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Threat and Error Management (TEM) in Air Traffic Control

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INTRODUCTION

This circular describes an overarching safety framework intended to contribute to framework the management of safety in aviation operations, known as Threat and Error Management (TEM). TEM is based on a model developed by the Human Factors Research Project of the University of Texas in Austin (United States), the University of Texas Threat and Error Management Model (UTTEM).

The main objective of introducing the TEM framework to the Air Traffic Services (ATS) community in general, and the Air Traffic Control (ATC) community in particular, is to enhance aviation safety and efficiency. This is achieved by providing an operationally relevant and highly intuitive framework for understanding and managing system and human performance in operational contexts. A further objective in introducing TEM is to lay the foundation for ATS providers for the adoption of a TEM-based tool that involves the monitoring of safety during normal operations as part of ATC safety management systems. The name of this tool is the Normal Operations Safety Survey (NOSS).

The development of NOSS is a consequence of Recommendation 2/5 "Monitoring of safety during normal operations" from the 11th ICAO Air Navigation Conference in 2003, as follows: "That ICAO initiate studies on the development of guidance material for the monitoring of safety during normal air traffic service operations, taking into account, but not limited to, the line operations safety audit (LOSA) programmes which have been implemented by a number of airlines."

In order to comply with Recommendation 2/5, ICAO will develop a manual including the methodology on NOSS, and this circular on TEM is intended as a precursor to the NOSS Manual. The TEM framework can be applied in all ATS operations, regardless of the implementation of NOSS. However, NOSS cannot be implemented without embracing the TEM concept.

It must be made clear from the outset that TEM and NOSS are neither human performance/Human Factors research tools, nor human performance evaluation/assessment tools. TEM and NOSS are operational tools designed to be primarily, but not exclusively, used by safety managers in their endeavours to identify and manage safety issues as they may affect safety and efficiency of aviation operations.

This circular contains the following:

a) A generic introduction to the TEM framework, including definitions; components of the framework; threat and error countermeasures; and threats, errors and undesired states in relation to outcomes;

b) A discussion on TEM in ATC, including definitions; threats in ATC; errors; undesired states; TEM-based analysis of actual ATC situations; managing threats and errors; TEM training for ATC personnel; integrating TEM in safety management; and Normal Operations Monitoring; and

c) Related documents.

The circular was developed with the assistance of the Normal Operations Safety Survey Study Group (NOSSSG).

INTRODUCING THREAT AND ERROR MANAGEMENT (TEM) IN ATC

1. Introduction

1.1 Threat and Error Management (TEM) is an overarching safety concept regarding aviation operations and human performance. TEM is not a revolutionary concept, but one that has evolved gradually, as a consequence of the constant drive to improve the margins of safety in aviation operations through the practical integration of Human Factors knowledge.

1.2 TEM was developed as a product of collective aviation industry experience. Such experience fostered the recognition that past studies and, most importantly, operational consideration of human performance in aviation had largely overlooked the most important factor influencing human performance in dynamic work environments: the interaction between people and the operational context (i.e., organizational, regulatory and environmental factors) within which people discharged their operational duties.

1.3 The recognition of the influence of the operational context in human performance led to the conclusion that the study and consideration of human performance in aviation operations must not be an end in and on itself. With regard to the improvement of margins of safety in aviation operations, the study and consideration of human performance without context addresses only part of the larger issue. TEM therefore aims to provide a principled approach to the broad examination of the dynamic and challenging complexities of the operational context in human performance, for it is the influence of these complexities that generates the consequences that directly affect safety.

2. The Threat and Error Management framework

2.1 The Threat and Error Management (TEM) framework is a conceptual model that assists in understanding, from an operational perspective, the inter-relationship between safety and human performance in dynamic and challenging operational contexts.

2.2 The TEM framework focuses simultaneously on the operational context and the people discharging operational duties in such a context. The framework is descriptive and diagnostic of both human and system performance. It is descriptive because it captures human and system performance in the normal operational context, resulting in realistic descriptions. It is diagnostic because it allows quantifying the complexities of the operational context in relation to the description of human performance in that context, and vice-versa.

2.3 The TEM framework can be used in several ways. As a safety analysis tool, the framework can focus on a single event, as is the case with accident/incident analysis; or it can be used to understand systemic patterns within a large set of events, as is the case with operational audits. The TEM framework can be used to inform about licensing requirements, helping clarify human performance needs, strengths and vulnerabilities, thus allowing the definition of competencies from a broader safety management perspective. Subsequently the TEM framework can be a useful tool in On-the-Job Training (OJT). The TEM framework can be used as guidance to inform about training requirements, helping an organization improve the effectiveness of its training interventions, and consequently of its organizational safeguards. The TEM framework can be used to provide training to quality assurance specialists who are responsible for evaluating facility operations as part of certification.

2.4 Originally developed for flight deck operations, the TEM framework can nonetheless be used at different levels and sectors within an organization, and across different organizations within the aviation industry. It is therefore important, when applying TEM, to keep the user's perspective in the forefront. Depending on "who" is using TEM (i.e. front-line personnel, middle management, senior management, flight operations, maintenance, air traffic control), slight adjustments to related definitions may be required. This circular focuses on the Air Traffic Control (ATC) environment, and the discussion herein presents the perspective of air traffic controllers' use of TEM.

3. The components of the TEM framework

3.1 Overview

3.1.1 There are three basic components in the TEM framework, from the perspective of air traffic controllers: threats, errors and undesired states. The framework proposes that threats and errors are part of everyday aviation operations that must be managed by air traffic controllers, since both threats and errors carry the potential to generate undesired states. Air traffic controllers must also manage undesired states, since they carry the potential for unsafe outcomes. Undesired state management is an essential component of the TEM framework, as important as threat and error management. Undesired state management largely represents the last opportunity to avoid an unsafe outcome and thus maintain safety margins in ATC operations.

3.2 Threats

3.2.1 Threats are defined as "events or errors that occur beyond the influence of the air traffic controller, increase operational complexity, and which must be managed to maintain the margins of safety". During typical ATC operations, air traffic controllers have to take into account various contextual complexities in order to manage traffic. Such complexities would include, for example, dealing with adverse meteorological conditions, airports surrounded by high mountains, congested airspace, aircraft malfunctions, and/or errors committed by other people outside of the air traffic control room (i.e. flight crews, ground staff or maintenance workers). The TEM framework considers these complexities as threats because they all have the potential to negatively affect ATC operations by reducing margins of safety.

3.2.2 Some threats can be anticipated, since they are expected or known to the air traffic controller. For example, an air traffic controller can use information from the weather forecast to anticipate runway changes or diversions. Another example is the unreliable quality of High Frequency (HF) communications that necessitates the availability of alternative options.

3.2.3 Some threats can occur unexpectedly, such as pilots carrying out instructions which were intended for another aircraft as a result of call sign confusion. In this case, air traffic controllers must apply skills and knowledge acquired through training and operational experience to manage the situation.

3.2.4 Regardless of whether threats are expected or unexpected, one measure of the effectiveness of an air traffic controller's ability to manage threats is whether threats are detected with the necessary anticipation to enable the air traffic controller to respond to them through deployment of appropriate countermeasures.

3.2.5 The TEM framework considers threats as actual (threats exist and cannot be avoided) and their consequences as potential. Unserviceable equipment is one example. Whether primary and/or secondary equipment fails, or whether equipment becomes unavailable as a result of pre-scheduled maintenance work, it is an actual threat. The difference is in terms of the potential consequences and the required countermeasures the air traffic controller employs to manage the threat. If the primary equipment fails unexpectedly, the potential consequences are more serious than if a secondary system is taken out of service for maintenance, the air traffic controller countermeasures are different for each scenario (switching from radar separation to procedural separation in the case of an unexpected radar failure or preparing to work without the secondary system in the second case). If the threat (loss of radar) results in errors being made, and separation being compromised, an undesired state now exists, a product of mismanaged threats and errors. At such point, a controller forgets about threats and errors, and manages the undesired state. The point to be made here is that, under the TEM rationale, threats are situations and/or events that cannot be avoided, or eliminated, by operational personnel; they can only be managed. This is why TEM adheres to the notion of threat management as opposed to threat avoidance or elimination. No matter what they do, no matter how much they anticipate the threat, air traffic controllers can only manage its potential consequences through countermeasures strategies. The definition of *threat* in paragraph 3.2.1 intends to convey this notion: "events...that occur <u>beyond the influence</u> of the air traffic controller...which must be managed..." It is a fundamental premise of TEM that threats are unavoidable components of complex operational contexts, and that is why TEM advocates management as opposed to avoidance or elimination.

3.2.6 It would be tempting to consider ergonomic deficiencies in equipment design, less than optimum procedures, and organizational factors in general, as latent threats. However, they are also actual threats. They are present at the work place, every day controllers go to work. Their consequences, however, are potential. Examples of those threats include equipment design issues in non-frequently used system functions such as back up modes or degraded modes, that only manifest themselves at the time when the system is used in that particular mode. Controllers cannot avoid or eliminate poor design or clumsily designed procedures (management can, and therein lays the rationale for the Normal Operations Safety Survey (NOSS) discussed in paragraph 19). No matter how much they anticipate them, controllers can only deploy countermeasures to manage the damaging potential of such threats.

3.2.7 Threat management is a building block to error management and undesired states management. Archival data on flight deck operations demonstrates that mis-managed threats are frequently linked to flight crew errors, which in turn are often linked to undesired states. However, the threat-error-undesired states relationship is not necessarily straightforward and it may not always be possible to establish a linear relationship, or one-to-one linkage between threats, errors and undesired states. There are two important caveats in the TEM Framework, strictly speaking: (1) *threats can on occasion lead directly to undesired states without the inclusion of errors;* and (2) *operational personnel may on occasion make errors when no threats are observable*. Furthermore it should be realized that with some threats, errors or undesired states there may not be a realistic opportunity to manage them.

3.2.8 Threat management provides the most proactive option to maintain margins of safety in ATC operations, by voiding safety-compromising situations at their roots. As threat managers, air traffic controllers are among the last line of defense to minimize the impact of threats on ATC operations.

3.3 Errors

3.3.1 Errors are defined as "actions or inactions by the air traffic controller that lead to deviations from organizational or air traffic controller intentions or expectations". Unmanaged and/or mis-managed errors frequently lead to undesired states. Errors in the operational context thus tend to reduce the margins of safety and increase the probability of an undesirable event.

3.3.2 Errors can be spontaneous (i.e. without a direct link to specific, obvious threats), linked to threats, or part of an error chain. Examples of errors would include: not detecting a readback error by a pilot; clearing an aircraft or vehicle to use a runway that was already occupied; selecting an inappropriate function in an automated system; data entry errors, and so forth.

3.3.3 Regardless of the type of error, its effect on safety depends on whether the air traffic controller detects and responds to the error before it leads to an undesired state, or if unaddressed, to an unsafe outcome. This is why one of the objectives of TEM is to understand error management (i.e. detection and response), rather than focusing solely on error causality (i.e. causation and commission). From a safety perspective, operational errors that are detected in a timely manner and are promptly countered (i.e. properly managed), and errors that do not lead to undesired states or do not reduce margins of safety in ATC operations become operationally inconsequential. In addition to its safety value, proper error management represents an example of successful human performance, presenting both learning and training values.

3.3.4 Capturing how errors are managed is then as important, if not more, than capturing the relevance of different types of errors. It is of interest to capture if and when errors are detected, by whom, the response upon detecting errors, and the outcome of those errors. Some errors are quickly detected and resolved, thus becoming inconsequential, while others go undetected or are mismanaged. A mismanaged error is defined as one that is linked to or induces an additional error or undesired state.

3.3.5 The TEM framework uses the "primary interaction" as the point of reference for defining the error categories. The three basic error categories in TEM are equipment handling errors, procedural errors and communication errors. The TEM framework classifies errors based upon the primary interaction of the air traffic controller at the moment the error is committed. Thus, in order to be classified as equipment handling error, the air traffic controller must be incorrectly interacting with the equipment (i.e. through its controls, automation or systems). In order to be classified as procedural error, the air traffic controller must be incorrectly executing a procedure (i.e. checklists; SOPs; etc). In order to be classified as communication error, the air traffic controller must be incorrectly interacting with people (i.e. flight crew, ground crew; other air traffic controllers, etc).

3.3.6 The three basic error categories are not mutually exclusive, nor are they exhaustive. A controller issuing instructions using non-standard phraseology may be involved in both procedural and communication errors. Equipment handling errors, procedural errors and communication errors may be unintentional or involve intentional non-compliance. Similarly, proficiency considerations (i.e., skill or knowledge deficiencies, training system deficiencies) may underlie all three categories of error. The TEM framework does not consider intentional non-compliance and proficiency as separate categories of error, but rather as sub-sets of the three major categories of error. In order to avoid adding levels of classification, and focusing upon collecting safety data that managers can act on, the error classification in the TEM framework is limited to what are considered to be three high-level categories of operational errors.

3.4 **Undesired States**

3.4.1 Undesired states are defined as "operational conditions where an unintended traffic situation results in a reduction in margins of safety". Undesired states that result from ineffective threat and/or error management may lead to compromised situations and reduce margins of safety in ATC operations. Often considered the last stage before an incident or accident, undesired states must be managed by air traffic controllers. Examples of undesired states would include an aircraft climbing or descending to another flight level/altitude than it should; or an aircraft turning in a direction other than flight planned or directed. Events such as equipment malfunctions or flight crew errors can also reduce margins of safety in ATC operations, these however are considered to be threats. Undesired states can be managed effectively, restoring margins of safety, or the air traffic controller's response(s) can induce an additional error, incident, or accident.

3.4.2 An important learning and training point for air traffic controllers is the timely switching from error management to undesired state management. An example would be as follows: if after a data entry error it is found that an aircraft has climbed to a flight level other than it should (undesired state), controllers must give higher priority to dealing with the potential traffic conflict (undesired state management) rather than correcting the data entry in the system (error management).

3.4.3 From a learning and training perspective, it is important to establish a clear differentiation between undesired states and outcomes. Undesired states are transitional states between a normal operational state (i.e. an aircraft in climb to an assigned altitude) and an outcome. *Outcomes*, on the other hand, are end states, most notably, reportable occurrences (i.e. incidents and accidents). An example would be as follows: an aircraft climbing to an assigned altitude (normal operational state) is re-cleared to another altitude. The flight crew incorrectly reads back the new assigned altitude as a higher one, but the air traffic controller does not catch the misread readback. The aircraft is thus climbing to an incorrect altitude (undesired state), which could result in a loss of separation (outcome).

3.4.4 The training and remedial implications of the differentiation between undesired states and outcomes are of significance. While at the undesired state stage, the air traffic controller has the possibility, through appropriate TEM, of recovering the situation, and returning it to a normal operational state, thereby restoring the required margins of safety. Once the undesired state becomes an outcome, recovery of the situation without loss of safety margins is no longer possible. This is not to imply that air traffic controllers would not attempt to mitigate the impact of the outcome, but that the margins of safety were compromised and must therefore be restored.

3.4.5 Figure 1 presents a graphic summary of the Threat and Error Management framework. It is suggested that the dotted lines represent paths that are less common than those indicated by the unbroken lines.

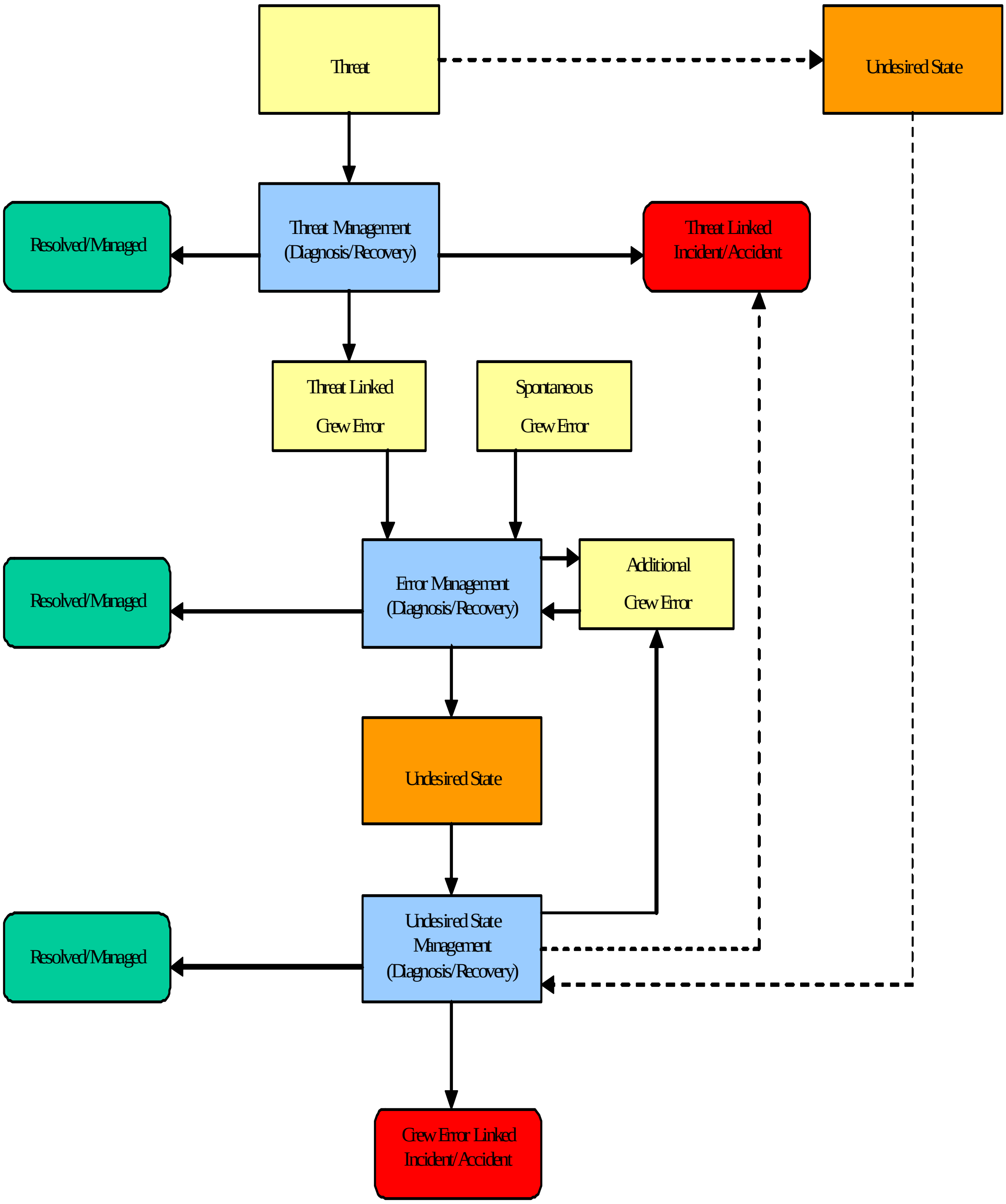


Figure 1. Threat and Error Management framework

4. Threat and Error Countermeasures

4.1 Air traffic controllers must, as part of the normal discharge of their operational duties, employ countermeasures to keep threats, errors and undesired states from reducing margins of safety in ATC operations. Examples of countermeasures would include checklists, briefings, and prescribed procedures, as well as personal strategies and tactics. It is an interesting observation from the flight deck environment that flight crews dedicate significant amounts of time and energies to the application of countermeasures to ensure margins of safety during flight operations. Empirical observations during training and checking suggest that as much as 70 per cent of flight crew activities may be countermeasures-related activities. A similar scenario is likely in ATC.

4.2 Many but not all countermeasures are necessarily air traffic controller actions. Some countermeasures to threats, errors and undesired states that air traffic controllers employ build upon "hard" resources provided by the aviation system. These resources are already in place in the system before air traffic controllers report for duty, and are therefore considered as systemic-based countermeasures. The following would be examples of "hard" resources that air traffic controllers employ as systemic-based countermeasures:

a) Minimum Sector Altitude Warning (MSAW);

b) Short-Term Conflict Alert (STCA);

c) Standard operating procedures (SOPs);

d) briefings; and

e) professional training.

4.3 Other countermeasures are more directly related to the human contribution to the safety of ATC operations. These are personal strategies and tactics, individual and team countermeasures, that typically include canvassed skills, knowledge and attitudes developed by human performance training, most notably, by Team Resource Management (TRM) training. There are basically four categories of individual and team countermeasures:

a) team countermeasures - leadership and the communication environment - essential for the flow of information and team member participation;

b) planning countermeasures - planning, preparation, briefings, contingency management - essential for managing anticipated and unexpected threats;

c) execution countermeasures - monitor/cross-check, scanning, flight strip management, workload and automation management - essential for error detection and error response; and

d) review/modify countermeasures - evaluation of plans, inquiry - essential for managing the changing conditions of a shift.

4.4 In its optimal form TEM is the product of the combined use of systemic-based and individual and team countermeasures.

4.5 In summary, the TEM framework captures the dynamic activity of an operational ATC crew working in real time and under real conditions. The utility of the framework is that it can be applied proactively or retrospectively, at the individual, organizational, and/or systemic levels.

5. **TEM: A safety investigation perspective**

5.1 In the night of July 1st 2002 a mid-air collision occurred between a Tupolev 154 and a Boeing 757 over the town of Ueberlingen, South Germany. One aircraft was descending to comply with an instruction from ATC; the other aircraft was descending in response to a Resolution Advisory (RA) from its Traffic Alert and Collision Avoidance System (TCAS). The aircraft involved were operating in airspace that was delegated by Germany to the Area Control Centre (ACC) in Zurich, Switzerland. That particular night there was maintenance work being performed on the automated ATC system of the Zurich ACC and also on the voice communication system between Zurich ACC and other ATC facilities.

5.2 As an example of the retrospective application of the TEM framework the following represents a list (non-exhaustive) of threats <u>from the controller's perspective</u> that could be identified from the investigation into this mid-air collision:

a) no information was provided to the controller about scheduled maintenance work;

b) maintenance was scheduled to be performed on multiple systems simultaneously;

c) the ATC system was only available in a degraded mode with reduced functionality;

d) no training for working with the ATC system in a degraded mode was provided;

e) a delayed and unexpected flight to a regional airport in the airspace had to be accommodated;

f) a second working position had to be opened in order to handle the flight to the regional airport;

g) there was a technical failure in the back-up phone system (which the controller had to use to coordinate the in-bound flight with the regional airport);

h) a single-person nightshift culture prevailed at the Area Control Centre (ACC) concerned; and

i) there were blocked simultaneous transmissions in the Radio Telephony (R/T) communication.

5.3 If the outcome of the event had been different (i.e. the aircraft had passed each other or separation had been maintained) **these same threats would still have existed**. From a safety management perspective this suggests that corrective action can and should be taken as soon as threats have been identified (i.e. <u>before</u> any negative outcomes draw attention to their existence).

6. TEM in ATC

6.1 When the TEM framework is introduced to operational aviation personnel (air traffic controllers, pilots, etc.) the common reaction is one of recognition. Operational personnel have been aware of the factors that are considered as "threats" in the TEM framework almost since the start of their aviation careers. The difference is that this awareness used to be implicit whereas the TEM framework makes it explicit, principled and therefore manageable. The following two scenarios are proposed to assist ATC staff to understand TEM.

6.2 In an ideal context, a generic ATC shift could develop along the following lines:

a) The Air Traffic Controller (ATCO) reports for duty ahead of the official starting time of the shift. The ATCO checks the daily briefing material available in a well-organized and clear format. Before taking over the working position from a colleague, the ATCO receives the last update on that day's weather situation and the technical status of the ATC equipment from the unit supervisor.

b) After plugging in the headset at the assigned working position, the ATCO spends a few minutes just listening to the communications between the colleague she is replacing and the traffic that the colleague is handling. The ATCO then indicates to her colleague that she is ready to take over, so the colleague briefs her on tasks that are pending and the short-term agreements that are in place at that time with adjacent air traffic control positions.

c) After the ATCO takes over the position and begins communicating with the traffic, her colleague remains at her side for a few minutes in order to ensure that the handover goes smoothly and nothing is forgotten. Once the controllers are both convinced that this is the case the colleague leaves to go on his rest break.

d) During the shift the weather remains fine, just as predicted, with a wind from a direction that is fully compatible with the runways in use. There are no technical problems with the ATC equipment and there is no maintenance work scheduled that day.

e) The traffic flow is sufficiently challenging to keep the ATCO occupied without overloading her. There are several complex traffic situations developing during the shift, but the ATCO is able to resolve these by issuing timely and concise instructions to the pilots concerned who cooperate fully to ensure a safe, orderly and expeditious flow of traffic.

f) After an hour and a half a relief colleague returns to take over the position from the ATCO. The colleague listens to the communications and monitors the traffic situation, after which he indicates that he is ready to take over. The ATCO lets the colleague assume responsibility for the traffic, but stays at his side for a few minutes to update him on the latest agreements with other control positions and the tasks that are still pending. Once convinced her colleague is comfortable at the position, the ATCO leaves the operations room and goes on a break.

g) The ATCO works two further sessions at different working positions after this first break. The traffic is challenging yet manageable, the weather remains fine as predicted, and there are no technical problems.

6.3 However, ideal contexts do not exist so this is how a shift could develop in reality:

a) The Air Traffic Controller (ATCO) reports just in time for duty. After arriving in the operations room, the ATCO goes straight to the position that he is supposed to take over. The ATCO barely has time to look at the traffic situation and plug in before the colleague walks away from the control position.

b) The traffic situation is complex and quite different from the way the ATCO would like to have it organized. The ATCO spends some time rearranging the setup of the ATC equipment and discovers that not all functionality of the automated system is available. Next the ATCO calls an adjacent control position to arrange the handover of one particular flight, only to be told that a temporary arrangement was in place with the colleague that covers all such handovers for the next two hours.

c) The meteorology office has forecasted deteriorating weather, but the ATCO is not aware of it since he did not look at the forecast before taking over the working position. Consequently the weather change comes as a surprise, and he is pressed to stay on top of the traffic while adapting to the new situation.

d) After more than two hours with heavy and complex traffic, the ATCO is relieved by a colleague who plugs in the headset and states that he is assuming responsibility for the position as of that moment. The ATCO walks away immediately, to rest before coming back to taking over the next position in 15 minutes.

e) In the subsequent session the ATCO works a position with little traffic. Due to distraction, the ATCO misses several calls from aircraft the first time they are made and only responds to the second call. The ATCO also has to be reminded by colleagues that he needs to transfer traffic to their frequencies, but he of course manages to do so well before the sector boundary.

f) After another short break, during which the ATCO attended to some urgent paperwork, he is back on a position with complex and heavy traffic. While engaged in busy communications with aircraft and other control positions, a technician comes up and asks him if it is OK to start testing the secondary radio channels as per the maintenance schedule. Since the work is according to a schedule obviously approved by management, the ATCO agrees reluctantly. Two more technicians appear and they all start working on the equipment near the ATCO, while he is controlling his traffic.

g) The ATCO then notices that the radios are not working properly. He asks the technicians to stop working and reaches for the emergency radio set. It takes a few moments to select the appropriate frequencies, but communications can be resumed using the emergency set. The traffic was not affected by the radio failure, and separation was maintained at all times. The technicians undo the mistake that caused the main radio to fail, and after a few minutes the ATCO can communicate with traffic as normal again.

6.4 Of the scenarios presented above, the second one would be the scenario that most operational air traffic controllers would identify with more easily. Also to other persons the differences between the scenarios will be easy to spot, and the first scenario will appear less realistic than the second one. What may not be immediately apparent however – and perhaps can not be emphasized strongly enough – is that even in the second scenario there are few events – if any – that would be likely to be reported under conventional safety reporting systems. In other words, the second scenario would be considered a normal shift in most if not all Air Traffic Services (ATS) organizations. Yet there are several elements in the scenario that potentially can affect safety, particularly when they are not managed adequately by the air traffic controller. These elements are the threats in the TEM framework.

7. **Threats in Air Traffic Control**

7.1 Threats in ATC can be grouped into the following four broad categories:

a) Internal to the Air Traffic Service Provider (ATSP);

b) External to the Air Traffic Service Provider (ATSP);

c) Airborne; and

d) Environmental.

7.2 These four categories can be subdivided into other categories as presented in the table below as an example. Awareness about these threats will assist the deployment of both individual and organizational countermeasures to maintain margins of safety during normal ATC operations.

ATSP Internal	ATSP External	Airborne	Environmental
Equipment	Airport Layout	Pilots	Weather
Workplace Factors	Navigational Aids	Aircraft Performance	Geographical

			Environment
Procedures	Airspace Infra-structure/Design	R/T Communication	
Other Controllers	Adjacent Units	Traffic	Distraction

8. ATSP Internal Threats

8.1 Equipment

8.1.1 Equipment design is a frequent source of threats for ATC. Malfunctions and design compromises are among the conditions that controllers have to manage to varying degrees during everyday operations. Additional threats under this category include radio communication that is of poor quality, and telephone connections to other ATC centres that may not always be functioning correctly. Inputs to automated systems may become a threat if the desired input is rejected by the system and the controller has to find out why the input wasn't accepted and how to remedy the situation. Inadequate equipment is a threat seen in many ATC facilities around the world. Lastly, a significant threat in ATC is maintenance work (scheduled or unannounced) concurrent with normal ATC operations. Maintenance activity also may produce threats that only manifest themselves when the equipment concerned is next put into service.

8.2 Workplace Factors

8.2.1 This category of threats comprises items such as glare, reflections, room temperature, non-adjustable chairs, background noise, and so forth. A controller's work is more difficult if there are reflections from the room lighting on the screens. A tower controller may have problems visually acquiring traffic at night if there are reflections from the interior lighting in the windows of the tower. A high background noise level, (i.e. from fans necessary to cool the equipment), may make it more difficult to accurately understand incoming radio transmissions. Similarly it may make outgoing transmissions harder to understand for the receiving parties.

8.3 Procedures

8.3.1 Procedures may also constitute threats for ATC. This applies not only to procedures for the handling of traffic, but also to procedures for internal and external communication and/or coordination. Cumbersome or inappropriate procedures may lead to shortcuts taken (intentional non-compliance) with the intent to help the traffic but with the potential to generate errors or undesired states.

8.4 Other Controllers

8.4.1 Other controllers from the same unit can be a threat as well. Proposed solutions for traffic situations may not be accepted, intentions can be misunderstood or misinterpreted, and internal coordination may be inadequate. Other controllers may engage in social conversation, creating a distraction from the traffic, or relief may be late. Other controllers in the unit may be handling traffic less efficiently than they're expected to, as a result of which they can't accept the additional traffic a controller wants to hand-off to them.

9. ATSP External Threats

9.1 Airport Layout

9.1.1 The layout and configuration of an airport can be a source of threats to ATC operations in the tower environment. A basic airport with just a short taxiway connecting the ramp with the middle of the runway will require ATC to arrange for backtracking of the runway by most of the arriving and departing traffic. If a taxiway parallel to the runway were available, with intersections at both ends as well as in between, there would be no requirement for aircraft to backtrack the runway. Some airports are designed and/or operated in such a way that frequent runway crossings are necessary, both by aircraft under their own power and by towed aircraft or other vehicles. A taxiway around the runway would be a solution, provided the aircraft and vehicles concerned use it consistently.

9.2 Navigational Aids

9.2.1 Navaids that unexpectedly become unserviceable (i.e. because of maintenance) can pose a threat to ATC, it may create changes to procedures, or cause inaccuracy in navigation and effect separation of aircraft. Instrument Landing Systems (ILSs) available for both directions of the same runway are another example of this category of threats. Normally only one of the ILSs is active at any one time, so with a runway change the ILS for the current runway direction may not yet be activated although controllers are already clearing aircraft to intercept it.

9.3 Airspace Infrastructure/Design

9.3.1 The design or classification of airspace is another potential source of threats for ATC. If useable airspace is restricted it becomes more difficult to handle a high volume of traffic. Restricted or Danger Areas that are not permanently active may be a threat if the procedures for communicating the status of the areas to the controllers are inadequate. Providing an ATC service to traffic in Class A airspace is less open to threats than, for example, in Class E airspace where there can be unknown traffic that interferes with the traffic controlled by ATC.

9.4 Adjacent Units

9.4.1 Controllers from adjacent units may forget to coordinate traffic, a hand-off may be coordinated correctly, but incorrectly executed, airspace boundaries may be infringed. A controller from the adjacent centre may not accept a proposed non-standard hand-off, requiring an alternative solution be devised. Adjacent centres may not be able to accept the amount of traffic that a unit wants to transfer to them. There may be language difficulties between controllers from different countries.

10. **Airborne Threats**

10.1 Pilots

10.1.1 Pilots who are unfamiliar with the airspace or airports can pose a threat to ATC. Pilots may not advise ATC of certain manoeuvres they may need to make (i.e. when avoiding weather) which can be a threat to ATC. Pilots may forget to report passing a waypoint or altitude, or they may acknowledge an instruction and subsequently fail to comply. In the TEM framework, an error by a pilot is a threat to ATC.

10.2 Aircraft Performance

10.2.1 Controllers are familiar with the normal performance of most aircraft types or categories they handle, but sometimes the performance may be different to that expected. A Boeing 747 (B747) with a destination close to the point of departure will climb much faster and steeper than one with a destination that is far away because of a lighter fuel load, it will also require a shorter take-off roll on the runway. Some new-generation turboprop aircraft will outperform medium jet aircraft in the initial stages after take-off. Subsequent aircraft series may have a significantly higher final approach speed than earlier series. All these differing performance aspects, if not recognized, can pose threats to ATC.

10.3 Radio/Telephony (R/T) Communication

10.3.1 Readback errors by pilots are threats to ATC. (Similarly, a hearback error by a controller is a threat to the pilot.) R/T procedures are designed with the aim to detect and correct such errors (thus avoiding threats) but in actual practice this doesn't always work to perfection. Communications between pilots and controllers may be compromised by language issues. The use of two languages on the same frequency, or two or more ATC units sharing the same frequency are also considered threats under this category.

10.4 Traffic

10.4.1 Controllers become accustomed to the normal flow of traffic in their areas and how these are usually handled. Non-routine aircraft activity such as photo flights, survey flights, calibration flights (navaids), parachute jumping activities, road traffic monitoring flights and banner towing flights all pose threats to how routine traffic is handled. The earlier a controller is aware of any additional traffic the better the opportunity to adequately manage the threat.

11. Environmental Threats

11.1 Weather

11.1.1 Weather is perhaps the most common category of threats to all aspects of aviation, including ATC operations. Managing this threat is made easier by knowing the current weather and the forecast trend for at least the duration of a controller's shift. For example: changes in wind direction may involve runway changes. The busier the traffic, the more crucial becomes the timing for a runway change. A controller will plan strategies to make the change with a minimal disruption to the traffic flow. For en-route controllers, knowing areas of significant weather will help to anticipate requests for diversions. Appropriate knowledge of local weather-phenomena (i.e. turbulence over mountainous terrain, fog-patterns, intensity of thunderstorms, etc.) and/or sudden weather-occurrences like windshear or microbursts contributes towards successful weather threat management.

11.2 Geographical Environment

11.2.1 Threats in this category comprise high terrain or obstacles in the controller's area of responsibility. Less obvious threats can be posed by, for example, residential areas that must not be overflown below certain altitudes or during certain hours. At some airports runway changes are mandatory at specified times of day for environmental reasons.

12. Errors in Air Traffic Control

12.1 Section 3.3 discusses errors from the perspective of the TEM framework. This section furthers the discussion, and provides specific examples of errors in air traffic control from the perspective of TEM. One of the premises in TEM is that perspectives on errors as portrayed by traditional views on human error do not properly reflect the realities of operational contexts. Operational personnel in ultra-safe industries, of which aviation is a perfect example, do not adopt courses of action merely by choosing between a good and a bad outcome. Rather they adopt courses of action that seem to be the best in the light of their training, experience and understanding of the situation. They make sense of the operational context in which they are immersed, based upon cues and clues provided by the context of the situation. Only afterwards, when the result of such attempt at making sense is known (the outcome), is it possible to suggest, with the benefit of hindsight, that a different view would probably have resulted in a more desirable outcome.

12.2 In cases where the outcome was an undesirable one, the attempt at making sense leading to that outcome is usually classified as an "error". This can only be done when the outcome is known (which is not the case when the deliberation took place) and when additional information about the context of the situation is available (which was not available to the people attempting to make sense of the prevailing operational conditions) that suggests another course of action may have been more appropriate than the one taken.

12.3 What is stated in the previous paragraphs about generic decision errors does apply similarly for equipment handling errors, procedural errors and/or communication errors. At the time when the equipment is handled, the procedure is applied or the communication takes place, the people involved are convinced that what they're doing is the best thing (or at least the correct thing) to do in that situation. It is not until afterwards that it is possible to see that perhaps the equipment should have been handled differently, or that another procedure should have been applied, or that the communication was not adequate.

12.4 The question that begs answering thus becomes: "why was this additional information not available to the controller at the time of the event?" Among the various answers, one that is relevant to TEM is that they were not actively engaged in the identification of threats. Threats are such an integral and embedded part of the operational context that they are routinely dealt with without giving it a second thought. Through extended exposure to a threat-rich environment, operational personnel have learned to live with threats as normal components of operational contexts. Yet, for all the existing "normalisation" of threats, mismanaged threats continue to hold their full safety-damaging potential.

12.5 Under TEM, a threat is not a problem as such in and of itself, but it could develop into one if not managed properly. Not every threat leads to an error, and not every error leads to an undesired state, yet the potential is there and so should be recognized. For example, visitors in an ATC operations room are a "threat": their presence in itself is not a dangerous situation, but if the visitors engage in discussions with the ATC crew or otherwise distract them, they might lead the controller to make an error. Recognizing this situation as a threat will enable the controllers to manage it accordingly, thereby minimizing or preventing any distraction and thus not allowing the safety margins in the operational context to be reduced.

12.6 Specific examples of errors in air traffic control from the perspective of TEM are included hereunder. The list is illustrative and not comprehensive.

Equipment handling errors	➢ Radar usage: selecting an inappropriate radar source; selecting an inappropriate range, not selecting the correct mode (SSR on/off, mode C on/off). ➢ Automation: making incorrect inputs to the automated system. ➢ Radio/intercom: incorrect frequency selected; selecting an incorrect button/address on the intercom; transmitting while another transmission is in progress. ➢ Flight progress strips: incorrect placement of strips on flight progress board; strips placed in incorrect stripholders (colour coding); strips not passed to correct controller.
Procedural errors	➢ Handover at working position: omitted/incorrect items; rushed handover; leaving the position before new controller is ready to take over. ➢ Information: information about approach/departure procedure not or not timely provided to pilots; information about weather/ATIS not or not timely provided to pilots; information about status of navigational aids not or not timely provided to pilots. ➢ Documentation: wrong approach/departure charts used; briefing material not read. ➢ Checklists: items missed, checklist not used or at the wrong time. ➢ Separation minimums: wrong separation minimum applied (i.e. Wake Turbulence Separation).
Communication errors	➢ ATC to pilots: missed calls; misinterpretations of requests; incorrect hear-back; wrong clearance, taxiway, gate or runway communicated. ➢ Controller to controller: within unit miscommunication or misinterpretation; miscommunication or misinterpretation during coordination with an external partner.

13. Undesired States in Air Traffic Control

13.1 The notion of undesired states is unique to the process of monitoring safety in normal operations. An undesired state is transient in nature – it only exists for a limited period of time, after which the undesired state becomes an outcome (that is, either a resolved or managed situation, an incident or an accident). Conventional safety data collection systems only become active after an outcome is classified as potentially consequential to safety, i.e. after an incident or accident has taken place, or some infringement of regulations, procedures, or instruction has occurred. Nothing can be done to change an outcome, for an outcome is an end-state.

13.2 By way of example, during normal operations monitoring, there often is an opportunity to observe a situation evolving in real time where there is a difference in the way the controller expects the traffic to develop and the way in which it actually develops. There are opportunities for the controller to identify this divergence and take corrective measures to avoid an unwanted outcome before margins of safety are compromised. The time between the provoking threat or error and the application of corrective measures (or the absence thereof) can be considered the lifespan of the undesired state.

> *An undesired state is often the first indication to a controller that an earlier threat or error was not adequately managed.*

13.3 Examples of undesired states – on the ground:

a) Aircraft continuing taxiing when/where it should stop; aircraft stopping when/where it should continue taxiing;

b) Aircraft entering a taxiway that it shouldn't use; aircraft not entering a taxiway that it should use;

c) Aircraft proceeding to another gate/stand than where it should go;

d) Aircraft making a pushback from the gate when it should hold; aircraft holding at the gate when it should be pushing back; and

e) Aircraft vacating the runway at another position than where it should; aircraft not vacating the runway at the position where it should.

13.4 Examples of undesired states – airborne:

a) Aircraft not turning when it should; aircraft turning when it should not; aircraft turning in direction other than that flight planned;

b) Aircraft climbing/descending to another flight level/altitude than it should; aircraft not climbing or descending to the flight level/altitude where it should;

c) Aircraft not reaching the required flight level/altitude at the time/point when/where it should;

d) Aircraft flying to another waypoint/position than where it should; aircraft not flying to the waypoint/position where it should; and

e) Aircraft flying at another speed than it should.

14. Managing Threats and Errors

14.1 The first step in the process of managing threats is threat identification. As an example, a meteorological office that provides regular weather forecasts already constitutes a way to understand bad weather as a threat. Likewise, a controller may ask aircraft about wind (direction and speed) at a certain altitude or level, to be able to provide more accurate radar vectors.

14.2 A further step is to share real-time information about the existence of threats with other controllers. To use an example of "aircraft performance", when observing the climb performance of a B747 with a destination relatively close to the departure airport the tower controller could alert the departure controller to the fact that the B747 is climbing faster than average. Passing information about differing wind speeds and directions at different altitudes from one controller to the next is another example of sharing knowledge about threats.

14.3 In the case of "environment" being a threat, managing it can be made easier for controllers if the high terrain or obstacles are depicted on the radar map. This applies as well for residential areas that must be avoided for noise abatement purposes below certain altitudes or during certain hours. If these areas can be presented on the radar map when necessary, controllers will be able to manage the threat more adequately.

14.4 At the individual level, threats can also be managed by keeping track of the number of threats that are present at any given time. The more threats there are at the same time, the more reason there may be to adjust the operation as it is being carried out at that moment.

14.5 As a general rule, it could be said that the greater the lead-time between threat identification and when the threat manifests itself, the better the chance there is that the threat will be adequately managed. Briefings about expected survey flights, photo flights, road traffic control missions, etc. will enable, including this traffic, in the planning. Without a briefing, such additional workload may come as a surprise and could disrupt the operation.

14.6 The following table shows threat and error countermeasures for ATC:

Team Climate	
COUNTERMEASURE	DESCRIPTION
Communication Environment	Environment for open communication is established and maintained
Leadership	Supervisor shows leadership and coordinated the team/sector/unit activities
Overall Team Performance	Overall, team performs well as risk managers
Planning	
COUNTERMEASURE	DESCRIPTION
Briefing	An interactive and operationally thorough briefing is provided
Plans Stated	Operational plans and decisions are communicated and acknowledged
Contingency Management	Team members develop effective strategies to manage threats to safety
Execution	
COUNTERMEASURE	DESCRIPTION
Monitor/Cross-check	Team members actively monitor and cross-check other team members
Workload Management	Operational tasks are prioritised and properly managed to handle primary ATC duties
Automation Management	Automation is properly managed to balance operational and/or workload requirements
Flight Strip Management	Flight strips are properly organized and updated to keep track of traffic developments
Review/Modify	
COUNTERMEASURE	DESCRIPTION
Evaluation of Plans	Existing plans are reviewed and modified when necessary
Inquiry	Team members are not afraid to ask questions to investigate and/or clarify current plans of action

Note— Managing Error is discussed in ICAO (Doc. 9758) — Human Factors Guidelines for ATM Systems.

15. **TEM-based analysis of actual ATC situations**

15.1 Case 1 – Radar Approach Control environment

Situation: a Boeing 737 (B737) was given an interception heading for the ILS but failed to intercept the localiser. An Airbus 320 (A320) on the opposite base leg was descending to the same altitude as that of the B737 and the lateral distance between the two a/c rapidly became less as a result of the B737 continuing on its interception heading. The controller noticed the B737 crossing the localiser, instructed it to turn right to intercept and also instructed the A320 to turn right to avoid the B737. The pilot of the A320 reported visual contact with the B737 throughout the manoeuvring.
Threat: pilot failing to turn (intercept) as instructed by ATC.
Undesired State: B737 not intercepting the localiser and continuing on heading; distance between aircraft rapidly diminishing.
Possible consequence: loss of separation.
Undesired State Management: additional instructions to both aircraft by controller after detection of deviation.
Outcome: situation managed/resolved.

15.2 Case 2 – Aerodrome Control environment

Situation: A Boeing 747 (B747) was rolling out on the runway after landing. On the parallel taxiway another B747 was approaching the rapid exit taxiway where the landing aircraft would vacate the runway and was told by Ground Control to hold short of that intersection. The Tower (TWR) controller informed the B747 on the runway that the other aircraft would give way, and told the pilot to "keep it rolling, and after vacating contact Ground on 121.7". This was acknowledged, after which the B747 was observed to continue taxiing on the runway to the next rapid exit taxiway, this meant that the runway was occupied by the B747 for longer than the controller had anticipated. The TWR controller had to instruct a DC10 on short final to make a go-around.
Threats: conflicting aircraft working on different frequencies; misinterpretation of TWR instruction by landing B747 crew.
Error: use of non-standard phraseology by TWR controller.
Undesired State: B747 continuing on the runway to a more distant rapid exit taxiway with a DC10 on short final.
Undesired State management: DC10 instructed to go-around by TWR.
Outcome: situation managed/resolved.

15.3 Case 3 – Aerodrome Control environment

Situation: to expedite departures the traffic was distributed over three different intersections near the beginning of the runway. When the TWR controller wanted to clear an ABC B737 that was lined up at the very beginning of the runway for take-off, he noticed that an Airbus 310 (A310) was entering the runway in front of the ABC B737 from another intersection. The A310 had not received any instructions from the TWR to do so. When the A310 had checked in on the TWR frequency, they were told to "hold short" and this had been acknowledged by the crew. Since the A310 had already crossed the "clearance line" (painted yellow marking on the intersection), the TWR decided to let the A310 depart ahead of the ABC B737. It later was established that the A310 crew had misinterpreted information from Ground Control that was given earlier and on another frequency, i.e. "in sequence behind XYZ B737"; when the A310 crew saw the XYZ B737 taking-off (before the ABC 737) they took that as their cue to line up on the runway.
Threats: use of multiple intersections; use of the phrase "in sequence" by Ground Control; misinterpretation by A310 crew; failure of the A310 crew to comply with the "hold short" instruction from TWR.
Undesired State: A310 entering the runway without instruction/clearance from TWR.
Undesired State Management: movement of A310 detected by TWR controller; change made in order of departure sequence.
Outcome: situation managed/resolved.

15.4 Case 4 – Aerodrome Control environment

Situation: the last aircraft of a series of inbounds on the main landing runway was cleared for a circling approach to the departure runway and had received its landing clearance. There was no outbound traffic for the departure runway at that time. While the controller became involved in a social conversation with the ground controller and an assistant controller, an outbound aircraft was transferred by ground to tower and subsequently cleared for take-off from the departure runway. The circling aircraft had not landed yet, however. After a few moments the controller looked outside and noticed the aircraft on final for the departure runway while the outbound aircraft was lining up. The controller asked the outbound aircraft to expedite, and told the circling aircraft that there would be a departure in front. The pilot of the circling aircraft acknowledged the information and said that they had the departing traffic in sight. The departing aircraft got airborne before the landing aircraft crossed the threshold.
Threat: the controller became involved in a social conversation with the ground controller and an assistant controller (Distraction/Underload).
Error: the controller cleared the outbound aircraft for take off when there was traffic on final (with a landing clearance).
Undesired State: both aircraft were cleared to use the runway at the same time.
Undesired State Management: when the controller looked outside he realised he'd made an error. He considered instructing the aircraft on final to make a go-around, but in view of the position of both aircraft relative to the runway and the prevailing strong wind at the time he judged that the departing traffic could be gone in time to allow the inbound aircraft to complete its landing. Consequently he asked the outbound to expedite because of traffic on final. He also provided information about the situation to the inbound aircraft.
Outcome: situation managed/resolved.

15.5 Case 5 – Procedural Area Control environment

Situation: At time 0350 the area controller received coordination from an adjacent centre on a Boeing 767 (B767) estimating waypoint XYZ at 0440 Flight Level (FL) 370, negative Reduced Vertical Separation Minima (RVSM). This information was correctly written on the scratchpad, however FL350 was entered into the electronic label. (FL370 and the time 0350 were written close together on the scratchpad). A handover/takeover occurred at the working position and shortly afterwards the adjacent centre called the new controller with an amended estimate for XYZ. The controller read back the new estimate and FL350. The adjacent centre informed the controller that the B767 was at FL370. The controller confirmed this level with the adjacent centre. Shortly afterwards the Controller noticed that he had an Airbus 330 on a converging route at FL380 and instructed that aircraft to climb to FL390. This was done after coordinating with the adjacent centre and instructing them to tell the B767 to descend to FL350.
Threats: non-RVSM aircraft in RVSM airspace; similar digits written in close proximity on the scratchpad; data entry error (wrong FL) by the first Controller; position handover/takeover; amendment of the estimated time.
Undesired State: aircraft at another FL than it should be (i.e. from the second Controller's perspective).
Undesired State Management: the FL anomaly was detected as a result of strict adherence to standard coordination procedures (**threat management strategy**) at the time the amended estimate was coordinated. The Undesired State was managed by climbing the A330 and instructing the adjacent centre to descend the B767.
Outcome: situation managed/resolved.

15.6 Case 6 – Radar Area Control environment

Situation: moderate to high level of traffic worked over a 45-minute period, followed by a reduction in traffic to a low level. At this point, the data (planner) position was combined into the radar position thereby reducing the sector staffing to a single controller. A minimal sector briefing was carried out

between controllers. Shortly after assuming control for the entire sector, the single controller noticed a discrepancy between the aircraft's altitude and what had been coordinated with the next sector. He subsequently coordinated with the sector to pass the revised altitude information.
Threats: low workload; combining of two positions into one; single person operation; minimal briefing.
Error: incorrect altitude coordinated with the next sector. (N.B. If this error was made by the controller who went away after combining the positions it would become a threat for the remaining controller).
Undesired State: aircraft at other altitude than that coordinated with the next sector.
Undesired State Management: the controller coordinated the correct altitude with the next sector.
Outcome: situation managed/resolved.

15.7 Case 7 – Oceanic Control environment

Situation: a group of eight aircraft on an oceanic airway transitioned from non-radar airspace into radar coverage. The aircraft ranged in altitude from FL300 to FL370 and there was approximately 40 Nautical Miles (NM) between the first and last aircraft. Two aircraft were subsequently given the same altitude (FL320) and were spaced by approximately 13NM (5NM required). Estimates were passed to the next sector and the initiating controller asked if the receiving controller wanted speed restrictions placed on the aircraft to ensure the required spacing was maintained. This was declined despite the receiving controller's comments that while he would be able to radar monitor the aircraft, he would be unable to communicate directly with them due to frequency coverage limitations. Just as the first B747 was to exit the first controller's airspace, the B747 reported "encountering moderate turbulence and reducing speed to Mach .84".
Threats: transition from non-radar to radar airspace; same FL assigned to two aircraft; receiving controller declining speed restrictions; frequency coverage limitations; speed reduction by first B747.
Undesired State: aircraft with higher speed following slower aircraft at the same FL and same route creating the potential for an overtake situation in an area where neither controller may have been able to communicate with the aircraft.
Undesired State Management: the first controller issued a climb to the second B747 to FL 330 (the only available altitude) and effected proper coordination with the next sector.
Outcome: situation managed/resolved.

16. TEM training for ATC personnel

16.1 Appendix 1 to this document contains example material used by one Air Traffic Services Provider (ATSP) in a TEM training programme for its ATC officers. This material was produced before the contents of this document were available, so differences in presented definitions may occur. Appendix 2 contains more recent material from another ATSP for a TEM training programme that was based on the contents of this document. ATC training departments are encouraged to use the material from the Appendices together with the text of this document to design a suitable TEM training package for their environment.

17. Integrating TEM in Safety Management

17.1 The distinction between the different categories of threats may be trivial to operational controllers: the reality is that threats exist and need to be managed during everyday shifts. Training managers on the other hand may wish to note which categories of threats are being addressed in the curriculum for their unit (although they're most likely not presented as threats in the training). Some of the threats are often addressed in a less formal way, i.e. as anecdotal information during on-the-job training.

17.2 The airport with basic layout where backtracking of the runway is required for movements is an example. Controllers working at that aerodrome will have received specific training (in the classroom, in the simulator or on-the-job) to enable them to control the traffic correctly, and they will be used to managing the threat. Nevertheless, every backtracking aircraft poses a threat to the ATC operation and needs to be managed by the controllers.

17.3 From the perspective of an ATC safety manager, it is relevant to know how this particular threat is managed by the controllers on a day-to-day basis. Are they able to manage it without any significant problems, or are the difficulties involved in managing it so common that they go unreported? In the case of the former, there may be no requirement for the safety manager to take specific action. In case of the latter there obviously is a need for safety management action. The question then becomes: how can a safety manager know what threats exist in the operations of the unit and how these threats are being managed?

18. Normal Operations Monitoring

18.1 Safety managers of an increasing number of airlines have embraced a tool called the Line Operations Safety Audit (LOSA). LOSA is a tool for the collection of safety data during normal airline operations. Specifically, LOSA is a tool used to collect information on threats that pilots of the airline have to face in everyday operations, how these threats are managed, what errors may result from the threats and how the crews manage these errors. After the information from LOSA observations is processed, the airlines have a clear overview of the strengths and weaknesses of their flight operations with respect to threats, errors and undesired states encountered by their crews in normal operations. This is a category of safety information that is not available through any other methods.

Note— Guidance material on LOSA is provided in ICAO Line Operations Safety Audit (LOSA) Manual *(Doc 9803).*

19. Normal Operations Safety Survey (NOSS)

19.1 Following the successful implementation of LOSA by a number of airlines, ICAO is pursuing the development of a similar tool for the monitoring of safety in normal ATC operations. The name for this tool is Normal Operations Safety Survey (NOSS). Although NOSS is modelled after LOSA, it is a unique tool with unique characteristics, tailored for the ATC environment.

19.2 In its anticipated form, NOSS will entail over-the-shoulder observations during normal shifts and will not be applied in any training situations. The programme will require joint sponsorship from management and the association representing air traffic controllers. All participation will be voluntary, and data collected will be de-identified and treated as confidential and not for disciplinary purposes. NOSS will use a standard observation form, trained and standardized observers, trusted data collection sites, and a data "cleaning" process. In addition, it will spell-out targets for safety enhancement and provide feedback to participating controllers.

19.3 The idea behind NOSS is to furnish the ATC community with a means for providing robust data on threats, errors and undesired states to safety managers. Analysis of NOSS data, together with safety data from conventional sources, should make it possible to focus the safety change process on the areas that need attention the most.

19.4 ICAO is planning the publication of a NOSS Manual by the end of 2006.

Related documents

Human Factors Training Manual (Doc 9683)
Human Factors Guidelines for Air Traffic Management Systems (Doc 9758)
ICAO Safety Management Manual (Doc xxxx)
Line Operations Safety Audit (LOSA) Manual (Doc 9803)

Appendix 1

TEM in the operational environment (PowerPoint presentation - NavCanada)

Appendix 2

Threat and Error Management in Air Traffic Control (PowerPoint presentation - LVNL/ATC The Netherlands)

Threat and Error Management (TEM) in the Operational Environment

1

Human Factors Training

- Situational Awareness (SHELL and Reason's Models)
- Communication
- Teamwork

2

Objective

- To introduce a Threat & Error Management Model (TEM)
- To further understand the effects of Human Factors on performance and safety.

3

Outline

- A Description of Threat and Error Management
- Threat Management
- Alertness Management
- Strategies to Manage Errors

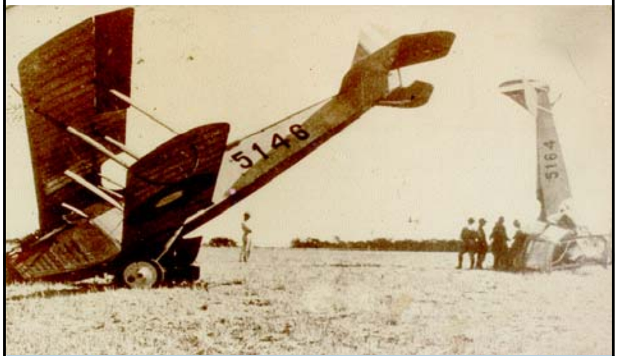
4

Assumptions of Human Factors Training

- Humans have limitations on performance
- Error is inevitable

5

"To err is human"



6

Error Management
versus
Error Avoidance

NAV CANADA

7

A Strategy to Manage Threat in the Operational Environment

NAV CANADA

8

Definition of Threat

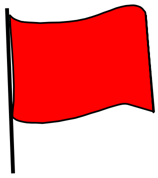
An indication of something coming; a menace or likely cause of harm

NAV CANADA

9

Threat $\neq$ Error

Threat $=$



NAV CANADA

10

Threats

- ➔Expected
  - ←Weather
  - ←Staff shortages
- ➔Unexpected
  - ←Equipment Failure
  - ←Emergencies

NAV CANADA

11

Four Steps in Threat Management

- Identify
- Assess
- Act
- Monitor

NAV CANADA

12

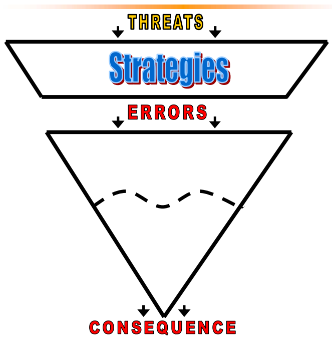
Methods to Identify Threats

Categories -

- •Supervision
- •Planning
- •Team Composition
- •Team Fitness
- •Environment
- •Task Complexity

13

Methods to Assess Threats



14

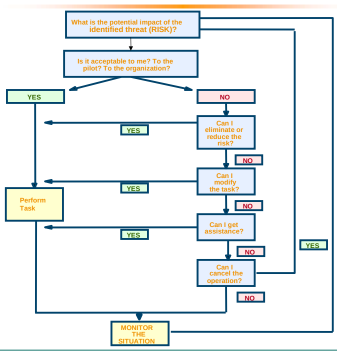
Methods to Assess Threats

Risk -

- •Severity
- •Probability
- •Exposure

15

Methods to Act on Threats



16

Barriers to Monitoring Threats

- Distractions
- Interruptions
- Preoccupations

17

Methods to Monitor Threats

Distractions, Interruptions, Pre-occupations (DIPs) -

- •Conversations
- •Heads-Down Work
- •Competing Activities
- •Responding to abnormal activities

18

Methods to Monitor Threats

Strategies to Reduce DIPs -

- •Recognize conversation is a powerful distracter
- •Recognize heads-down work greatly reduces your ability to monitor
- •Minimize conflicts between tasks
- •Avoid focusing on a single task for too long
- •Assign responsibility
- •Treat DIPs as RED FLAGS

19

Four Steps in Threat Management

- •Identify
- •Assess
- •Act
- •Monitor

20

Methods to Monitor Threats

Situational Awareness -

- •Predetermine Roles
- •Plan
- •Solicit input
- •Evaluate your status
- •Project ahead
- •Scan but focus on details
- •Create reminders
- •Watch for clues for loss of SA

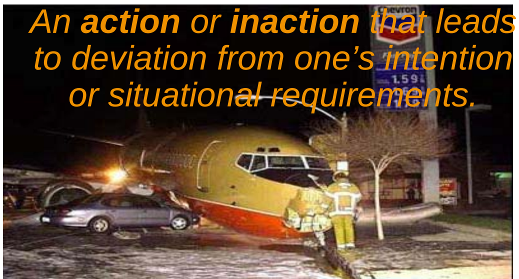
21

Strategies to Manage Errors in the ATS Environment

22

Definition of Error

*An **action** or **inaction** that leads to deviation from one's intention or situational requirements.*



23

Types of Errors

- Procedural
- Communication
- Proficiency
- Decision
- Intentional Non-compliance

24

Errors and Violations

ERRORS

- You make an error when your action deviates from your intention, or when your intention is inappropriate
- An error is not intentional

VIOLATIONS

- You commit a violation when you intentionally deviate from a regulation or from a procedure
- A violation is originally intentional but can become routine

NAV CANADA 25

Relation between errors and safety

- *How many errors do you make per day?*
- *How many errors are made per day in a typical ATS unit?*
- *How many accidents happen each day?*

NAV CANADA 26

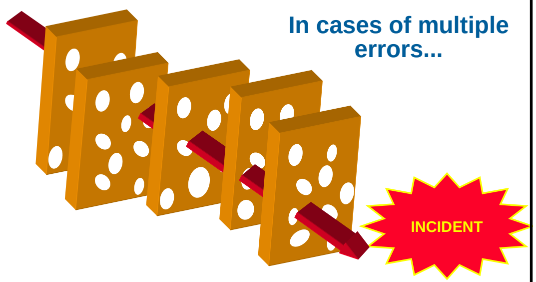
Response to Errors

- Trap
- Exacerbate
- Do Nothing

NAV CANADA 27

Errors and Incidents

In cases of multiple errors...



... an incident can occur

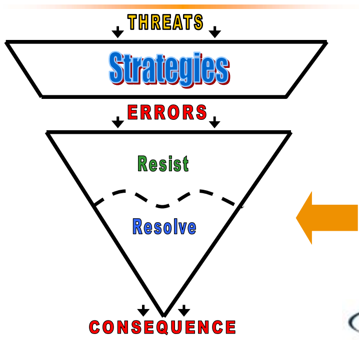
NAV CANADA 28

Video: Collision Course

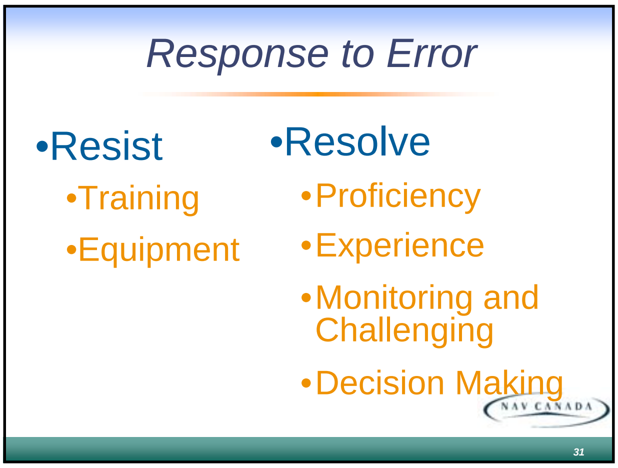
What are the Odds?

NAV CANADA 29

Methods to Manage Errors



NAV CANADA 30


Response to Error
•Resist
•Training
•Equipment
•Resolve
•Proficiency
•Experience
•Monitoring and Challenging
•Decision Making
NAV CANADA
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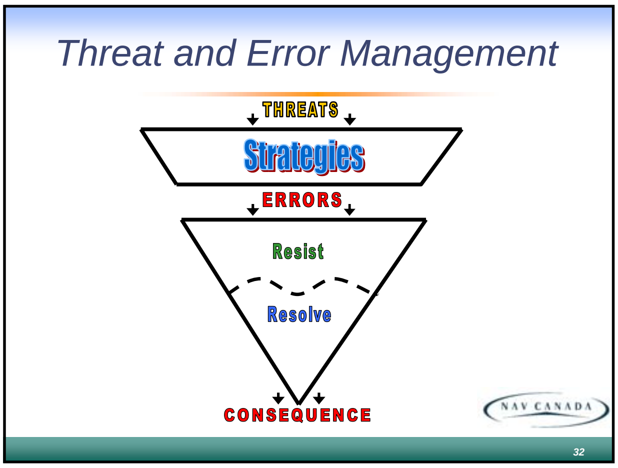
Threat and Error Management
THREATS
Strategies
ERRORS
Resist
Resolve
CONSEQUENCE
NAV CANADA
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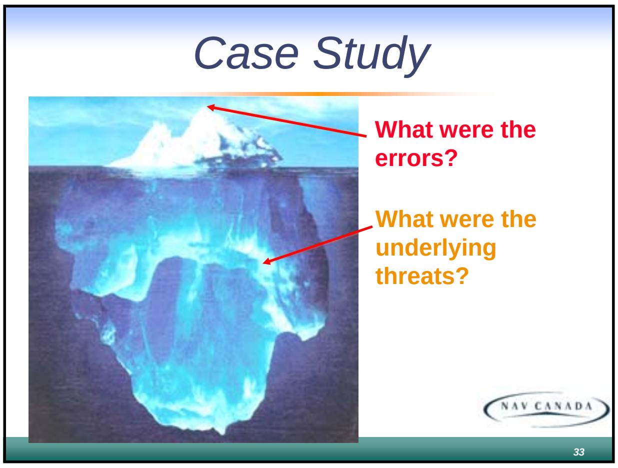
Case Study
What were the errors?
What were the underlying threats?
NAV CANADA
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Threat and Error Management in Air Traffic Control

[name of presenter]

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Before We Get Started..

- Presentation is based on material developed by ICAO
- The ICAO material will be published as a Circular (Q4 2005)
- New way of looking at familiar issues
  - Don't expect new revolutionary insights

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Presentation Overview

- "Ideal shift" versus "Real world shift"
- What are Threats, Errors and Undesired States?
- What is Threat and Error Management?
- What can Threat and Error Management mean for us?
- Relationship between TEM and Team Resource Management (TRM)
- Further developments

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Ideal Shift (1)

- Reporting for duty well ahead of time
- Comprehensive briefing materials available
- Update on weather and equipment status from Supervisor
- Detailed handover at working position
- Weather remains fine; wind direction compatible with available runways; no technical problems; no maintenance work

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Ideal Shift (2)

- Challenging traffic; workload not too high
- Complex situations resolved in timely manner by clear and concise instructions; all understood by co-operative pilots
- Relieved from position on time; break of sufficient duration; no additional duties
- Supervisor extends appreciation at end of shift for a job well done

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Real World Shift (1)

- Reporting for duty late because of road traffic
- Straight to working position without briefing; no contact with Supervisor
- Rushed handover by unimpressed colleague; not all items covered
- Equipment setup needs adjusting; not all system functionalities available

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Real World Shift (2)

- Caught off-guard by un-anticipated weather development
- Traffic situation requires full creativity and attention to stay on top
- Late relief from position; rushed and incomplete handover; short break with lots of other things to attend to
- All in a day's work….

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The Difference?

Threats and Errors

NB: normal shift – no incidents, no loss of separation

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TEM Terminology For ATC

- Threats: Events or errors that occur beyond the influence of the air traffic controller, increase operational complexity, and which must be managed to maintain the margins of safety
- Errors: Actions or inactions by the air traffic controller that lead to deviations from organisational or controller intentions or expectations
- Undesired States: operational conditions where an unintended traffic situation results in a reduction in margins of safety

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•VFR traffic
•Military activities
•Photoflights
•Parajumping activity
•Pilots

Threats (Aerodrome Environment)

Distractions
Runway crossings
Comsfailure/ sticking mike
Visitors
Shift handovers
Weather
Similar call signs
Maintenance
Non-standard local procedures
Airspace restrictions
Runway inspections
Heavy traffic
System malfunctions
Unfamiliar crews
Automation events
Missed approaches

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•VFR traffic
•Unfamiliar crews
•Photoflights
•Parajumping activity
•Pilots

Threats (Radar Environment)

Distractions
Military activities
Comsfailure/ sticking mike
Visitors
Shift handovers
Weather
Similar call signs
Maintenance
Non-standard local procedures
Airspace restrictions
Diversions
Heavy traffic
Co-ordination other sectors
System malfunctions
Automation events
Differing equipage

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What's New?

- ATCOs have always known about threats and errors
  - On-the-Job Training (OJT)
- Never made explicit
- No "inventory" of common threats & errors
- No clear picture of how threats & errors are managed on a day-to-day basis
  - Yet: few incidents/accidents

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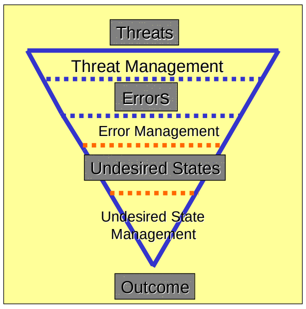
TEM Model



- Wrong readback (pilot)
- Hearback Error (ATC)
- Aircraft climbing/ descending to other level than expected
- Loss of separation

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Threats, Errors and Undesired States

- No linear relationship
  - Not every Threat leads to an Error; not every Error leads to an Undesired State
  - Not every Undesired State is preceded by an Error; not every Error is preceded by a Threat

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Threats, Errors and Undesired States

- Yet:
  - Threats that are not adequately managed often lead to Errors
  - Errors that are not adequately managed often lead to Undesired States
- An Undesired State is often the first indication to an air traffic controller that an earlier Error or Threat was not adequately managed
  - Managing the Undesired State becomes the #1 priority at that time
- Examples of T/E/US in hand-out

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Ueberlingen Threats

- No information provided about scheduled maintenance work
- Maintenance scheduled to be performed on multiple systems simultaneously
- ATC system only available in a degraded mode with reduced functionality
- No training for working with the ATC system in a degraded mode provided
- A delayed and unexpected flight to a regional airport in the airspace had to be accommodated
- A 2nd working position had to be opened in order to handle the flight to the regional airport
- There was a technical failure in the back-up phone system (required to coordinate the inbound flight with the regional airport)
- Single person nightshift culture
- Blocked and simultaneous R/T transmissions

If there had been no mid-air, these same Threats still would have existed

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Threat and Error Countermeasures (1)

Team	
Countermeasure	Description
Communication Environment	Environment for open communication is established and maintained
Leadership	Supervisor shows leadership and coordinated the team/sector/unit activities
Overall Team Performance	Overall, team performs well as risk managers
Planning	
Countermeasure	Description
Briefing	An interactive and operationally thorough briefing is provided
Plans Stated	Operational plans and decisions are communicated and acknowledged
Contingency Management	Team members develop effective strategies to manage threats to safety

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Threat and Error Countermeasures (2)

Execution	
Countermeasure	Description
Monitor/Cross-check/Scanning	Team members actively monitor and cross-check other team members. Individual controllers scan the aerodrome manoeuvring area; their flight progress strips and/or their radar screen
Workload Management	Operational tasks are prioritised and properly managed to handle primary ATC duties
Automation Management	Automation is properly managed to balance operational and/or workload requirements
Flight Strip Management	Flight strips are properly organised and updated to keep track of traffic developments
Review/Modify	
Countermeasure	Description
Evaluation of Plans	Existing plans are reviewed and modified when necessary
Inquiry	Team members are not afraid to ask questions to investigate and/or clarify current plans of action

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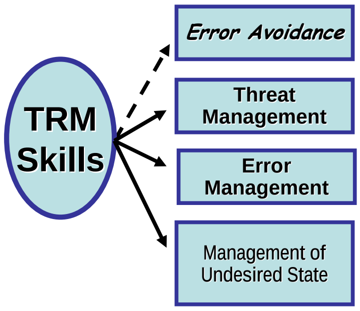
What Can TEM Mean For Us?

- Be aware of Threats and try to manage them
  - Individually or as a Team
  - Supervisor has a role as a facilitator
- If many Threats occur simultaneously:
  - Stop and Re-think
- Integrate TEM theory in training
  - Initial training and OJT

Relationship between TEM and TRM



Further Developments

- ICAO study group is developing a methodology for monitoring safety during normal operations
  - Normal Operations Safety Survey (NOSS)
- NOSS will provide an overview of the most significant Threats and Errors in the operation, and how these are managed
- Important information for Safety Manager
- Monitoring safety in normal operations should become an integral element of a safety management system