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Threat and Error Management (TEM) in Air Traffic Control

**Approved by the Secretary General
and published under his authority**

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FOREWORD

This circular describes an overarching safety framework intended to contribute to the management of safety in aviation operations and 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, which reads 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 has developed Doc 9910, *Normal Operations Safety Survey (NOSS)*, a methodology of NOSS, to which this circular on TEM is intended as a precursor. 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; managing threats and errors; TEM-based analysis of actual ATC situations; TEM training for ATC personnel; integrating TEM in safety management; and normal operations monitoring; and
- c) a list of related documents.

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

Note.— Throughout these guidelines, genders have been used interchangeably.

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INTRODUCTION

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.
 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.
 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 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.
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THREAT AND ERROR MANAGEMENT (TEM) IN AIR TRAFFIC CONTROL

1. THE THREAT AND ERROR MANAGEMENT (TEM) FRAMEWORK

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

1.2 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.

1.3 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.

1.4 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.

2. THE COMPONENTS OF THE TEM FRAMEWORK

2.1 Overview

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.

2.2 Threats

2.2.1 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.

2.2.2 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.

2.2.3 Some threats can occur unexpectedly, such as pilots carrying out instructions that 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.

2.2.4 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.

2.2.5 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 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 or how much they anticipate the threat, air traffic controllers can only manage its potential consequences through countermeasures strategies. The definition of *threat* in 2.2.1 intends to convey this notion: "events...that occur *beyond the influence* 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, which is why TEM advocates management as opposed to avoidance or elimination.

2.2.6 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 every day in the work place. Their consequences, however, are potential. Examples of these 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 18). No matter how much they anticipate them, controllers can only deploy countermeasures to manage the damaging potential of such threats.

2.2.7 Threat management is a building block to error management and undesired states management. Archival data on flight deck operations demonstrates that mismanaged 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.

2.2.8 Threat management provides the most proactive option for maintaining margins of safety in ATC operations by nullifying safety-compromising situations at their outset. As threat managers, air traffic controllers are among the last line of defence for minimizing the impact of threats on ATC operations.

2.3 Errors

2.3.1 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 mismanaged 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.

2.3.2 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.

2.3.3 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.

2.3.4 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.

2.3.5 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.).

2.3.6 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