the communication
Extra care is required when teaching trainees who do not have English as a first language.

The instructor must be precise with their use of language and be careful with slang and colloquial speech.

During flight training there will be many opportunities to observe and judge the effectiveness of a trainee's communication skills.
It is important to make the trainee aware of the consequences of poor communication skills and for them to be self-critical of their own performance. Emphasise the safety issues that can result through miscommunication.

The intent of 'maintaining effective interpersonal relationships' is to make pilots aware of the need to always foster positive and cooperative relationships with persons involved with or affected by the flying operation to be performed.

Persons affected could be an instructor, refueller, maintenance engineer, an air traffic controller or the farmer who owns the airfield where the aircraft will land; and the pilot must be able to elicit positive reactions from them. This does not mean that instructors must be teaching manners or how to be nice, but they must provide guidance on achieving positive outcomes. The flight instruction will involve observation of the pilot's interaction with others and the results of these activities.

If the instructor detects inadequacies, then the trainee must be advised and given strategies to improve their performance. Some personal characteristics that must be evaluated are:

- tone and phrasing of communications;
- openness;
- reaction to criticism;
- aggressiveness or lack of assertion;
- willingness to listen;
- respect for others;
- arrogance; and
- use of authority.

This is not an all-encompassing list, but it highlights some of the positive and negative characteristics that, if applied inappropriately, could cause an adverse response from others. As an example, an aggressive, brusque or demanding tone of voice during an R/T transmission could garner an adverse response from an air traffic controller, and instructors must identify these issues when they occur. Failure to discuss and rectify this sort of problem could have a negative influence on a pilot's future performance.

Assessing effective communications and interpersonal relationships
The performance criteria for 'Establishes and maintains effective and efficient communications means that the pilot first makes the effort to communicate or interact. The behaviours that the instructor may look for could include tone of voice, nonaggressive approach, willingness to listen, body language (when applicable) and assertiveness.

In summary, instructors must recognise and appreciate the importance of HF skills and make them an integral part of training; and assessors must be prepared to incorporate HF into flight tests. This will require diligence in the preparation of training plans by instructors and assessment planning by Flight Examiners. The application of good HF is integral to, and inseparable from, competent TEM which is covered in the next section.

Threat and Error Management
TEM was developed by the University of Texas and derived from observations on flight decks during Line Operations Safety Audits (LOSA). Although some pilots may see TEM as just another fad with a new range of buzz words, TEM is in reality the formalisation of what many would call common sense.

Management means a plan is developed, implemented and re-evaluated throughout the activity.

The application of this skill when managing threats and errors involves a plan for identifying the threat or error and implementing countermeasures to reduce or eliminate them. Direction may, in the case of a single pilot aircraft, require self-direction to ensure action is taken to

mitigate the hazards, in accordance with checklist or approved Flight Manual/POH procedures, SOPs or other acceptable means. Implementing countermeasures would involve monitoring the progress of events to ensure a safe outcome, which may require amendment of plans and actions.

TEM is an operational concept applied to the conduct of a flight that is more than the traditional role of airmanship as it provides for a structured and pro-active approach for pilots to use in identifying and managing threats and errors that may affect the safety of the flight. To achieve this, TEM uses many tools, including training, SOPs, checklists, briefings and single-pilot HF principles.

TEM has been generally accepted in the airline industry as an effective method of improving flight safety, and is now required by ICAO as an integral part of pilot training at all licence levels.

Generally risk management is the process of deciding whether or not operations can be conducted to an acceptable 'level' of risk (go or no-go) safely, whereas TEM is the concept applied to managing and maintaining the safety of a particular flight. The following sections provide a brief introduction to assist General Aviation (GA) pilots and trainers to apply the principles of TEM to their own operations.

Threats
Threats are defined as external events or errors that:
   • occur outside the influence of the flight crew;
   • increase the operational complexity of the flight; and
   • require crew attention and management if safety margins are to be maintained.

They may be anticipated, unexpected or they may be latent within the operational system. Generally, threats are considered to be external (e.g. bad weather) or internal i.e. those the pilot or trainee bring to the operation (e.g. fatigue, complacency).

Pilots need good SA to anticipate and recognise threats as they occur. Threats must be managed to maintain normal flight safety margins. Some typical external threats to operations might be:
   • adverse weather;
   • weight and balance;
   • density altitude;
   • runway length;
   • other traffic;
   • high terrain or obstacles; or
   • the condition of the aircraft.
Some typical internal threats to GA operations might be:
   • fatigue;
   • complacency;
   • over or under confidence;
   • lack of flight discipline;
   • hazardous behaviour;
       ◦ impulsiveness;
       ◦ machoism;
       ◦ invulnerability;

◦ resignation; and
◦ anti-authority or
• lack of currency and proficiency.

Errors
The TEM model accepts that it is unavoidable that pilots, as human beings, will make errors. Errors are defined as flight crew actions or inactions that:
• lead to a deviation from crew or organisational intentions or expectations;
• reduce safety margins; and
• increase the probability of adverse operational events on the ground and during flight.

They can be classified as handling errors, procedural errors or communications errors.

While errors may be inevitable, safety of flight requires that errors that occur are identified and managed before flight safety margins are compromised. Typical errors in GA flight might include:
• incorrect performance calculations;
• inaccurate flight planning;
• non-standard communications;
• aircraft miss-handling;
• incorrect systems operation or management;
• checklist errors; or
• failure to meet flight standards e.g. poor airspeed control.

Undesired Aircraft State
Threats and errors that are not detected and managed correctly can lead to an undesired aircraft state, which could be a deviation from flight path or aircraft configuration that reduces normal safety margins. The definition of undesired aircraft state is:
• Pilot induced aircraft position or speed deviations, misapplication of flight controls or incorrect systems configuration associated with a reduced margin of safety.

An undesired aircraft state can still be recovered to normal flight but, if not managed appropriately, may lead to an outcome such as an accident or incident. Safe flight in an aircraft requires recognition and recovery from an undesired aircraft state in a very short timeframe before an outcome, such as loss of control, failure to achieve optimum performance or uncontrolled flight into terrain occurs.

Examples of errors and an associated undesired aircraft states in GA aircraft might be:
• mismanagement of aircraft systems (error) resulting in aircraft anti-ice settings not turned on during icing conditions (state);
• loss of directional control during a stall (error) resulting in an unusual aircraft attitude (state);
• inappropriate scan of aircraft instruments (error) resulting in flight below VYSE (best single-engine rate of climb speed [blue line speed]).

Good TEM requires the pilot to plan and use appropriate countermeasures to prevent threats and errors leading to an undesired aircraft state. Countermeasures used in TEM include many standard aviation practices and may be categorised as follows:
• **planning countermeasures:** including flight planning, briefing, and contingency planning;

  • **execution countermeasures:** including monitoring, cross-checking, workload and systems management; and
  • **review countermeasures:** including evaluating and modifying plans as the flight proceeds, and inquiry and assertiveness to identify and address issues in a timely way.

Once an undesired aircraft state is recognised, it is important to manage the undesired state through the correct remedial solution and prioritise aircraft control for return to normal flight, rather than to fixate on the error that may have initiated the event.

TEM application

Threats and errors occur during every flight as demonstrated by the considerable database that has been built up in observing threats and errors in flight operations worldwide through the LOSA collaborative. One interesting fact revealed by this programme is that around 45% of flight crew errors go undetected or are not responded to by crew members.

TEM must be integral to every flight, and includes anticipation of potential threats and errors as well as planning of countermeasures. Also included must be the identification of potential threats, errors and countermeasures in the self-briefing process at each stage of flight, and avoiding becoming complacent about threats that are commonly encountered (e.g. weather, traffic, terrain etc).

The following summary is intended to assist pilots to apply TEM in GA operations:

Pre flight:
  • just as you perform a number of tasks on a regular basis in preparation for flight (e.g. interpreting NOTAMs and MET information, checking fuel contents), pilots must include TEM as part of routine pre-flight planning and preparation;
  • a few minutes (or more) spent on the ground anticipating possible threats and errors associated with each flight will provide the opportunity to plan and develop countermeasures (e.g. action in the event of unpredicted weather changes). A good starting point is to ask what actions, conditions or events are likely to promote errors, leading to the identification of internal and/or external threats applicable to that flight. This can reduce your workload airborne as you may have already partially prepared yourself with how to deal with those threats and errors.

In flight:
  • brief (self-brief and passengers) planned procedures before take-off and prior to commencing each significant flight sequence (eg. approach to an unfamiliar aerodrome, low-level operations etc);
  • include anticipated threats and countermeasures in briefings;
  • continuously monitor and cross-check visual and instrument indications and energy state to maintain situation awareness;
  • prioritise tasks and manage workload to avoid being overloaded, and to maintain SA;
  • when confronted by threats and/or errors a priority is to ensure the aircraft is in an appropriate configuration to optimise your ability to maintain control of the aircraft and flight path;
  • monitor the progress of every sequence and abort if necessary;
  • do not fixate on threat or error management to the detriment of aircraft control;
  • identify and manage any undesired aircraft state; and;
  • recover to planned flight and normal safety margins before dealing with other problems.

Post flight:
  • take a few minutes at the end of each flight to reconsider what threats, errors and/or undesired aircraft states were encountered during the flight. Ask yourself how well they were managed and what you would do differently to improve management of those threats and errors;
  • record your threats, errors, and/or undesired aircraft states and discuss them with more experienced pilots to assist with the development of improved TEM strategies.

Teaching threat management
In the TEM model, threats can be defined as a situation or event that has the potential to impact negatively on the safety of a flight, or any influence that promotes opportunity for pilot errors. Instructors must understand that threats (and errors) are a part of everyday aviation operations and must be managed. First, instructors must stress to trainees that threats fall into two main groupings: anticipated and unexpected.
However, there is a third group called latent threats. These threats may not be observable by pilots involved in flight operations and may need to be uncovered by safety analysis.
Some examples of latent threats are optical illusions (approaches to sloping runways), poor manuals, or equipment design faults (landing gear and flap levers located too close to each other) or unnecessary pressure to get a job done. Therefore, it is incumbent upon instructors to show trainees how to detect the three groups of threats, and the steps to take to mitigate these potential hazards.

Detection of anticipated threats relies mainly on knowledge and experience. As pilots learn (and gain experience) they will be able to predict where threats may occur. For example, being able to obtain and interpret a meteorological report will allow a pilot to prepare for adverse weather. Likewise, experience assists pilots to understand more about their own capabilities and limitations.

During flight training, instructors should point out meteorological observations and effects, and question the trainee to determine their application of the information that is available. Prior to each flight, the instructor should discuss the proposed flight and ask the trainee to identify the obvious threats to safety. During the early stages of training the instructor should not necessarily expect a comprehensive list of threats, but as the training progresses, a trainee's level of knowledge is expected to improve. Much will depend on the instructor's approach to TEM training.

Some examples of threats that an instructor must be aware of with a new trainee (and which the instructor should inform the trainee about) are:
  • conduct in the vicinity of aircraft on the ground;
  • performance of competent pre-flight inspections;
  • correct adjustment of flight controls and harness restraint;
  • a clear handover/takeover procedure;
  • ensuring propeller clearance before engine start; and
  • listening before transmitting on the radio.

And the aircraft has not even moved yet!

In a very short time, instructors should expect a trainee to manage these identified threats as a matter of course. As the trainee gains knowledge, experience and skills, they will learn to manage all the threats that develop.

Unexpected threats are more likely during flight operations and must be well managed. These threats are generally managed by applying skills and knowledge acquired through training and flight experience. Typically, a practice engine failure or simulated system failure are methods of training a pilot to manage unexpected threats.

Knowledge and repetition prepare a trainee to mitigate these events, but an instructor should link such training activities to the threat management component of TEM. Again, if errors occur during these sequences, they must be highlighted and advice provided to reduce their effects. During flight training the instructor must identify unexpected threats such as incorrect ATC instructions, traffic hazards or adverse weather and point them out to the trainee should they fail to identify them.

Then it is important to question the trainee to see what steps they would take to mitigate the threats, ensuring that the action is completed in the time available.

Instructors may have to develop scenarios or 'what if' questions, to further test the trainee.

Threats are also categorised in the TEM model into environmental and organisational threats. Environmental threats occur outside the control of the aircraft operator due to the environment in which the operations take place and have to be managed by the pilot in the available time. Some examples would be:

- **Weather:** turbulence, ice, wind;
- **Aerodromes:** congestion, complex surface navigation, poor signage/markings;
- **ATC:** non-standard phraseology, complex clearances, poor English language; and
- **Terrain:** mountains, valleys, built up areas.

On the other hand, organisational threats (which are often latent) can be controlled by the operator or reduced by aviation organisations putting in place mitigators such as safety management systems (SMS), fatigue risk management systems, standard operating procedures, checklists, ground handling measures (marshallers) or operational health and safety procedures. However, the last line of defence will be the pilot.

Some examples of organisational threats in GA are:

- **operational pressure:** tight scheduling of training flights;
- **aircraft:** poor serviceability;
- **maintenance:** maintenance error or event; and
- **documentation error:** incorrect or expired charts.

Teaching error management

The acknowledgement that errors will occur has changed the emphasis in aviation operations to error recognition and management rather than error prevention.

Notwithstanding the fact that under ideal circumstances, errors will not occur, aviation is not an ideal situation and pilots must be trained to manage errors.

So once again responsibility falls on the instructor to conduct the training. Rather than just pointing out errors as they occur, instructors must show trainees how to minimise the chances of errors happening, and then if they do happen, recognise the fact and implement strategies to manage them. Error management could be something as simple as "Oops, I should not have done **that**, I will do **this** now". If the subsequent actions are appropriate then the error has been mitigated.

The important point is that the error was recognised by the pilot, acknowledged and corrective action was taken. Instructors must afford the trainee the opportunity to recognise a committed error rather than intervening as soon as they see an error committed, they must wait (if time allows) to see if the error is identified by the trainee. If it is not, this is a deficiency on the part of the trainee, and the instructor should then analyse why the error happened, why it was not recognised and how to prevent future occurrences.

In the TEM model, errors must be observable and are classified as aircraft handling, procedural or communications errors. The point of reference that defines these classifications is the 'primary interactions'.
- A handling error would occur when a pilot is interacting with an aircraft's controls, automation or systems.
- A procedural error would be when a pilot is using procedures such as checklists, SOPs or emergency actions.
- A communication error occurs when pilots are interacting with other people such as ATC, ground assistants or other crew members.

A question that instructors may also ask themselves is "Is it a communications error if I fail to get the message across to a trainee during training?"

Instructors must be familiar with these classifications so they can identify a trainee's weakness and provide guidance to address the deficiencies.

When teaching TEM, instructors must emphasise the application of HF skills (discussed earlier). If deficiencies are identified in any of the HF skills, they must be rectified or general flying and TEM competency will be compromised.

Mitigators that are in place such as checklists, SOPs and aviation rules must be applied and complied with. Whether a checklist is used from memory or read, instructors must accept no deviations to its application and terminology.
All of these are provided to enhance safety (by helping reduce errors) and instructors must continually stress their importance.

Teaching undesired aircraft state management
Unmanaged or mismanaged threats or errors may result in an undesired aircraft state. Ideally, pilots must be taught to manage threats and errors before an undesired aircraft state develops. During flight training, instructors will be dealing with many undesired aircraft states as trainees develop their flying skills.
In this context, instructors have the dual role of practicing TEM by ensuring that undesired aircraft states are managed and then teaching trainees how to do the same. Because trainees may not have the manipulative and cognitive skills of a qualified pilot, they will often not meet specified flight tolerances or procedures.

Some typical examples would be:
- taxiing too fast;
- too fast or slow on final approach; or
- inability to maintain altitude or heading during straight and level flight.

Although such examples would normally be classified as undesired aircraft states when committed by a qualified pilot, they are not unusual events during flight training. The

difference is that the instructor should be aware of the threats and errors and should not let an undesired aircraft state develop into an undesired outcome (accident or incident). Highlighting undesired aircraft states as they occur, and providing guidance and advice on their prevention will enrich the trainee's learning experience.

A critical aspect that instructors must teach is the switch from error management to undesired aircraft state management. During the error management phase, a pilot can become fixated on determining the cause of an error and forget the old adage 'aviate, navigate and communicate'. It is essential for a pilot to recognise when an undesired state must be managed, and then to take appropriate action. For example, if a pilot becomes uncertain of position on a navigation flight, a timely decision would need to be made to perform a 'lost procedure'. The pilot may be tempted to ascertain why they became lost and blunder on regardless (undesired aircraft state), rather than initiating a logical procedure to re-establish their position, seek assistance from other aircraft or ATC or plan a precautionary landing.

Assessing TEM
The basic concept for TEM is simple:
- identify the threat, error or undesired aircraft state; and
- manage the threat, error or undesired aircraft state.

Although this sounds uncomplicated, assessors must obtain evidence to ensure that TEM is being practiced. Assessors cannot assume that just because a pilot completed a faultless trip, competent TEM was used.

Trainees must be questioned and their actions observed to ensure the evidence is valid, authentic, sufficient and current. On a flight test it is likely that scenarios will need to be created to allow proper assessment of TEM. A competent pilot on a flight test is less likely to get into an undesired aircraft state or would quickly correct an undesired aircraft state (e.g. low approach speed) and it could be necessary for the assessor to artificially create such a circumstance. For example:
- when approaching a destination aerodrome simulate a thunderstorm over the airfield to duplicate both a threat and an undesired aircraft state;
- simulate a radio failure approaching a reporting point or entering a control zone;
- simulate precautionary or forced landing;
- simulation of instrument or display failure;

Instructors are required to conduct formative assessments throughout flight training. Additionally, instructors will have many more opportunities than Flight Examiners to observe the progress of a pilot's HF and TEM skills. Because they conduct ab initio training instructors will observe the improvement of these skills and must have a good idea of the trainee's expected rate of learning.
The results of these formative assessments may require that changes to the training plan are developed to ensure that competence is achieved. Ultimately it is the instructor who ensures the trainee meets the final competency standards.

The task is more difficult for the assessor in that the HF and TEM assessment will be made on a test generally involving only one flight. Remember that at this stage of the training the candidate must be able to manage threats and errors, so scenarios will have to be developed to ensure adequate assessment. The assessment must be holistic with TEM being assessed from the very beginning of the test.

During the pre-flight, observation and questioning will give the assessor insight into the countermeasures that a pilot applies to anticipated threats.
The simulation of systems malfunctions and emergencies will afford the opportunity to evaluate threat, error and undesired state management competencies.

Hand-in-hand with TEM assessment, HF competencies will also be open to appraisal. In fact it would be impossible to assess TEM without looking at the HF components. Although a flight test involves the assessment of a multitude of competencies, with proper planning and some thought, assessors will be able to successfully assess HF and TEM on licence and rating tests.

As a practical example, it would be possible to assess a number of elements from the HF and TEM standards if an assessor sets a scenario for a precautionary landing.
Consider the list below:
- **Lookout:** selection of suitable landing area, weather and terrain avoidance;
- **SA:** perception of present situation and options, action plan, potential hazard awareness, aircraft configuration and performance;
- **Decision making**: decision to conduct precautionary search, assessment of landing area and decision to land;
- **Task prioritisation:** work management and prioritisation;
- **Communications:** communications with ATC, other aircraft;
- **Threat management:** weather, low-level operations, aircraft handling;
- **Error management:** recognition of any errors, countermeasures, checklist use;
- **Undesired aircraft state:** taking appropriate action to prioritise management of an undesired aircraft state.

It can be seen from any one activity that it is possible to assess a number of competencies.