



The Principles of Threat and Error Management (TEM) for Helicopter Pilots, Instructors and Training Organisations

FOR HELICOPTER PILOTS AND INSTRUCTORS

TRAINING LEAFLET



HE 8



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INTRODUCTION

— — This leaflet was developed by the European Helicopter Safety Implementation Team (EHSIT), a component of the European Helicopter Safety Team (EHEST). The EHSIT is tasked to process the Implementation Recommendations (IRs) identified from the analysis of accidents¹ performed by the European Helicopter Safety Analysis Team (EHSAT).

— — Data from the EHSAT accident review confirms that a continuing significant number of helicopter accidents occur due to poor decision making and human performance made both prior and during flight. The aim of this leaflet is to introduce the concept of Threat and Error Management (TEM) to flight crews and training organisations.

— — TEM proposes that threats, errors and Undesirable Aircraft State (UAS) are everyday events that flight crews must manage to maintain safety.

— — EASA Part FCL² and the International Civil Aviation Organization (ICAO) require that Human Factors and TEM be introduced into all pilot training. In every flight phase all pilots, from student through professional, shall demonstrate 'attitudes and behaviours appropriate to safe conduct of flight, including recognising and managing potential threats and errors.'

— — TEM training needs to be structured and designed to meet competency standards. Therefore, it is essential that flight training organisations develop techniques and material for teaching TEM and that flight examiners conducting flight tests have methods and tools to assess competency. Training and assessment information is included in this document for use by students, instructors and examiners.

¹ see the EHEST Analysis of 2000-2005 European helicopter Accidents, Final Report 2010.

² see Part FCL GM1 to Appendix 5

1. TEM MODEL

1.1 Threat and Error Management Components

There are three basic components in the TEM model, from the perspective of flight crews:

- Threats
- Errors
- Undesired Aircraft State (UAS)

Management in the context of TEM is defined as 'plan, direct and control an operation or situation.' In practical terms this means the timely detection and response of threats and/or errors that may lead to UASs.

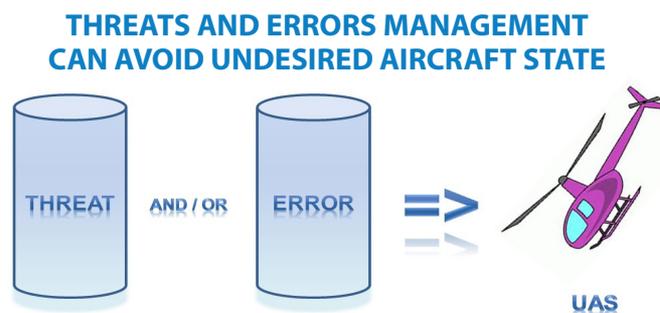


Figure 1: Undesired Aircraft State (UAS)

1.2 Threats

The first component of the TEM model is the threat. Threats are events that occur *beyond the influence of the flight crew*, increase operational complexity, and which must be managed to maintain the margins of safety.

Unmanaged or mismanaged threats frequently lead to a UAS.

The TEM model considers 3 categories of threats, anticipated, unanticipated and latent which all have the potential to negatively affect flight operations by reducing margins of safety. The objective of threat management is to gain awareness of the potential threats within the operating environment both prior to and during flight. Understanding what a threat is, and being aware of these threats enables the flight crew to both plan and execute the flight in a safe manner by selecting the appropriate countermeasure and achieving a safe outcome.

Anticipated

Some threats can be anticipated, since they are expected or known to the flight crew such as:

- Thunderstorms/icing/wind shear and other forecast inclement weather;
- Congested airport/heliport;

- Wires/obstacles;
- Complex SIDs/STARs/clearances;
- Cross and/or downwind approaches/landings;
- Outside air temperature/density altitude extremes;
- Mass and balance;
- Forecast/known bird activity.

Unanticipated

Some threats can occur unexpectedly, suddenly and without warning. In this case, flight crews must apply skills and knowledge acquired through training and operational experience such as:

- In-flight aircraft malfunction;
- Automation - anomalies/over reliance;
- Un-forecast weather/turbulence/icing;
- ATC re-routing/congestion/non-standard phraseology/navigation aid un-serviceability/similar call-signs;
- Ground handling;
- Wires/obstacles;
- GA/Ultra-light/light aircraft activities;
- Unmanned aircraft systems;
- ACAS RA/TA;
- Un-forecast bird activity;
- Laser attacks;
- Contaminated/sloping landing areas;

Latent

Lastly, some threats may not be directly obvious to, or observable by, flight crews immersed in flight operations, and may need to be uncovered by safety analysis. These are considered latent threats and may include organisational weaknesses and the psychological state of the pilot such as:

- Organisational culture/changes;
- Incorrect/incomplete documentation;
- Equipment design issues;
- Operational pressures/delays;
- Optical illusions;
- Fatigue/rostering;
- Stress;
- Complacency;
- Over or under confidence;
- Lack of recent experience and proficiency

Regardless of whether threats are anticipated, unanticipated, or latent, one measure of the effectiveness of a flight crew's ability to manage threats is whether threats are detected promptly enough to enable the flight crew to respond to them before a UAS develops by taking the appropriate actions.



Threat management is a building block to error management and UAS management, and provides the most proactive option to maintain margins of safety in flight operations. As threat managers, flight crews are the last line of defence to keep threats from impacting flight operations.

1.3 Errors

Errors are defined *actions or inactions by the flight crew* that lead to deviations from organisational or flight crew intentions or expectations. Errors can be divided into the two following types:

- Slips and lapses are failures in the execution of the intended action. Slips are actions that do not go as planned, while lapses are memory failures. For example, pulling the mixture instead of the (intended) carburetor heat is a slip. Forgetting to apply the carburettor heat is a lapse’.
- Mistakes are failures in the plan of action. Even if execution of the plan were correct, it would not have been possible to achieve the intended outcome.

Unmanaged or mismanaged errors, as with threats, have the potential to reduce the margins of safety and could lead to additional errors or UAS.

The TEM model considers 3 categories of error, aircraft handling, procedural and communications all of which have the potential to negatively affect flight operations. Indicative examples are listed below:

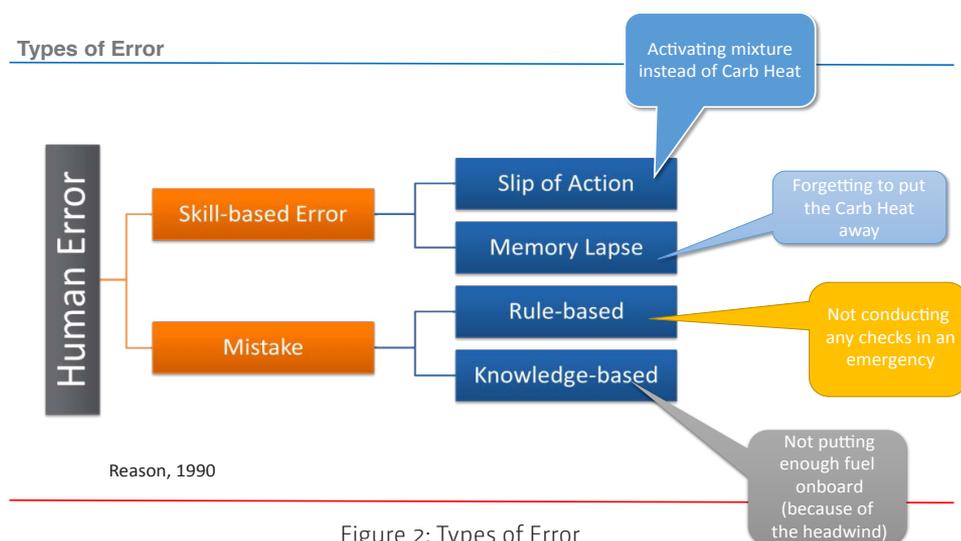


Figure 2: Types of Error

Aircraft handling

To be classified as an aircraft handling error, the pilot or flight crew must be interacting with the aircraft (for example through its controls, automation or systems).

- Manual handling, flight controls: vertical, lateral or speed deviations, flight or power settings;
- Automation: incorrect upper-mode settings and failure to monitor mode, engage/disengage and arm/disarm;

- Systems, radio, instruments: incorrect anti-icing, incorrect altimeter, incorrect fuel switches settings or incorrect radio frequency dialled;
- Heliport/airport operations: hovering – too low/too fast, attempting to turn down wrong taxiway or runway, failure to hold short or missed taxiway or runway.

Procedural

To be classified as a procedural error, the pilot or flight crew must be interacting with a procedure (for example checklists; SOPs; etc.).

- Documentation: wrong mass and balance, fuel information, ATIS, or clearance information recorded, misinterpreted items on paperwork; incorrect logbook entries or incorrect application of MEL procedures.
- SOPs: failure to cross-verify automation inputs;
- Checklists: from memory; items missed, checklist performed late or at the wrong time; wrong challenge and response;
- Callouts: omitted or incorrect callouts;
- Briefings: omitted briefings; items missed;

Communications

To be classified as a communication error, the pilot or flight crew must be interacting with people (ATC, ground crew, other crewmembers, etc.)

- Crew to external: missed calls, incorrect phraseology; transmitting while another transmission is in progress; misinterpretations of instructions, incorrect read-back, wrong clearance, taxiway, pad or runway communicated;
- Pilot to pilot/crew: miscommunication or misinterpretation.

Regardless of the type of error, it is the detection, interpretation and response that influence the potential effect on safety. The objective of error management is the timely detection and prompt appropriate response in flight operations in order for the error to become operationally inconsequential.

A mismanaged error is defined as an error that is linked to or induces an additional error or UAS.

1.4 UAS

UASs are *flight crew-induced* aircraft position or speed deviations, misapplication of flight controls, or incorrect systems configuration, associated with a reduction in margins of safety. UASs that result from ineffective threat or error management may lead to compromising situations and reduce margins of safety in flight operations. UASs must be managed by flight crews.

The TEM model considers 3 categories of UAS, aircraft handling, ground navigation and incorrect aircraft configurations which all have the potential to negatively affect flight operations by reducing margins of safety. Indicative examples are listed below:

Aircraft handling

- Vortex ring state;
- Loss of Tail rotor Effectiveness (LTE);

- Degraded Visual Environment (DVE);
- Aircraft control (attitude);
- Vertical, lateral or speed deviations;
- Unnecessary weather penetration;
- Unauthorised airspace penetration;
- Operation outside aircraft limitations;
- Unstable approach;
- Continued landing after unstable approach;
- Over shooting the landing area or a hard landing.

Ground navigation (heliport operations)

- Proceeding towards wrong taxiway or runway;
- Wrong taxiway, ramp, pad or hold spot.

Incorrect aircraft configurations

- Systems;
- Flight controls;
- Automation;
- Engine;
- Mass and balance.

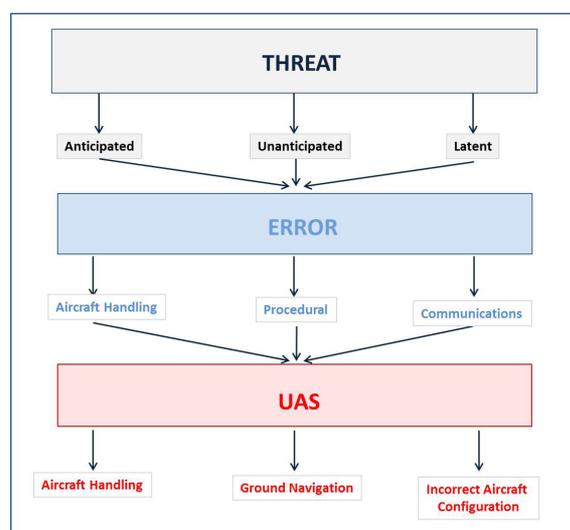


Figure 3: Threat and Error Management (TEM) model

Figure 3 shows threats and errors are part of everyday aviation operations that must be managed by flight crews, since both threats and errors carry the potential to generate a UAS. Once a UAS has arisen it is equally important to manage the UAS as it is the last opportunity for flight crews to ensure a safe outcome in flight operations.

UASs can be managed effectively by returning the aircraft to normal operations, or alternatively, they can be mismanaged resulting in an additional error, or occurrence (incident/accident).

Another important point in the use of TEM for flight crews is the timely switching from error or threat management to UAS management. An example would be as follows:

A pilot detects a generator failure (unanticipated threat) while on approach to a controlled airport and responds to the failure. While dealing with the generator failure (threat management) and responding to an ATC clearance, the airspeed reduces (manual handling error), and rate of descent increases without the pilot realising. The first signs of vortex ring state are now apparent (UAS). The pilot identifies this handling error by checking the instruments and responding to visual cues and returns the aircraft to a stabilised approach, thereby managing the UAS to achieve a safe approach and landing (outcome).

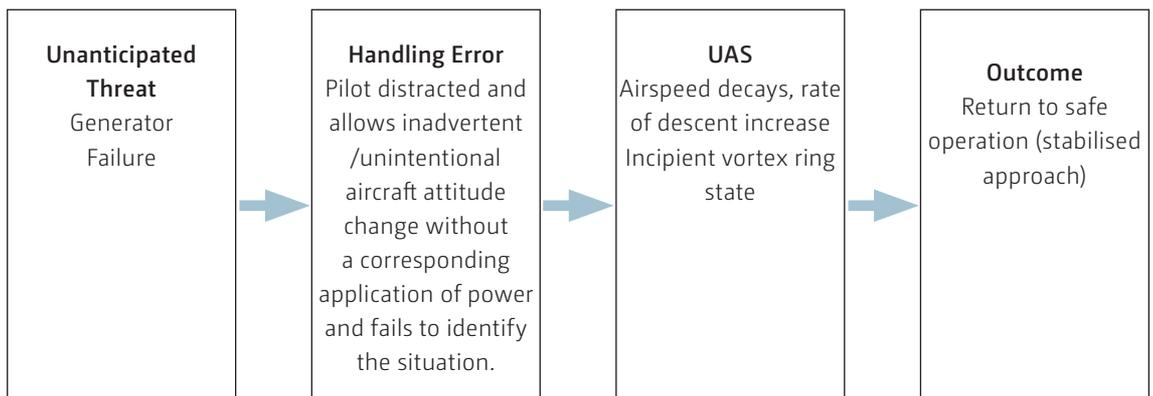


Figure 4: TEM example

As the example in Figure 4 above shows, the flight crew has the possibility through the successful application of TEM to recover the situation and return to safe flight operations.

1.5 Potential Outcome

It is also important to understand there is a clear differentiation between UAS and outcomes. A UAS is a transitional state. An outcome, on the other hand, is an end state. The potential outcomes can be categorised as:

- Return to safe operations (inconsequential)
- An additional error
- Occurrence – Incident/Accident

1.6 Countermeasures

Flight crews must, as part of the normal discharge of their operational duties, employ countermeasures to keep threats, errors and UASs from reducing margins of safety in flight operations. Examples of countermeasures would include: planning, checklists, briefings, training, SOPs, and CRM.

There are basically three categories of countermeasures:

Planning countermeasures are essential for managing anticipated and unexpected threats, for example:

- Thorough planning/briefing, concise, not rushed, and meet requirements;
- Plans/aims/decisions communicated and acknowledged;
- Workload assignment roles and responsibilities defined and communicated for normal and non-normal situations;
- Contingency management with effective strategies to manage threats to safety;
- Threats and their consequences anticipated and all available resources used to manage threats.

Execution countermeasures are essential for error detection and error response, for example:

- Crew members actively monitored and cross-checked systems and other crew members;
- Aircraft position, settings, and crew actions verified;
- Operational tasks prioritised and properly managed to handle primary flight duties;
- Avoidance of task fixation;
- Avoidance of work overload;
- Automation properly managed to balance situational and workload requirements;
- Automation setup briefed to other crew members;
- Effective recovery techniques from automation anomalies.

Review countermeasures are essential for managing the changing conditions of a flight, for example:

- Evaluation and modification of plans;
- Crew decisions and actions openly analysed to make sure the existing plan was the best plan;
- Crew members asked questions to investigate and/or clarify current plans of action;
- Crew members not afraid to express a lack of knowledge: 'Nothing taken for granted';
- Crew members state critical information or solutions with appropriate persistence;
- Crew members speak up without hesitation.

Further guidance on countermeasures can be found in the ICAO manual, Line Operations Safety Audit (LOSA) (Doc 9803).

2. TEACHING TEM

Part FCL.920 Instructor competencies and assessment states:

All instructors shall be trained to achieve the following competences:

-Integrate Threat and Error Management (TEM) and crew resource management.

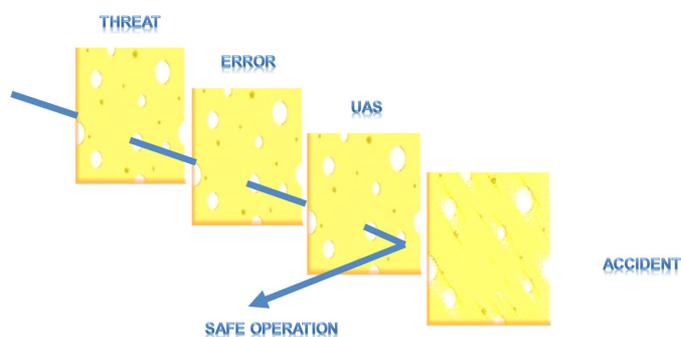


Figure 5: From Threat to Safe Operation

2.1 Teaching Threat Management

Instructors must understand that threats (and errors) are a part of everyday aviation operations that must be managed through all the phases of flight. The instructor should instil in the student that TEM is an on-going process and should be considered not only in flight but both in the pre-flight and post flight stages, namely:

Pre-flight:

- Time spent on the ground anticipating possible threats associated with the flight will provide the opportunity to plan and develop countermeasures (e.g. action in the event of weather changes);
- Brief (self, crew members and passengers) planned procedures before take-off;
- Include anticipated threats and countermeasures in briefings (e.g. adverse wind).

In flight:

- Brief (self, crew members and passengers) planned procedures prior to commencing each significant flight sequence (e.g. approach to an aerodrome/heliport);
- Include anticipated threats and countermeasures in briefings (e.g. adverse wind);
- Prioritise tasks and manage workload to avoid being overloaded (e.g. use checklists);
- Identify and manage any UAS;
- Recover to stable flight and normal safety margins before dealing with other threats/errors/UASs.

Post flight:

Reconsider what threats, errors and/or UAS were encountered during the flight. Ask the student how well these were managed and what could have been done differently to improve the management of similar threats and errors on future flights.



It is very important for instructors to emphasise to students that anticipated and unanticipated threats are identifiable and most likely to affect them before and during flight operations.

Latent threats are not always obvious to the instructor or students since they may include organisational weaknesses and the psychological state of the pilot as identified in paragraph 1.2.

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

Unanticipated threats are most likely in flight. 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 can be a method of training a student to manage an unanticipated threat. Knowledge and repetition prepare a student to manage such events should they occur for real in flight.

Instructors should develop relevant TEM training scenarios including 'what if' questions or examples that will address the different categories of threats and thereby develop the student's ability to detect and respond appropriately to threats.

During flight training the instructor must identify unanticipated threats such as incorrect ATC instructions, traffic hazards or adverse weather and point them out to the student if they fail to identify them. Then it is important to ask the student to see what countermeasures would mitigate the threats, ensuring that these are completed in the time available.

In flight the instructor may well foresee an impending threat well in advance of the student in such cases a good technique to teach the student to recognise an unanticipated threat is for example:

Prompt	– Reducing visibility
Question	– What are our available options/actions?
Response	– Turn 180° or land
Decision	– Student selects appropriate response
Action	– Student turns or lands

2.2 Teaching Error Management

The acknowledgement that errors will occur has changed the emphasis in aviation operations to error recognition and management rather than just error prevention. Rather than just pointing out errors as they occur, instructors should show students how to minimise the chances of errors happening, and then if they do happen, recognise the fact and implement strategies to manage them.

Instructors must afford the student the opportunity to recognise an error rather than intervening as soon as the error occurs. If it is safe to do so the instructor should allow the student the time to identify the error and correct it.

2.3 Teaching UAS Management

Unmanaged or mismanaged threats or errors may result in an UAS. Ideally, pilots should be taught to manage threats and errors before an UAS develops. During flight training, instructors will be dealing with many training UASs as students develop their flying skills.

Some typical training UAS examples would be:

- Erratic hovering;
- Lateral movement during Take-off and landing;
- 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 be classified as UAS 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 UAS develop into an undesired outcome (accident or incident).

In this context, instructors have the dual role of practicing TEM by ensuring that UASs are managed and then teaching students how to do the same. Because students may not have the manipulative and cognitive skills of a qualified pilot, they will often not meet specified flight tolerances or procedures.

A critical aspect that instructors must teach is the switch from error management to UAS 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, communicate'. Refer back to worked example in Section 1.4.

2.4 Debriefing

Debriefing is an essential tool for teaching TEM and should be applied during and post flight. The content of TEM debriefing, although at the discretion of the instructor, should address in flight the critical issues as they occur and leave the detailed analysis and in-depth discussion to post flight.

It may be appropriate for the instructor to take control of the helicopter in order to debrief the student in flight. By the instructor taking full control the student can relax and concentrate on the instructor's comments.

3. ASSESSING TEM

The basic concept for TEM is simply to:

Timely detect, interpret and promptly respond appropriately to the threat, error or UAS.

Although this sounds uncomplicated, instructor/examiners must obtain evidence to ensure that TEM is being practiced. Since observation is the sole means available to the instructor/examiner to obtain this evidence, it is important that the instructor/examiner actively questions the pilot pre-flight, in flight and post flight to gain insight into the reasons why specific TEM was applied. It must be emphasised that questioning during flight should not distract the pilot. **Instructor/examiners cannot assume that just because a pilot completed a safe flight, competent TEM was used.**

On a flight test it is unlikely a competent pilot will get into an UAS or, if encountered, would fail to correct it and therefore it could be necessary for the examiner to suggest a suitable scenario to assess TEM. For example:

- create a scenario that will be analysed during the pre-flight briefing;
- when approaching a destination aerodrome simulate a thunderstorm over the airfield;
- simulate a radio failure approaching a reporting point or entering a control zone;
- simulate precautionary or forced landing;
- simulate an instrument or display failure.

To assist the instructor/examiner in assessing a pilot's TEM performance the following can be considered:

Maintain effective lookout

- 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 of traffic;
- Performs airspace-cleared procedure before commencing any manoeuvres.

Maintain situation awareness

- Monitors all aircraft systems using a systematic scan technique;
- Collects information to facilitate on-going system management;
- Monitors flight environment for deviations from planned operations;
- Collects flight environment information to update planned operations.

Assess situations and make decisions

- Identifies problems;
- Analyses problems;
- Identifies solutions;

- Assesses solutions and risks;
- Decides on a course of action;
- Communicates plans of action – (if appropriate);
- Allocates tasks for action – (if appropriate);
- Takes actions to achieve optimum outcomes for the operation;
- Monitors progress against plan;
- Re-evaluates plan to achieve optimum outcomes.

Set priorities and manage tasks

- Organises workload and priorities to ensure completion of all tasks relevant to the safety of the flight;
- Puts the safe and effective operation of the aircraft ahead of competing priorities and demands;
- Plans events and tasks to occur sequentially;
- Anticipates critical events and tasks to ensure completion;
- Uses technology to reduce workload and improve cognitive and manipulative activities;
- Avoids fixation on single actions, tasks or functions.

Maintain effective communications and interpersonal relationships

- Establishes and maintains effective and efficient communications and interpersonal relationships with all stakeholders to ensure the safe outcome of the flight;
- Defines and explains objectives to applicable/involved stakeholders;
- Demonstrates a level of assertiveness that ensures the safe completion of the flight;
- Encourages passengers to participate in and contribute to the safe outcome of the flight.

Recognise and manage threats

- Identifies relevant environmental or operational threats that are likely to affect the safety of the flight;
- Develops and implements countermeasures to manage threats;
- Monitors and assesses flight progress to ensure a safe outcome; or
- Modifies actions when a safe outcome is not assured.

Recognise and manage errors

- Applies checklists and standard operating procedures to prevent aircraft handling, procedural or communication errors and identifies committed errors before safety is affected or aircraft enters an undesired aircraft state;
- Monitors aircraft systems, flight environment and crewmembers, collects and analyses information to identify potential or actual errors;
- Implements countermeasures to prevent errors or takes action in the time available to correct errors before the aircraft enters an UAS.

Recognise and manage UAS

- Recognises UAS;
- Prioritises tasks to ensure management of UAS;
- Manipulates aircraft controls or systems, or modifies actions or procedures to maintain control of the aircraft and return to normal flight operations, in the time available.

In addition Appendix I provides an example of a TEM assessment criteria showing the different aspects that could be assessed by the instructor/examiner.

4. DEFINITIONS & ACRONYMS

ACAS RA/TA: Airborne Collision Avoidance System Resolution Advisory / Traffic Advisory.

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

ATC: Air Traffic Control.

ATIS: Automated Terminal Information Service.

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.

Aircraft's internal environment: 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, procedures, publications, checklists and automation.

External environment: 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.

GA: General Aviation.

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

LOFT: Line Orientated Flight Training.

MEL: Minimum Equipment List.

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

SID: Standard Instrument Departure.

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

SOP: Standard Operating Procedure.

STAR: Standard Terminal Arrival.

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.

Threat: Events which occur beyond the influence of the flight crew, increase operational complexity and which must be managed to maintain the margin of safety.

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

APPENDIX I

An example of threat and error management assessment criteria

Objective:

To determine that the candidate:

- (1) Can recognise, assess and manage potential threats in the performance of the various task elements, in accordance with TEM techniques.
- (2) Can avoid or trap errors which may occur in the performing of the various task elements, in accordance with TEM techniques.
- (3) Follows SOP's with evident situational awareness to avoid and trap errors which may occur in the performance of the various task elements.
- (4) Applies strategies which will mitigate the effects of any errors which may occur, in accordance with TEM techniques.

Not yet competent	COMPETENT	VERY COMPETENT
(1) Is ignorant of potential threats in the performance of the various task elements	(1) Recognises, verbalises and assesses potential threats in the performance of the various task elements	(1) Immediately recognises, verbalises and assesses all potential threats in the performance of the various task elements
(2) Takes no significant action to reduce or manage the potential impact of threats in the performance of the various task elements	(2) Takes reasonable action to reduce and manage the potential impact of threats in the performance of the various task elements	(2) Effectively manages potential threats and/or implements strategies to minimise the impact of potential threats in the performance of the various task elements
(3) Limited adherence to SOP's and procedures, poor situational awareness and/or no review of flight progress. Is ignorant of errors which occur in the performance of the various task elements	(3) SOP's and procedures are followed, and good situational awareness evident to avoid and trap errors which may occur in the performance of the various task elements	(3) Strict adherence to SOP's and procedures. Applies effective strategies to avoid and trap errors which may occur in the performance of the various task elements
(4) Is ignorant of or deficient in the application of strategies which could mitigate the effects of any errors which occur	(4) Adequately mitigates the effects of any errors which occur	(4) Applies strategies which effectively mitigate the effects of any errors which

Action:

The examiner may:

- Question the candidate on potential threats which may impact the operation of the helicopter in the performance of the various task elements.
- Observe the candidate's assessment and management of threats in the performance of the various task elements, in accordance with TEM techniques, and determine that the performance meets the objectives.
- Observe the candidate's avoidance and trapping of errors in the performance of the various task elements, in accordance with TEM techniques, and determine that the performance meets the objectives.
- Observe the candidate's adherence to SOP's and (as well as is possible) monitor the candidate's situational awareness of threats and errors.
- Observe the candidate's application of strategies to mitigate the effects of errors in the performance of the various task elements, in accordance with TEM techniques, and determine that the performance meets the objectives.



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