Conclusions from the analyses of six approach and landing incidents that might have resulted in controlled flight into terrain but for timely warnings by TAWS.

BY DAN GURNEY

LAST LINE OF DEFENSE

Learning From Experience

Most flight crews on most days manage the threats and avoid error-prone behavior that can occur in flight operations, as presented in this series of "TAWS saves" analyses. However, in some situations, threats and opportunities for error can overcome human defenses, and a technological solution is required. If the threats involve terrain or obstacles, then terrain awareness and warning system (TAWS) warnings and prompt, correct action by the flight crew serve as the last line of defense against controlled flight into terrain.[1]

Threats

The threats that were identified in the incident analyses can be placed in two groups:

- Threats arising from pre-existing conditions that can be encountered in most operations, including: false visual cues during a "black hole approach"; instrument approach charts that lack altitude/range tables, are cluttered and difficult to decipher, or depict ambiguous procedures; nonprecision approach procedures; and approach procedures incorporating distance measuring equipment (DME) offset from the runway threshold or primary navaid.[2]

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- Situational threats arising from particular flight conditions and situations, including: nighttime and/or instrument meteorological conditions; a late change of plan; and failure to react, or react correctly, to alerts and warnings.

In isolation, these threats may pose no undue risk; but when they combine, the risk of catastrophic error increases significantly.

All the pre-existing conditions can be identified by management audit and crew vigilance. The risk-assessment process should identify conditions that might act as risk multipliers.[3] For example, runways that are prone to black hole conditions should be considered as significant risks at night. Similarly, nonprecision approaches and instrument approach procedures depicted on cluttered or ambiguous charts should be considered as particularly high risks.

Whenever threat conditions are identified, they should be reported and either eliminated, mitigated or avoided. Flight crews must recognize situational threats. This requires focused attention, instrument-scan patterns that help maintain good flight path awareness and sound decision making to avoid or mitigate the risks presented by the threats.

Photo: BAE Systems

This altimeter was in a BAe 146 that struck a mountain 120 ft below the summit on approach to Melilla, Spanish Morocco, on Sept. 25, 1998. The flight crew did not respond immediately to a GPWS warning, and all 38 people aboard were killed.

Errors

The errors identified in the incident analyses appear to have originated from circumstantial conditions or from unidentified or mismanaged threats, with the following results:

- Inadequate situational awareness when the flight crew believed that they understood the situation but did not. This led to errors that included: succumbing to visual illusions or misidentifying visual cues; misinterpreting procedures depicted by instrument approach charts or incorporated in standard operating procedures (SOPs); and failing to understand a procedure or to have a shared mental model of the procedure. These are errors that originate in the cognitive process — that is, what we think about, how and on what we focus our attention, and why we believe that something is important.
- Selection of a wrong course of action, an error that often involved simple slips, mistakes or memory lapses. Typically the result of inadequate training or poor discipline, this type of error originates from weaknesses in cognitive control — that is, the way we control our thinking through self-discipline, double-checking, managing time, avoiding preconceptions and not rushing to conclusions.

All the errors could have been — and should have been — detected before the TAWS warnings occurred through self-monitoring and cross-crew monitoring not only the aircraft's flight path but also individual and crew behavior. Such monitoring requires application of crew resource management (CRM) skills involving communication for developing a shared mental model and cross-checking facts and common understandings.

An error is a source for learning and an opportunity to gain experience. When errors are detected in normal operations, they should be reported so that the circumstances can be identified and assessed, and safety actions taken if warranted. Confidential reporting systems increasingly are being used to bring errors to light. However, crews also should openly debrief errors to identify the contributors and the mechanisms of detection and recovery. The crew should pay attention to the good points as well as the not-so-good, what was interesting and previously not known, and why.

Moreover, it is essential for each pilot to conduct a self-debriefing to clarify his or her understanding of any error, the situational threats under the circumstances and/or the beliefs and behavior that may have led to the error.

Threat and Error Management

Monitoring is an essential element in threat and error management. Yet, in each of the incidents, monitoring failed for one reason or another. In some incidents, the crews either lacked information, such as altitude/range tables, or failed to use information that was available, such as electronic flight information system (EFIS) maps. The solution to these problems requires organizational action to provide vital information and procedures, and personal commitment to use them.

The monitoring process must be accurately defined in SOPs, trained and practiced to enable skillful application. To be effective, monitoring must be truly independent; there is little value in both pilots using the same source as a cross-check. Independent cross-checking also is important for flight path control; there is no point in the pilot monitoring calling out altitudes and ranges for the pilot flying to follow during the approach if the pilot monitoring has misidentified the information or the information is incorrect.

"Monitoring independence" starts with the approach briefing. Each pilot should monitor the briefing by cross-checking the details on his chart and ensuring that he understands the plan for the approach. An approach briefing is a "flight plan for the mind" and provides a master pattern for subsequent comparisons. The crew must have a common understanding, a shared mental model that is correct for the situation. Most pilots think in pictures but communicate with words; both processes can be taught and improved.

Situational Awareness

In each incident, the flight crew lost awareness of the aircraft's position relative to the runway in terms of altitude, distance and time.

Humans tend to build internal models, or patterns, of the way things should be, both in the sense of an "ideal" current situation and for future events. Crews need to guard against short-term tactical thinking in which response to what is expected often dominates the sound assessment and judgment of strategic thought. Pilots must control their thinking, consider early what a situation could become, consider options and alternatives, and, if in doubt, ask questions.

The most important element in decision making is the objective. When the objective is a safe landing on the runway, the situation-assessment process must include attention to the location of the runway and a continual updating of the shared mental model of the aircraft's position relative to the runway. Crews should use all their tools: display the runway position on the EFIS; pay attention to vertical displays; and select the terrain map for all approaches, as well as for departures.

Taking Action

A TAWS warning can create surprise and stress due to the unexpected nature of the event. Generally, pilots experience the need to understand the situation before taking action and, thus, begin a new assessment process. This delays action. Stress also increases difficulties in perceiving information and thinking, which also delays action.

A TAWS warning requires immediate action without thought, an automatic behavior. To gain this skill, crews need to practice their pull-up technique in response to a TAWS warning in surprising, stressful training situations. For example, simulator instructors can place a "glass mountain" in the aircraft's flight path to surprise the pilots and enable them to hone their pull-up reaction. During the debriefing, the crew might argue that the warning was out of context, they "knew where they were" and there was no real terrain threat. The counter argument is that this is precisely the mindset that the incident crews might have had. They likely were convinced that they knew where they were and that the TAWS warning was wrong, not them. Fortunately, except for hesitation by one crew, the incident crews reacted correctly, pulled up and avoided impending collisions with terrain or obstructions.

Training must overcome the doubting mindset and the compulsion to understand the situation before responding to a TAWS warning. A pull-up must be conducted without hesitation.

Moreover, the use of conditional phrases in TAWS procedures should be avoided. There is no need for the "if visual" and "if certain of position" phrasing that often was included in previous ground-proximity warning system (GPWS) procedures to prevent reaction to inappropriate warnings. TAWS is significantly more reliable than GPWS and is not prone to generating inappropriate warnings (Figure 1). When a TAWS warning is generated, there is no time for thinking and assessment; the crew must react immediately. After climbing to the minimum safe altitude, the crew must determine the reason for the warning before descending again. Remember that most TAWS warnings are the result of human error.

Building Defenses

All six incidents involved aircraft with modern technology, "glass" flight decks and equipment that should have enhanced situational awareness. Yet, all the incidents involved close encounters with terrain or obstacles. The aviation industry was "lucky" that accidents were avoided and a good safety record was maintained — but just how lucky?

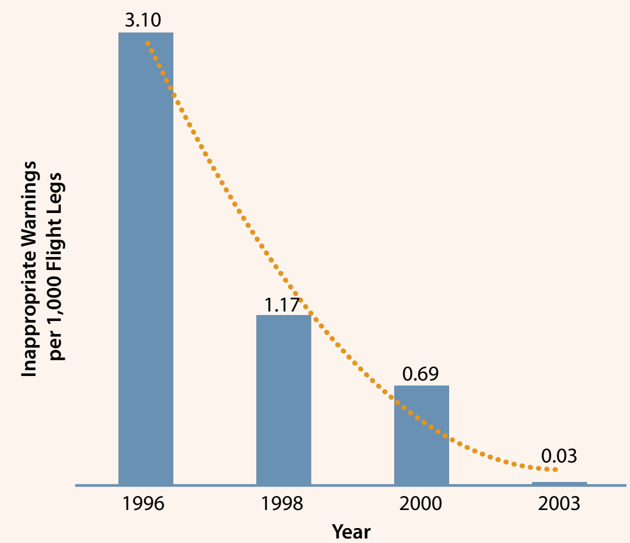
In the majority of the incidents, the flight crews apparently were unaware of the aircraft's position relative to the runway, either in space or time, or both. In two incidents, the aircraft were at very low altitudes, with crews preparing to land, yet were still 1.5 nm (2.8 km) from the runways. The single incident in which an obstacle warning was generated involved the only aircraft in the operator's fleet that had the TAWS obstacle mode activated.

Luck in these incidents could be defined as having defenses that just matched the hazard or risk. However, in an industry that seeks defense in depth and considering that all of the incidents involved the last defense — the crew pulling up following a TAWS warning —"luck" is unacceptable. We cannot expect that the last line of defense will always hold; in one incident, the crew failed to react immediately and correctly to a warning.

In-depth defenses should be based on active threat and error management at all managerial and operational levels. This requires constant vigilance to identify threats and errors, risk assessment and timely decisions to select corrective courses of action. These processes depend on thinking skills, which are the foundations of airmanship, leadership and professional management.

As of Nov. 1, 2006, more than 35,000 aircraft had been fitted with TAWS. Aircraft equipped with the system had flown 300 million flight sectors without a controlled-flight-into-terrain accident. This is a major success for the industry, and every effort must be made to continue and protect this achievement. ●

Frequency of Inappropriate TAWS Warnings



TAWS = Terrain awareness and warning system

Source: Dan Gurney, from Honeywell

Figure 1

[This series, which ran in *Aviation Safety World* from July through December 2006, is adapted from the author's presentation, "Celebrating TAWS Saves, But Lessons Still to Be Learned," at the 2006 European Aviation Safety Seminar, the 2006 Corporate Aviation Safety Seminar and the 2006 International Air Safety Seminar. Don Bateman, Yasua Ishihara and the Honeywell EGPWS safety team contributed to the research and preparation of the paper.]

Dan Gurney served in the British Royal Air Force as a fighter pilot, instructor and experimental test pilot. He is a co-author of several research papers on all-weather landings. Gurney joined BAE Systems in 1980 and was involved in the development and production of the HS125 and BAe 146, and was the project test pilot for the Avro RJ. In 1998, he was appointed head of flight safety for BAE Systems. Gurney is a member of the FSF CFIT/ALAR Action Group, the FSF European Advisory Committee and the FSF steering team developing the "Operators Guide to Human Factors in Aviation."

Notes

1. *Terrain awareness and warning system* (*TAWS*) is the term used by the International Civil Aviation Organization to describe ground-proximity warning system (GPWS) equipment that provides predictive terrain-hazard warnings; *enhanced GPWS* (*EGPWS*) and *ground collision avoidance system* (*GCAS*) are other terms used to describe TAWS equipment.
2. A *black hole approach* typically occurs during a visual approach conducted on a moonless or overcast night, over water or over dark, featureless terrain where the only visual stimuli are lights on and/or near the airport. The absence of visual references in the pilot's near vision affects depth perception and causes the illusion that the airport is closer than it actually is and, thus, that the aircraft is too high. The pilot may respond to this illusion by conducting an approach below the correct flight path — that is, a low approach. In the extreme, a black hole approach can result in ground contact short of the runway.
3. A checklist designed for assessing such risks, the *Approach-and-landing Risk Awareness Tool*, is part of the FSF *Approach-and-landing Accident Reduction (ALAR) Tool Kit*. Information about this and other resources for preventing ALAR and controlled flight into terrain is available at <www.flightsafety.org>.