Introduction to Threat and Error Management (TEM)

Adapted from FAA/Industry TEM/LOSA Training
Introduction

- CRM has evolved since the early 1980s
- CRM was originally developed to address crew errors
- Threat and Error Management (TEM) is the 6th Generation
- 5th and 6th generation CRM returned the focus to error management
- Additional focus on threats add concepts of risk management
A little bit about culture...  
...managing the “wetware.”
Balancing Priorities

Safety

Decision Making

Mission

Money
Safety Culture

- Is there really such a thing as a “safety culture?”
- If so, what does it look like?
- If I don’t have one, how do I get it?
- Why do we care about “culture” anyway?
Every Organization

Has

A Safety Culture
Traits of a Healthy Culture: High Reliability Organizations (HROs)

- Preoccupation with failure (track small failures)
- Reluctance to (over)simplify
- Sensitivity to operations
- Commitment to resilience (ability to recover)
- Deference to expertise

Weick & Sutcliffe
Applications

- TEM principles have also been incorporated into:
  - Maintenance Resource Management (MRM)
  - Line-Oriented Safety Audit (LOSA)
  - Maintenance and Ramp LOSA
- Brings a human performance focus to risk management
- Aligns with SMS and SAS
- International (ICAO) standard for all levels of pilot certification and operator training programs
- Possible starting point for part 135 S.P. CRM training
ICAO Requirements

Annex 1, Personnel Licensing:

• “The applicant shall have demonstrated a level of knowledge appropriate to the privileges granted to the holder of a…licence…”
  – “human performance including principles of threat and error management”

Annex 6 Part 1 Operation of Aircraft

• 9.3.1 An operator shall establish and maintain a ground and flight training programme…The training programme shall:
  – “include…human performance including threat and error management”
Threat and Error Management
Human Performance and Risk

System Description

Hazard Ident

Risk Analysis

Risk Assmt

Risk Control

Normal Operations

Condition (Threat)

Error

UAS/UOS

PREVENTION (Resist)

RECOVERY (Resolve)

Consequence

Threat and Error Management
Levels of Risk Management

Time Available for Planning

In-Depth
- Policy/Procedures
- Task Analysis
- Training Design
- Development of Personal Minimums

Deliberate
- Flight/Job Planning
- Dispatch/Operational Control
- Pre-flight/Pre-Task briefings

Real Time/Time Critical
- Builds on others levels
- Mission/Situation events in real time

Adapted from U.S. Navy OPNAVINST 3500.39C/U.S. Air Force AFI 90-802
Human Error

• “Human error is a symptom of trouble deeper in the system.”¹

• “Underneath every simple, obvious story is a deeper, more complex story.”¹

• “The key question in any organizational accident is not who blundered but how and why did the defenses fail?”²

¹ Prof. Sidney Dekker
² Prof. James Reason
Hazards (Threats)

“A hazard is condition…

…that can result in an aircraft accident”

Hazards don’t have part numbers…

…it’s their affect on human or system
What is a Threat?

• Any condition that increases the complexity of the operation.

• Threats, if not managed properly, can decrease safety margins and can lead to errors.

• “Threats should serve as a Red Flag.”
  – Watch out!
  – Something bad can happen!
• There are two types of threats
  – **External Threats** – Those outside of our direct control (e.g., weather, lack of equipment, hard to understand documentation, results of others’ errors, inadequate lighting)

  – **Internal Threats** – Those within our control (e.g., fatigue, proficiency/recency of experience, situation awareness, stress)
What is an Error?

• The mistake that is made when threats are mismanaged.

• There are 5 types of errors:

  1. Intentional non-compliance errors
  2. Procedural errors
  3. Communication errors
  4. Proficiency errors
  5. Operational decision errors
Threats That Can Lead to Cockpit Error

- Weather
- Maintenance
- Ground Crew
- Cabin Crew
- Passenger events
- ATC
- Terrain
- Similar call sign
- Time pressures
- Flight diversion
- System malfunction
- Distractions
- Heavy traffic
- Unfamiliar airport
- Automation event
- Missed approach
- Continental TEM Model
Threats That Can Lead to Mechanic Error

- Access equipment
- Lighting
- Temperature
- Lack of Skill
- Airplane/parts design
- Time pressure
- Communication
- Documentation
- Task distraction/interruption
- Hazardous materials
- Noise
- Tools
What is Threat Management?

- **Threat Management** – There are two aspects to Threat Management:

  1. Recognizing that a threat exists

  2. Coming up with a strategy to deal with the threat, so that it does not reduce safety margins or contribute to an error
Threat Management Strategies

- Situation Awareness
  - Monitor
  - Evaluate
  - Anticipate
- Coordinate
  - Verbalize
  - Verify
  - Monitor
- Debrief the Job/Flight
  - What threats did we recognize?
  - How well did we manage them?
What is Error Management?

• **Error Management** – The mitigation or reduction in seriousness of the outcome.

1. The **resist** and **resolve** defense mechanisms may be applied to an existing error before it becomes consequential to safety.

2. By analyzing the resist and resolve actions in reviewing an error, you may:
   - **Improve strategies or counter-measures** to identify and manage both internal and external threats, like fatigue, condition of ground equipment, etc.
Error Outcome

• There are three types of error outcomes:

1. **Inconsequential** – The error has no immediate effect on safety.

2. **Undesired State** – Risk or unsafe operational conditions are increased.

3. **Additional Error** – The error causes another error(s).
Threat & Error Management Model

**RESIST**
Things that already exist within the system to protect against errors.

**RESOLVE**
The human corrects the error before it leads to an unwanted consequence.

**THREATS**

**ERRORS**

**CONSEQUENCE**

**Strategies**

- RESIST
- RESOLVE
Threat and Error Management

**Safe Operations**

**Threats**

**Errors**

**UAS**

**Incident / Accident**

**CRM/TEM Skills**
- Planning and Decision Making
- Leadership Effectiveness
- Situation Awareness
- Communication
- Monitor/Cross-Check
- Workload Management
- Automation Management

**Threat**
- Occurs outside the influence of the crew
- Identify and Prepare

**Error**
- Crew action or inaction that reduce safety margins
- Identify and Repair

**UAS**
- Undesired Aircraft State results from mismanaging errors
- Identify and Recover
Analyze the Failures

Consequences

Resist

Resolve

Errors

Strategies

Threats
Sources of Learning

• National Transportation Safety Board (NTSB)
  – Requires accident # e.g. FTW97LA209

• Australian Transport Safety Bureau (ATSB)

• Aviation Safety Reporting System (ASRS)
  – http://asrs.arc.nasa.gov/
Understanding Risk: Human/System Performance

- Condition
- System
- Environment

Performance

- Outcome
- Success
- Failure

Operation/Situation

<table>
<thead>
<tr>
<th>Competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functions/Activities (i.e. Inspection, Checklist, Maintenance)</td>
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<tr>
<td>System/Equipment Design (i.e. Barriers, Guards, Fire Suppression)</td>
</tr>
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Understanding Risk: The Bow Tie Model

**Condition that can lead to harm**

- Threat (Hazard)
- Threat
- Threat

**Operation/Situation**

**Prevention (Resist)**

- Proactive Controls

**Recovery (Resolve)**

- Reactive Controls

**Potentail Causes**

- Control Failure
- Control Failure

**Potential Outcomes**

- Consequence
- Consequence
- Consequence

**Understanding Risk**

- System/Equipment Design (i.e. Barriers, Guards, Fire Suppression)
- Functions/Activities (i.e. Inspection, Checklist, Maintenance)
- Competence
The Bow Tie Model: Operations

Potential Causes

- Condition that can lead to harm
  - Threat
  - Threat
  - External Threats
    - Control Failure
    - Control Failure

Proactive Controls

Reactive Controls

Error/Failure

Operation/Situation

Potential Outcomes

- Harm to people & damage to assets or environment
  - Consequence
  - Consequence
  - Consequence

Competence

Functions/Activities (i.e. Inspection, Checklist, Maintenance)

System/Equipment Design (i.e. Barriers, Guards, Fire Suppression)
The Bow Tie Model: Support Services

Potential Causes

- Threat
- Threat
- External Threats
  - Control Failure
  - Control Failure

Proactive Controls

Reactive Controls

Operation/Situation

Error/Failure

Harm to people & damage to assets or environment

Threats to Operations

- Threat
- Threat
- Threat

Competence

- Functions/Activities (i.e. Inspection, Checklist, Maintenance)
- System/Equipment Design (i.e. Barriers, Guards, Fire Suppression)
Maintenance and Operations

Maintenance

Operations

Error/Failure

Threat

External Threats

Control Failure

Operation/Situation

Threat(s)

Consequence

Control Failure

System/Equipment Design (i.e. Barriers, Guards, Fire Suppression)

Functions/Activities (i.e. Inspection, Checklist, Maintenance)
The Bow Tie Model: HFACS

Condition that can lead to harm
- Organizational Influences
- Supervision
- Environmental Preconditions
- Outside Influence

Proactive Controls

Unsafe Acts

Operation/ Situation

Reactive Controls

Risk: Likelihood... 

...Severity

Harm to people & damage to assets or environment

Consequence

Consequence

Consequence

Competence
- Functions/Activities (i.e. Inspection, Checklist, Maintenance)
- System/Equipment Design (i.e. Barriers, Guards, Fire Suppression)
Example: Continental Express Flight 2574
Eagle Lake, TX, 1991

47 screws removed from the horizontal stabilizer during horizontal stab de-ice boot replacement the night before and, following a shift change, were not replaced.

• Maintenance error – Unairworthy airplane
• Threats
  – Time and schedule pressure
  – Supervisory structure
  – Shift Change procedures
• Consequence: Inflight LOC and breakup
Barriers/Controls: Flight 2574

• Missing barriers/controls: Maintenance
  – Proactive: Incomplete analysis of maintenance task
  – Reactive: Replacement not identified as RII
• Missing controls: Operator
  – Proactive: No way to detect at preflight
  – Reactive: No recovery possible from failure
• Maintenance Process must consider operational scenario: criticality of task and ability to detect
• Approval process needs to consider operator SRM (Order VS 8000.367A)
Addressing Threats and Errors

**Ops**

- **In-Depth**
  - Writing manuals/SOPs
  - Developing personal minimums
  - Developing currency/lesson plans

- **Deliberate**
  - Flight Planning
  - Crew/Student briefings

- **Real Time**
  - Situation Assessment/Awareness
  - Post-flight debrief

**MX**

- **In-Depth**
  - Writing manuals/SOPS
  - Developing checklists/job cards/processes
  - Scheduling
  - Training development

- **Deliberate**
  - Job task planning
  - Crew scheduling
  - Shift change briefs

- **Real Time**
  - RII (formal/informal)
06/01/1997 Vmax Probe N1200M – 1st Flight, Lake Jackson, TX

Pilot:
- Retired Engineer
- Private Pilot, 63 years old
- 261 hours TT/8 in 90-days
- Did not wear a helmet
- No high-speed tests

Airplane:
- Engine; 808cc, 2-stroke, liquid cooled
- Restraint system:
  - Originally conformed to industry standard
  - Replaced section of console to gain access to components
  - Reattached panel of lesser thickness and bonded into position
  - Right hand lap portion was reattached to this replacement panel
  - Restraint system failed
Vmax Probe: The Plane
Barriers/Controls: Vmax Probe

• Missing barriers/controls: Design
  – Proactive: Incomplete analysis handling
  – Reactive: Crashworthiness

• Missing controls: Operator
  – Proactive: Currency, test plan
  – Reactive: Protective equipment

• Design Process must consider operational scenario:
  – Performance objectives
  – Handling characteristics
  – Pilot capabilities
  – Crashworthiness
Addressing Threats and Errors

**Design**

- **In-Depth**
  - Analysis of handling and performance
  - Analysis of crashworthiness
- **Deliberate**
  - Reconsider balance between performance, handling, and crashworthiness
- **Real Time**
  - N/A

**Operation**

- **In-Depth**
  - Test Plan
  - Training/Currency
  - Consider experienced test pilot
  - Consult with experienced test pilot
- **Deliberate**
  - Disciplined testing
- **Real Time**
  - Flight Testing at altitude
  - Go around decision
Conclusions

• Become a better Threat Manager
  – Learn to actively identify threats in your operation
  – Learn strategies for managing threats

• Become a better Error Manager
  – Learn to look for errors that you have made and correct them before they lead to unwanted consequences
  – Understand why the Resist and Resolve aspects of Error Management did not work, and…
    ▪ Find better strategies to deal with the threats that lead to the error, or
    ▪ Fix threats (like broken equipment) that lead to the error

• Continue building a Safety Culture by encouraging open, honest communications
“Carelessness and overconfidence are more dangerous than deliberately accepted risk”
Wilbur Wright, 1901

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Wilbur Wright gliding, 1901
Photographs: Library of Congress