While CFIT record has improved markedly, certain issues have also come to light

Several low-cost but crucial measures can be taken by stakeholders to reduce the likelihood of false EGPWS warnings or, more seriously still, the system's failure to provide a valid warning

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A controlled flight into terrain (CFIT) accident occurs when an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no awareness of the impending collision on the part of the crew. ICAO has been involved for many years in a worldwide effort to prevent this type of accident, which usually involves heavy loss of life.

ICAO's first action in this regard can be traced to 1978, when requirements for equipping commercial air transport aircraft with the ground proximity warning system (GPWS) were introduced in Part I of Annex 6 to the Chicago Convention. This led to a significant decrease in the number of CFIT occurrences, but not to their complete elimination. A further step was taken with the development of GPWS with a forward-looking function, generally referred to as the enhanced ground proximity warning system (EGPWS), and known in the United States as the terrain awareness and warning system (TAWS). With the advent of EGPWS/TAWS in 1996, there have been no CFIT accidents involving aircraft equipped with this technology (see adjacent figure).*

While the aviation community can be justifiably proud of its achievement in reducing CFIT accidents, there is no place for complacency. Operational experience has identified concerns about the use of EGPWS that must be addressed to ensure that the timely warning that has proven so valuable to accident avoidance is available all of the time.

The EGPWS safety issues that have been identified concern the upkeep of software on which EGPWS/TAWS depends, as well as the obstacle, runway and terrain database, the provision of global navigation satellite system (GNSS) positioning, the operation of the system's "peaks and obstacles" function, and the geometric altitude function of the equipment.

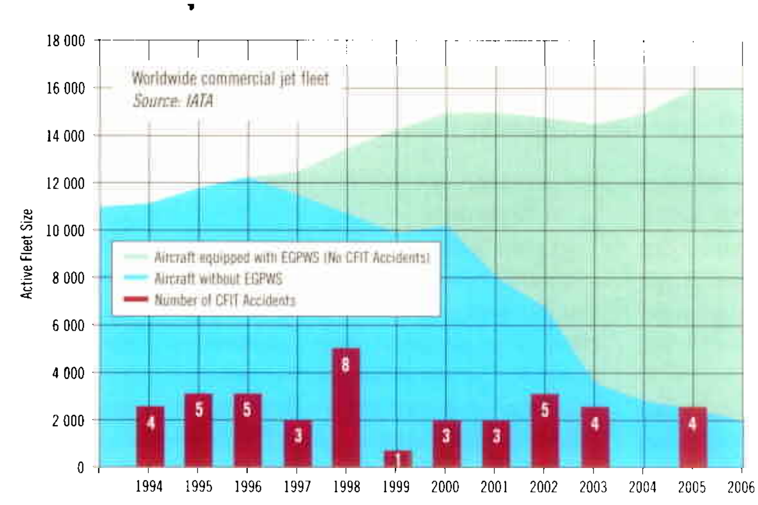
Perhaps the most easily rectified shortcoming involves the software utilized by EGPWS/TAWS. Software updates are issued regularly, yet industry sources reveal these are not being implemented by all operators, or are not installed in a timely manner. Aside from the fact updates are often available free of charge from equipment manufacturers, there is ample reason to perform this task since the use of current information is clearly critical to safety.

Application of software updates improves the characteristics of the equipment. Such improvements are possible on the basis of operational experience, and enable warnings in situations effectively closer to the runway threshold where previously it was not possible to provide such warnings.

Without information provided by the latest version of software, operation of EGPWS/TAWS may be compromised in specific situations. The flight crew, who has no convenient means of knowing the software status of the equipment on which they ultimately rely, may have a false sense of confidence in its capability.

An example of the effect of outdated EGPWS software arose recently at Zacatecas, Mexico, where a CFIT accident was narrowly averted, not by a timely EGPWS warning but by the aircraft striking power lines on its final approach, prompting the crew to initiate a go-around in time. The Airbus A319 was on a very high frequency omnidirectional radio range/distance measuring equipment (VOR/DME) approach using a stabilized, continuous descent technique in conditions where fog was reported. The descent commenced some 2.5 kilometres early and continued below the minimum descent height (MDH 459 ft) until about 100 feet below threshold level, at which point the aircraft hit the power lines some 2,200 metres (7,220 ft) short of the threshold.

Although the A319 was equipped with EGPWS/TAWS, no warning was provided in this instance. It was reported that, apart from operational deficiencies, the aircraft's EGPWS software was out of date. A software update that would have provided 30 seconds' warning in the circumstances of the incident had been issued by



Mandated operation of EGPWS/TAWS has brought impressive results: to date, no aircraft equipped with this technology has suffered a CFIT accident

the equipment manufacturer four years earlier, and by the airframe manufacturer one year prior to the incident, but it appears this had not been applied.

Similarly, it is crucial to regularly update the obstacle, runway and terrain database provided by manufacturers for use with their equipment, since the proper functioning of the EGPWS/TAWS may otherwise be jeopardized. Again, updates are issued for these databases on a regular basis, free of charge by equipment manufacturers. EGPWS/TAWS operation can also be undermined by the lack of suitable navigational input. The equipment was designed to function with a position update system, but not all installations are linked to GNSS receivers. While the required position data can be acquired by using an effective ground-based navaid network, the most reliable of which is provided by DME/DME, such support for area navigation systems is not available everywhere. Use of GNSS, accessible worldwide, eliminates the possibility of position shift, which is another source of false warnings (or worse, the failure to provide a genuine warning).

There is also concern that the potential advantage of the obstacle and terrain database information may be reduced or even negated by the failure of the operator to enable the peaks and altitude function provided with some EGPWS/TAWS equipment.

Operation of EGPWS/TAWS is subject to altimetry-based errors. This problem can be avoided when the equipment, originally designed to work with the QNH altimeter setting, is operated together with GNSS-provided geometric altitude. Additionally, use of the geometric altitude function prevents errors that arise from the use of the QFE altimeter setting for approach and landing.

The limited coverage of obstacle data for the database has also raised concerns. While this information is needed for operations worldwide, in practice data for obstacles higher than 30 metres (98 ft) are available only in certain regions and countries, specifically Australia, the Caribbean, Central America, New Zealand, North America and Western Europe. Wherever data for obstacles are not available, or whenever the peaks and obstacles function of the EGPWS/TAWS is not enabled, the equipment's basic GPWS function cannot alert the crew to the presence of obstacles close to the flight path.

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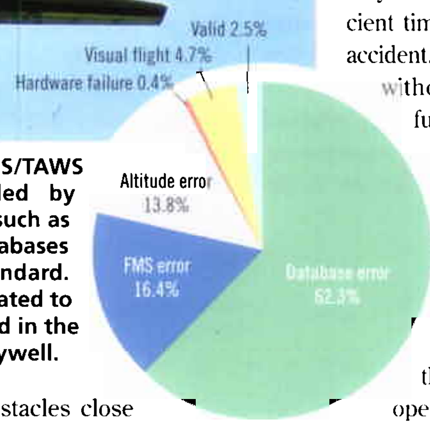

The problem of false EGPWS/TAWS warnings can be curtailed by adopting certain practices such as updating software and databases to the latest available standard. Most false warnings are related to database errors, as reflected in the pie chart supplied by Honeywell.

In some instances, lack of timely information on runway thresholds prior to the commissioning of a new runway has been cited as a problem. Such information, moreover, is not always to the required accuracy, or is not always provided as World Geodetic System – 1984 (WGS-84) coordinates, although WGS-84 is the common horizontal reference system.

Data for new runways must be distributed well in advance of the service entry date if this information is to be incorporated in the applicable databases and subsequently implemented by operators prior to commencement of the runway's operation. Aside from timeliness, it is imperative that such data meet ICAO's quality requirements, as specified in ICAO Annex 14, Volume I, Appendix 5.

In some cases, it has been found that terrain data meeting the WGS-84 standard is not available, or that conversions of data to the WGS-84 standard are not correct.

The type of deficiencies cited above can only heighten the probability of false warnings or, more seriously, the risk that a genuine warning will not be forthcoming. The problem with false warnings is their potential negative conditioning: if they occur too often, a flight crew may not react promptly and aggressively when there is a valid alert. The frequent occurrence of false warnings is also known to encourage crews to operate with the EGPWS/TAWS function selected off. In this case the basic GPWS will still provide a warning, but as shown in the past, the basic GPWS may not provide a warning in sufficient time for the avoidance of an accident. In any event, operating without the EGPWS/TAWS function engaged simply defeats the purpose behind installing the forward-looking element.

Collectively, these various shortcomings in the software, databases and procedures that support EGPWS/TAWS operation can degrade the value of the warning system, and clearly call for attention by national regulatory authorities, aircraft operators and airframe manufacturers. To reduce the risk of CFIT as much as possible, countries around the world need to ensure that timely information of required quality on runway thresholds, as well as terrain and obstacle data, are provided for databases in accordance with the common reference systems (ICAO Annex 15, Chapter 3). ICAO requirements for runway, terrain and obstacle data are established in relevant annexes to the Chicago Convention, specifically Annex 11, *Air Traffic Services*; Annex 14, *Aerodromes*, Volume I — *Aerodrome Design and Operations*, and Volume II — *Heliports*; and Annex 15, *Aeronautical Information Services*.

States are required to ensure that electronic terrain and obstacle data related to their entire territory are made available for international civil aviation in the manner specified in ICAO Annex 15 (paragraphs 10.2, 10.3 and 10.4). Notably, current requirements for the provision of such data are addressed by a recommended practice contained in Annex 15 (10.6.1.3), which applies to specifications for terrain and obstacle data for defined areas (i.e. the territory of the State, terminal control areas, and so forth).

Annex 15 also requires that States — as of November 2008 — ensure electronic terrain data and obstacle data are made available in accordance with the specifications for Area 1 (i.e. the entire territory of the State, including aerodromes and heliports), as well as terrain data in accordance with Area 4 specifications (Area 4 pertains to runways where precision approach Category II or III operations have been established). As of November 2010, States are also required to make sure that electronic terrain and obstacle data are made available in accordance with the Annex 15 specifications for Areas 2 and 3. (Area 2 refers to the terminal control area as published in a State's aeronautical information publication, or a 45-kilometre radius from the aerodrome or heliport reference point, whichever area is the smaller; at IFR aerodromes and heliports where a terminal control area has not been established, it covers the zone within a 45-kilometre radius of the aerodrome or heliport reference point. Area 3 pertains only to IFR aerodromes/heliports, and concerns a defined space extending from the edge of the runway and the aerodrome/heliport movement area.)

ICAO has developed guidance material in the form of Document 9881, *Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information*, to assist States in the provision of terrain and obstacle data.

Aircraft operators can obtain the greatest benefit from EGPWS/TAWS by following certain practices. They should:

- update software to the latest available standard;
- update databases to the latest available standard;
- ensure that the GNSS position is provided to EGPWS/TAWS;
- enable the EGPWS/TAWS geometric altitude function (if available);
- enable the EGPWS/TAWS peaks and obstacles function (if available); and
- implement any applicable service bulletins offered by airframe manufacturers.

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Information on the location of runway thresholds is needed for database entry well in advance of the commissioning date of a new runway

Irrespective of these recommended practices, it is essential that other necessary efforts aimed at CFIT prevention, such as crew training, use of standard operating procedures and implementation of a safety management system by the operator, are also undertaken.

Aircraft manufacturers also have a role to play in efforts to reduce the risk of CFIT. Aside from offering EGPWS/TAWS in new aircraft and supporting retrofit of older aircraft through issuance of appropriate service bulletins, they could facilitate utilization of GNSS positioning by accommodating the preference of many operators for less costly receivers. At present, only multi-mode receivers are recognized by airframe manufacturers as a GNSS source, but these units typically cost in excess of U.S. $40,000 each. Other types of receivers now available can provide EGPWS/TAWS with GNSS position at an installation cost of less than $10,000.

With respect to false warnings, industry sources indicate that over 62 percent of unjustified warnings arise from database errors, while more than 16 percent arise from flight management system (FMS) errors and over 13 percent stem from altitude errors (see pie chart, page 14). The practices and actions suggested above are important because they have the potential to significantly reduce the 92.5 percent of false warnings resulting from database, FMS and altitude errors.

In summary, while without doubt the reduction of CFIT accidents is a major achievement, the risk of a CFIT accident remains higher than it should be. The shortcomings or deficiencies in equipment and procedures necessary for the prevention

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* Recent presentations and articles have highlighted the importance of EGPWS/TAWS in avoiding accidents. These include presentations on TAWS by Capt. Dan Gurney at the Flight Safety Foundation (FSF) European Aviation Safety Seminar in Athens in March 2006, the FSF Corporate Aviation Safety Seminar in Phoenix in May 2006, and the FSF International Air Safety Seminar in Paris in October 2006 ("Celebrating TAWS Saves, But Lessons Still to be Learned"). Capt. Gurney also recently wrote on this subject in the FSF magazine, AeroSafety World ("Last Line of Defence: Learning from Experience," January 2007).

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The overall model provides for linked estimates. Multiplying the threat rates by the transition-to-errors matrix provides an estimate of error rates and so on, through to undesired aircraft states. Extension to outcomes would not add value as users would be forced to compare undesired aircraft states and outcome rates to estimate the undesired states that do not result in accidents or serious incidents. As such, the calculation can be improved by iteratively applying this process until a consistent set of estimates is established.

The approach outlined above offers a structured method of combining all the safety data available to an airline or other organization with an interest in aviation safety. The risk model that results can be used to determine, for example, which types of adverse outcomes pose the greatest risk, and can indicate which improvements in upstream safety performance would materially reduce that risk. This approach can show, for instance, which undesired aircraft states contribute most significantly to risk. If these undesired aircraft states relate to specific FOQA parameters, clear improvement targets can then be set.

The model also provides a basis for incorporating lessons learned from investigations of adverse events. For example, if we are looking at the transition from unstable approach to outcomes in the categories of CFIT, landing short, hard landing and runway excursion, it would be useful to look at what could or did affect the outcome from the point that the crew decided to continue with the landing. Such a review could focus on flight crew training, technical and human factors, procedures, ground proximity warning system (GPWS) operation, airport and runway design (e.g. runway centreline lighting).

Finally, the model offers a breakthrough by promising to address the risk precursors to adverse outcomes in a quantitative fashion. This in turn offers the ability to better assess the benefits from safety improvement — the type of assessment that is increasingly relevant in today's economic conditions. While at this stage the promise should not be oversold, it is surely worth pursuing.

CFIT prevention

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of CFIT, as described above, call for action by States, operators and airframe manufacturers. States need to improve the provision of crucial terrain and aeronautical information, as required by ICAO standards; operators must update their systems, a task that can be achieved at very little cost; and airframe manufacturers should provide operators with the necessary service bulletins that affect EGPWS/TAWS operation.

The measures cited above would considerably reduce the risk of CFIT accidents by eliminating the possibility of there being no warning when a prompt warning should be forthcoming. Equally important, they would lower the risk of CFIT by reducing the possibility of navigation and position shift errors and the occurrence of false warnings.

It is also necessary, in the pursuit of safety, to make available to everyone the information and lessons learned from the investigation of incidents and accidents. To this end, it is essential that all near-CFIT incidents and CFIT accidents are reported and investigated.