006 Defensive Flying for Glider Pilots: An Introduction to Threat and Error Management (TEM)
(Preparation for Flight)

Introduction

The easiest way to understand Threat and Error Management (TEM) is to liken it to defensive driving for a motorist. The purpose of defensive driving is not to teach people how to drive a vehicle (e.g., how to change gear) but to emphasize driving techniques that people can use to minimize safety risks (e.g., techniques to control rear-wheel skids). Similarly, TEM does not teach pilots how to technically fly an airplane; instead, it promotes a proactive philosophy and provides techniques for maximizing safety margins despite the complexity of one's flying environment. In this sense, TEM training can be framed as defensive flying for pilots.

TEM proposes that threats (such as a defective winch cable joint), errors (such as a pilot failing to follow the correct launch failure procedure), and undesired aircraft states (such as a stall on the subsequent recovery) are everyday events that pilots must manage to maintain safety. Therefore, pilots that successfully manage these events regardless of occurrence are assumed to increase their potential for maintaining adequate safety margins. It is this notion that provides the overarching objective of TEM—to provide the best possible support for pilots in managing threats, errors, and undesired aircraft states.

This document provides an introductory orientation to TEM via a discussion of definitions, and techniques. TEM concepts are further explained using real-world examples.

The final section, TEM tools and techniques, highlights the practical, proactive nature of TEM and its relevance for all glider pilots.

Threats and their Management

Pilots have to manage various complexities in the operating environment on a typical day of flying. In TEM, such complexities are known as threats.

Threat definition

Threats are defined as events or errors that:

- Occur outside the influence of the pilot. (ie not caused by the pilot)
- Increase the operational complexity of the flight

- Requires his attention and management if safety margins are to be maintained.

Using this definition, a threat can be high terrain, cloud conditions, a winch or tow plane malfunction (e.g., lack of fuel), or other people's errors, such as pedestrians walking across a landing area. All these events occur independently of the pilot yet they add to the pilots' workload and need to be managed. Sometimes they can be managed discreetly and sometimes they interact with one another further complicating the necessary management. In gliding clubs, threats can be divided into two categories:

1. Environmental threats, which are outside the clubs direct control, such as weather and General Aviation (GA), and
2. Gliding club threats, which originate within flight operations, such as aircraft malfunctions and ground problems. The table below shows the various threat types with examples.

Threat Types with Examples

Environmental Threats	**Examples**
Weather	Windshear, turbulence, lightning, Cloud.
Visibility	Fog, sun, cloud shadow,
Surface	Mud, ice, rabbit holes
General Aviation	Overhead traffic (winch cables), poor lookout, radio congestion,
Navigational	GPS jamming
Terrain	Obstructions or terrain
Club Threats	**Examples**
Aircraft	Aircraft defects/ damage, equipment failures
Operational pressure	Launch rates, trial lesson, launch queues
Retrieve crews	Distractions, errors, interruptions, situational awareness
Launch crews	Distractions, errors, interruptions, situational awareness
Aircraft maintenance	Maintenance or repair errors, communications
Visitors	Management of visitors, separation from risk
Manuals charts	Access to pilot briefing information. Accuracy of data provided.

Threat management can be broadly defined as how pilots anticipate and/or respond to threats. A mismanaged threat is defined as a threat that is linked to or induces pilot error. Some of the common tools and techniques used in gliding clubs to manage threats and prevent pilot errors include providing weather and daily briefing, operating procedures and regular refresher training. .

Errors and their Management

From the TEM perspective, error is a pilot action or inaction that leads to a deviation from pilot or organizational intentions or expectations.

Put simply, threats come "at" the pilot, while errors come "from" the pilot.

Pilot errors can be the result of a momentary slip or lapse, or induced by an expected or unexpected threat. For example, a delay during the launch procedure may induce a procedural shortcut that results in further error, just as a stopped launch could distract the pilot from completing the checklist properly, causing him to take off with a canopy unlocked. Other errors are more deliberate. Known as intentional non compliance errors in the TEM phraeseology, these errors are often proven shortcuts used by the pilot to increase operational efficiency even thought they are in violation of Standard Operating Procedures (Towing a glider to the launchpoint with only 2 people would be an example).

Error Definition

Errors are defined as pilot actions or inactions that:

- Lead to a deviation from pilot or organizational intentions or expectations;
- Reduce safety margins; and
- Increase the probability of adverse operational events on the ground or during flight.

Pilot errors can be divided into three types:

1. aircraft handling,
2. procedural and
3. communication errors.

Aircraft handling errors are those deviations associated with the direction, speed and configuration of the aircraft. They can involve technological errors, such putting the wrong setting in a GPS, or flying errors, such as getting too fast and high during an approach.

Procedural errors are pilot deviations from regulations, flight manual requirements or club standard operating procedures.

Lastly, communication errors involve a miscommunication between the pilots, or ground crew.

The table below shows the various error types with examples.

Aircraft handling error	Examples
Navigation	Airspace infringement,
Aircraft configuration	Incorrect use of airbrakes,brakes, flaps, trim, undercarriage etc.
Field landing	Late field selection, poor field selection
On the ground	Attempting to land in confined spaces, taxying in confined spaces
General Flying	Un co-ordinated flying, speed and g deviations, misjudged take-offs and landings, inadequate lookout
Systems	Incorrect radio, GPS and altimeter settings
Procedural errors	**Examples**
Briefings	Missed items on self brief, missed general brief.
Checklist/ drills	Omitted or incorrectly followed check list. Missed items, wrong time.
Documentation	Misread or fail to read weight and balance, or flight manual.
Procedural	Fail to check controls, failure to follow winch launch failure drill.
Communications	**Examples**
Pilot to ground	Misinterpret briefing, give unclear instructions to launch crew
Pilot airborne	Miscommunication of information, jamming frequency , poor radio use.

Error management is now recognized as an inevitable part of learning, adaptation, and skill maintenance; hence, a primary driving force behind TEM is to understand what types of errors are made under what circumstances (i.e., the presence or absence of which threats) and how pilots respond in those situations.

What the pilot must learn is how to detect and respond to an error; and how to behave. Stress management, peer pressure, rush, hurry.)For example, do pilots detect and recover the error quickly, do they acknowledge the error but do nothing, perhaps because they believe it is inconsequential or will be trapped later, or do they only "see" the error when it escalates to a more serious undesired aircraft state? This is the heart of error management: detecting and correcting errors. However, research shows approximately 45% of errors go undetected or are not responded to by the pilot, which gives credence to an important point for effective error management: An error that is not detected cannot be managed.

An error that is detected and effectively managed has no adverse impact on the flight. On the other hand, a mismanaged error reduces safety margins by linking to or inducing additional error or an undesired aircraft state.

Undesired Aircraft States and their Management

Unfortunately, not all errors are well managed. Sometimes they lead to another error or a safety-compromising event called an undesired aircraft state (UAS).

Undesired Aircraft State Definition

An undesired aircraft state (UAS) is defined as a

Position, speed, attitude, or configuration of an aircraft that:

- Results from pilot error, actions, or inaction; and
- Clearly reduces safety margins

In other words, a UAS is a safety-compromising state that results from ineffective error management. Examples include unstable approaches, midair collisions, heavy landings, and spinning after a launch failure. Events such as malfunctions or failure to refuel a launch vehicle can also place the aircraft in a compromised position; however, in the TEM phraeseology, these events are considered threats as they are not the result of actions by the pilot.

UAS Types with Examples

UAS Type	Example
Aircraft handling	Poor position in circuit, incorrect speed, unstable approach, heavy landing, poor weather penetration, midair collisions,
Ground manoeuvring/handling	Causing obstruction, incorrect tow-out, taxying in confined spaces, incorrect pre-launch procedures.
Incorrect Configuration	Aircraft mis rigged, incorrect flap setting, undercarriage, trim, canopy latch not secured.

TEM Tools & Techniques

The principles of TEM are not new to aviation. In fact, Orville and Wilbur Wright no doubt practiced threat and error management when they took their first controlled flight with the Wright Flyer in 1903. Since then, various tools and techniques have been developed over the past century to help flight crews manage threats, errors, and undesired aircraft states.

Some tools—the ***"hard"*** safeguards—are associated with aircraft design, and include automated control connection systems, instrument displays, and aircraft warnings. The Flarm collision avoidance system, which provides pilots with visual and audio warnings of nearby sailplanes to prevent midair collisions, is a good example of a "hard" TEM safeguard. Even with the best designed equipment however, these "hard" safeguards are not enough to ensure effective TEM performance.

Other tools—the ***"soft"*** safeguards—are very common in gliding (and other high-risk sports). They include regulations, standard operating procedures, and checklists to direct pilots and maintain equipment; and licensing standards, checks, and training to maintain proficiency. With the hard and soft safeguards in place, the last line of defence against threat, error, and undesired aircraft states, is still, ultimately, the pilot. Checklists/ drills and procedures only work if pilots use them. Therefore, TEM tools work best when pilots adopt TEM techniques.

The TEM philosophy stresses three basic concepts: ***anticipation, recognition, and recovery***. The key to anticipation is accepting that while something is likely to go wrong, you can't know exactly what it will be or when it will happen. Hence, a chronic unease reinforces the vigilance that is necessary in all safety-critical sports. Anticipation builds vigilance, and vigilance is the key to recognizing adverse events and error. Logically, recognition leads to recovery. In some cases, particularly when an error escalates to an undesired aircraft state, recovering adequate safety margins is the first line of action: Recover first, analyse the causes later. For example, a pilot incorrectly enters a waypoint into his GPS; the aircraft track will now pass through class A airspace. Once the pilot executes the incorrect entry and the GPS unit directs him towards controlled airspace, the flight is considered to be in an undesired aircraft state. When the error is spotted (hopefully not too late) the pilot can either analyze what's wrong with the GPS and fix the problem or save valuable time by simply switching off the GPS and navigate with map and compass. The latter option is more effective from the TEM perspective because it focuses effort on recovering from the undesired aircraft state rather than analyzing its causes.

Acknowledgements

This work is an adaptation of the summary of research work undertaken by the University of Texas with a grant from the FAA. Most sections are copied directly, with minor editing to make the content appropriate for Glider Pilots.

It is adapted with permission of the authors by Don Puttock MBA, an experienced professional gliding instructor based in the UK, as part of the glider pilot training programme.

EASA are introducing changes to the pilot training syllabus (planned 2012), this will make it essential instructors are familiar with these concepts and are required to include the ideas within European Glider Pilot training.

The original work "Defensive Flying for Pilots: An Introduction to Threat and Error Management written by Ashleigh Merritt, Ph.D. & James Klinect, Ph.D.
The University of Texas Human Factors Research Project1
The LOSA Collaborative, December 12, 2006

Further reading

1. "Defensive Flying for Pilots: An Introduction to Threat and Error Management written by Ashleigh Merritt, Ph.D. & James Klinect, Ph.D.

2. NPA17b, EASA flight crew licensing Gliding Instructor and glider pilot training syllabus.
3. On Error Management; lessons from Aviation Robert L Helmreich