Journal of Aviation/Aerospace Education & Research

Volume 10
Number 3 *JAAER Spring 2001*

Article 4

Spring 2001

Controlled Flight into Terrain: How the Airlines and the Federal Aviation Administration are Addressing the Problem

Roger C. Matteson

CONTROLLED FLIGHT INTO TERRAIN: HOW THE AIRLINES AND THE FEDERAL AVIATION ADMINISTRATION ARE ADDRESSING THE PROBLEM

Roger C. Matteson

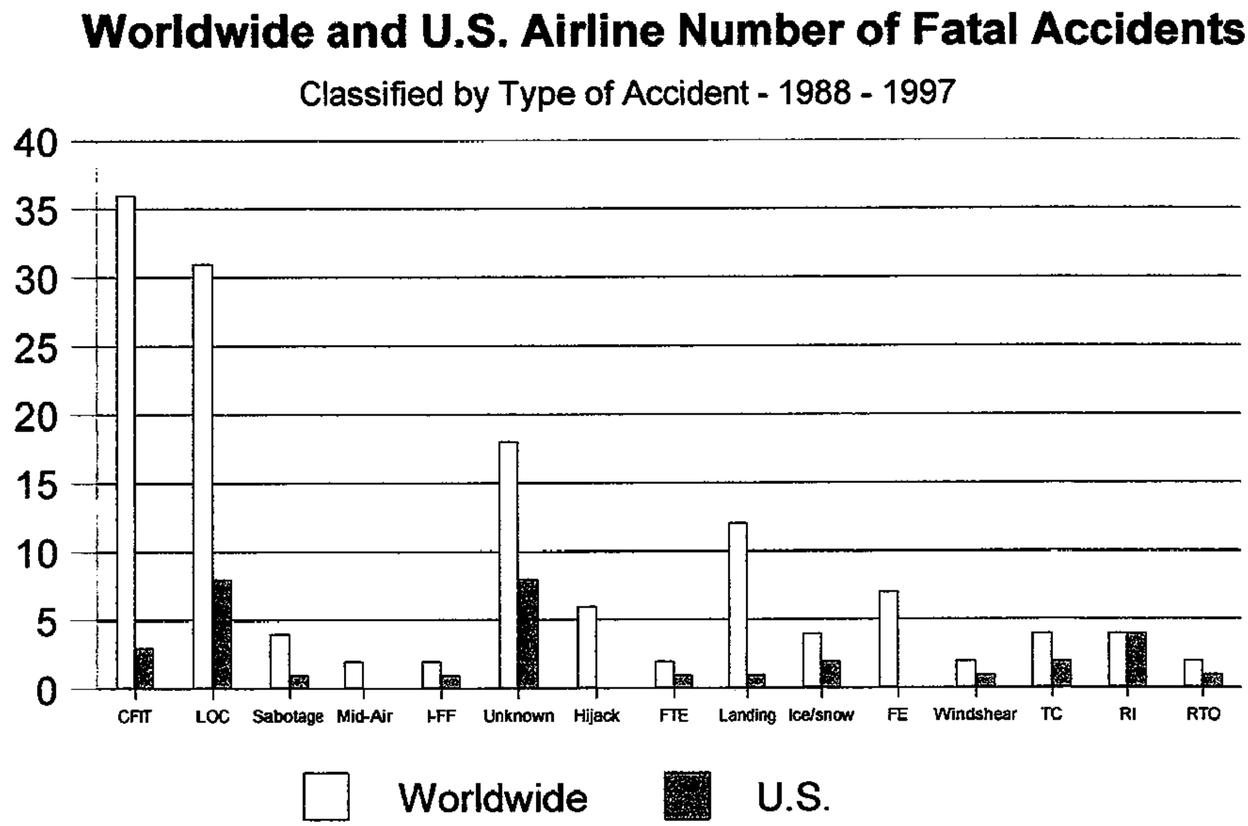
ABSTRACT

Controlled Flight into Terrain (CFIT) is not a new problem. It has been around since the beginning of manned flight. A CFIT accident occurs when an airworthy aircraft, under the control of a pilot, is flown (unintentionally) into terrain, water, or obstacles with inadequate awareness on the part of the pilot (crew) of the impending collision (Wiener, 1977). It would seem that CFIT would be an easy problem to solve or reduce but unfortunately, that has not been the case. CFIT is still the leading cause of all fatal aircraft accidents in the world. Figure 1 illustrates the CFIT accident rate compared to other types of fatal airline accidents. It can be noted that CFIT is not the leading cause of the U.S. fatal accident rate however, the world wide CFIT rate is still a major concern. This paper will address the issues as they pertain to CFIT, to include the causes, prevention and the future aspects in dealing with CFIT.

Although the reduction of the CFIT accident rate has been reduced over the years, there still is more that can be done. The "Swiss Cheese" model of accident causation illustrates that for an accident to occur, failures have to occur at several levels of responsibility (Reason, 1990). The model illustrates the following:

1. Organizational Factors
   - excessive cost cutting
   - reduction in flight hours
2. Unsafe Supervision
   - deficient training program
   - improper crew pairing
3. Preconditions for Unsafe Acts
   - loss of situational awareness
   - poor CRM
4. Unsafe Acts
   - failed to scan instruments
   - penetrated IMC when VMC only
5. Accident and Injury
   - crashed into side of mountain (Reason, 1990)

The aircraft that pilot's fly today are the safest and most complex in history. So why are we still having problems with CFIT? The answer is as complex as the aircraft. As pilots, we do not like to admit that pilot error could be a contributing factor. If we cannot identify or refuse to recognize the source of the problem, then we cannot begin to find a solution. Pilots must be willing to admit that they are the weak link in the chain and approach this problem in an aggressive manner. With the introduction of advanced avionics, the aviation industry has seen the CFIT accident rate go down. Initial and recurrent training will also be a key factor when approaching the problem.



LOC = Loss Of Control
I-FF = In-Flight Fire
FTE = Fuel Tank Explosion
FE = Fuel Exhaustion
TC = Takeoff Configuration
RI = Runway Incursion
RTO = Refused Takeoff

Figure 1 (NTSB, 1999)

Probable Causes of CFIT Accidents

To be able to find a solution, we have to look at some specific accidents that the primary cause was CFIT. By reviewing these accidents, we can compile information that was derived from the accident investigation and begin to recognize some common causal factors. One of the more recent accidents involved an American Airlines B-757 near Cali, Columbia on December 20, 1995. Although several factors led to the accident, situational awareness of the cockpit crew seemed to very low, which led to the impact with a mountain peak. According to Dr. Mica Endsley from the University of Southern California, situational awareness can be defined as "The perception of elements in the environment, the comprehension of their meaning and their projection into the near future" (Mancuso, 1995). In other words, the crew did not know their location at a critical time of flight.

It should be noted that the Cali accident was not investigated by the National Traffic Safety Board (NTSB) but by Columbia's Aeronautica Civil which is the Columbian equivalent of our Federal Aviation Administration (FAA) (Garrison, 1997). In the accident, the crew reportedly entered the wrong data into the flight management computer (FMC) and commanded the aircraft to go the Romeo Non Directional Beacon (NDB) versus the Rozo NDB (Dornhein, 1996). Rozo was the correct NDB to

https://commons.erau.edu/jaaer/vol10/iss3/4
DOI: https://doi.org/10.15394/jaaer.2001.1282

use for the approach into Cali. The flight crew failed to recognize that the new data entered into the FMC would take them off course. American Airlines proposed that the flight crew's failure to perceive the FMC-initiated turn away from the intended routing, was one probable cause for the accident (Dornhein, 1996). From that moment on, they were not fully aware of their location.

Other probable causes that were brought out in the investigation are:

1. Design of the FMS to include displays, database, and lack of terrain displayed.
2. The psychological relationship of pilots to onboard automation.
3. System warnings with full power when speedbrakes are deployed.
4. Lack of angle of attack information in the cockpit for pilots to be able to achieve maximum-performance climbs.
5. Ambiguous naming (Columbia government) of navigation aids.
6. Linguistic barriers between pilots and controllers (Garrison, 1997).

On January 13, 1998, a Learjet 25B crashed approximately two miles short of the George Bush Intercontinental Airport in Houston, Texas. In this case, the aircrew was conducting an approach into the airport using an Instrument Landing System (ILS). The captain started the approach but transferred control to the first officer shortly after passing the final approach fix (FAF). Although the ILS indicator in the cockpit showed that the aircraft was on the localizer, the glideslope showed that the aircraft was well above glidepath. The captain elected to continue the approach by telling the first officer to increase rate of descent to "catch" the glideslope (Katz, 1999). The crew continued below the decision height and impacted the ground. All data retrieved from the accident indicated that the aircraft was actually below glidepath. An error was detected in the glidepath indicator during the accident investigation.

The NTSB determined that several incidents occurred that led up to the Learjet going below the glidepath and colliding with the ground:

1. The crew did not perform an approach briefing that was required by the flight crew's company.
2. The captain's decision to continue the approach by transferring control to the first officer after passing the FAF.
3. The captain's decision to continue the approach while the glideslope indicator was showing well above glidepath.
4. The airplane's corporate operator to properly fix the glideslope indicator, that had been reported not properly indicating correct glidepath information on a previous flight (Katz, 1999).

It was also noted that if a Ground Proximity Warning System (GPWS) was installed, it may have given the pilots adequate warning before impact with the terrain. Although this may have helped to prevent this accident, a GPWS was not required for this type of aircraft or operation.

An accident involving a Korean Air B-747 happened on August 6, 1997 in Guam. The aircrew was flying a localizer-only approach, when the aircraft impacted the ground about three miles short of the Guam International Airport (McKenna, 1997). The aircraft was flying at night in heavy rain and clouds. The NTSB determined the probable cause of the accident was the captain's failure to adequately brief and execute the nonprecision approach (NTSB, 2000). Other possible contributing factors that may have led to the accident are:

1. The first officer and flight engineer failed to effectively monitor and cross check the captain's execution of the approach.
2. The captain's fatigue due to a recent trip returning from Hong Kong on August 4th.
3. Koreans Air's inadequate flight crew training.
4. The FAA's intentional inhibition of the minimum safe altitude warning (MSAW) system at Guam.

An interesting side note about the Korean Air accident is apparently the low altitude alarms aboard the plane were operating properly, but the pilots largely ignored them (Jackson, 1998).

An accident involving a Express II Jetstream BA3100, occurred while on a localizer back course in Hibbing, Minnesota on December 1, 1993. According to the NTSB, a breakdown in crew coordination was the probable cause of the accident (Air Safety Center„ 1999). This led to loss of altitude awareness by the flight crew during an unstabilized approach at night and impacting the ground short of the runway. According to the accident report, contributing to the accident was:

1. Failure of the company management to adequately address the previous identified deficiencies in airmanship and crew resource management (CRM).
2. The failure of the company to identify and

correct a widespread, unapproved practice during instrument approach procedures.

3. The FAA inadequate surveillance and oversight of the air carrier (Air Safety Center $_a$, 1999).

Although the above examples are not the only factors that contribute to CFIT type accidents, they can help to formulate some common causes. All four involved some type of degradation of crew communication which resulted from a low situational awareness in the cockpit. In the American Airlines accident, wrong data was entered in the FMS and neither aircrew backed up the data. The Learjet aircrew failed to conduct an approach briefing prior to executing the approach. The Korean Air crew failed to monitor the captain's execution of the approach and the action's of the Express II captain led to the breakdown in crew coordination.

The next common factor in these accidents is lack of advanced avionics or the proper use of the systems that are on board the aircraft. The Cali accident involved systems that failed to warn the pilots of rapidly increasing terrain, speedbrakes deployed or maximum performance climb information. Also, the accident prompted the FAA to recommend a new system to be installed called the Enhanced GPWS (EGPWS). Information about this system will be addressed later in this paper. The Learjet 25B crash involved using an inoperative glideslope indicator. In the Korean Air disaster, the Air Traffic Control (ATC) system, MSAW, was not working. If the MSAW system was operating, the air traffic controller could have advised the aircrew of possible ground impact. Also, this case brings out the fact that the low altitude warning alarms were working in the cockpit, but the aircrew failed to take any actions. Finally, in the Express II incident, the loss of altitude awareness was due to possible actions of the captain to limit time in severe icing conditions (Air Safety Center $_b$, 1999). The findings by the NTSB also found that if a GPWS system was installed, it may have given the pilots enough warning to avoid collision with the ground.

Training Aircrew in CFIT Prevention

According to Daniel Maurino, the coordinator of the ICAO flight safety and human factors program, the introduction of advanced systems on a large scale, may have produced two flaws:

1. It was technology-driven rather than human-centered.

2. It stopped short of the micro-level of system design analysis (Maurino, 1993).

Maurino's analysis of the problem seems to indicate that with the development of advanced systems, the human element was not taken entirely into consideration.

In 1992, the Flight Safety Foundation (FSF) and the International Civil Aviation Organization (ICAO), organized a CFIT Task Force. The task force set as a five year goal a fifty percent reduction in CFIT accidents (Flight Safety Foundation, 1999). According to the FSF, the task force achieved that goal in 1996 and 1997 by concentrating on four areas:

1. Distributed a Safety Alert to thousands of operators on the use of GPWS.

2. Developed a CFIT checklist.

3. Created a video training tape titled "CFIT: Awareness and Prevention."

4. Produced a CFIT Education and Training Aid (Flight Safety Foundation, 1999).

The emphasis of these four areas deals with the pilot's interaction with avionics and with each other. The goal of each was to increase the pilot's awareness of possible CFIT scenarios and to avoid the possibility of an accident. Each were developed out of actual CFIT accidents to increase pilot awareness and how to react in similar situations.

The FAA's Safer Skies Initiative was established in April, 1998 with the goal of reducing fatal commercial aviation accidents 80% by the year 2007 (Air Safety Center $_b$, 1999). Some of the recommendations by the FAA include:

1. Adopting standard operating procedures which deal with prevention of CFIT.

2. Revise training programs which would incorporate CFIT training into CRM programs.

3. Training air traffic controllers in CFIT prevention and the MSAW system (Air Safety Center $_b$, 1999).

With the development of CFIT prevention into the CRM programs, commercial operators can incorporate CFIT training into their initial and recurrent CRM training. It has already been established by the airline industry that CRM has helped aircrew to increase situational awareness. With the addition of CFIT training, CRM will be able to incorporate a high degree of awareness of possible scenarios that can lead up to these types of accidents.

After the crash of the Korean Air B-747 in Guam, the airline's chief of flight crew operations, testified to the NTSB that CRM training had been revised since the accident. Captain Lee Jung Taek stated in his testimony

https://commons.erau.edu/jaaer/vol10/iss3/4
DOI: https://doi.org/10.15394/jaaer.2001.1282

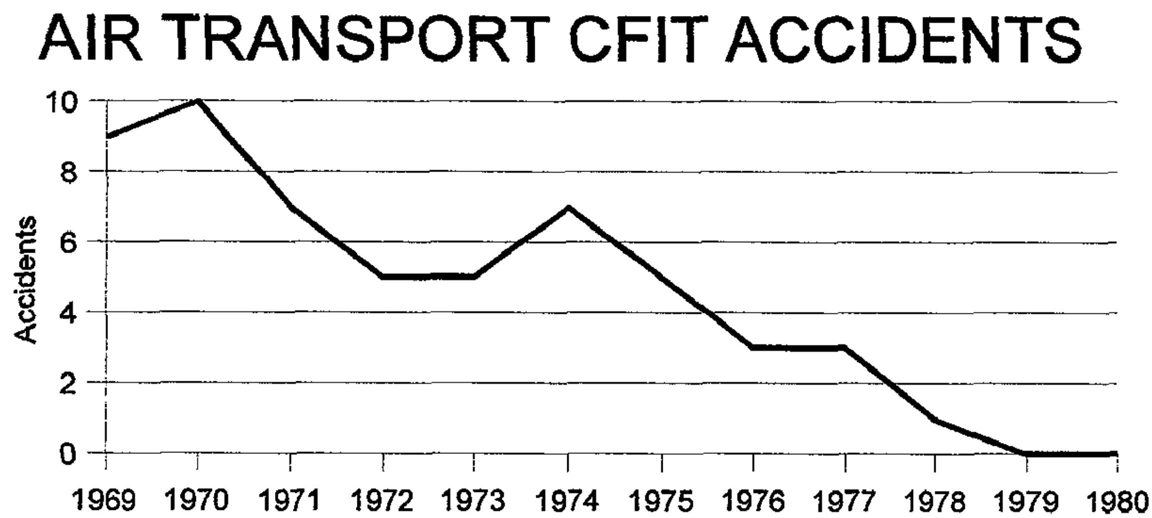


Figure 2 (FAA, 1997) Part 121 & 125 CFIT Accidents 1969 - 1980

USA Part 121& 125

that co-pilots are now trained to repeat advice about abnormal or dangerous conditions to the captain (McKenna, 1998). One interesting note that was not brought up in this investigation, is the fact of cultural differences. In some Asian cultures, it is unacceptable for an underling to question a supervisor. This could impede two way communication in the cockpit.

Current and Future Avionics Used to Prevent CFIT

With these new training programs being implemented in the commercial carriers, the other area that needs to be looked at is avionics. One of the major causes in the reduction of CFIT was the introduction of GPWS in the mid 1970's. As the figure 2 indicates, the CFIT accident rate has significantly declined since GPWS was introduced but it did not eliminate it. As has been pointed out in this paper, three reasons that may have attributed to that are:

1. Not properly training aircrew to include CRM training with use of GPWS.
2. Limitations in the system that will not give warnings in critical areas of flight.
3. Aircrew ignoring the low altitude warning indications.

Along with training aircrew in the recognition and avoidance of CFIT scenarios, the aviation industry has developed several types of avionics to aid the aircrew in CFIT accident reduction. Although GPWS had gone through major upgrades and changes over the years, there are still certain flight regimes that GPWS is ineffective in giving adequate warning. It can only provide information to the pilots on the terrain directly below the aircraft, utilizing a radar altimeter. If the terrain directly in front of the aircraft increases rapidly, the GPWS may not be able to detect the increase in time to give the pilot adequate warning to react. One of the findings in the American Airlines accident in Cali, Colombia, was that the aircraft did have a functioning GPWS, but it was not effective due to the rapid increasing terrain (Dornhein, 1996).

The EGPWS system had been out for several months prior to the December, 1995 accident in Cali. It was this accident that prompted the FAA to encourage the airlines to put the system in all of their aircraft (Evans, 2000). What makes the EGPWS different from older versions, is it has a memory database and a forward looking display that tells pilots what the actual terrain is like ahead of the aircraft. GPWS versions use the terrain change directly below the aircraft to warn the pilots. If the terrain was to increase rapidly, GPWS may not give the pilots adequate warning to avoid contact with the ground. EGPWS along with a Global Positioning System (GPS), relies on a worldwide database of the terrain that is loaded in the FMS and periodically updated. Pilots can see the terrain that is in front of the aircraft through an existing weather radar display, Electronic Flight Instrument System display or some other Multi Functional Display (MFD) in the cockpit (AlliedSignal, 1996).

A slightly different version of GPWS is called Auto-Ground Collision Avoidance System (Auto-GCAS) that has been developed by the military. Auto-GCAS is a last defense system that overrides the pilot's controls to automatically execute a climb or turning recovery (Scott, 1996). The system assumes that the pilot is unaware of the circumstance and takes over the controls momentarily. Auto-GCAS uses a terrain database as well as a radar altimeter to predict the upcoming terrain. When the system predicts a possible collision with the ground, it automatically executes the escape maneuver. If the any components of the system fails, the Auto-GCAS commands the aircraft to climb. The system was successfully tested on U.S. Air Force F-16 aircraft, but can be adapted to any aircraft with varying escape profiles. (Scott, 1996)

Another unique system that is being tested is the Transponder Landing System (TLS). The TLS utilizes the aircraft transponder and the Air Traffic Control Radar Beacon System (ATCRBS) on the ground to give the pilot position and attitude information (Picou, 1999). The TLS will provide the pilot with the same display as an ILS would. The TLS also has the ability to adjust the beam so it would not be a fixed signal as in the ILS, and would have the ability to guide aircraft for landing out to 22 nautical miles (Picou, 1999).

Although the EGPWS is the most advanced and an improvement over the standard GPWS system, there are still some inherent flaws in the system. The Allied Pilots Association is lobbying for a system that gives pilots a four dimensional view of the upcoming terrain (Goyer, 1998). The EGPWS currently displays only a three dimensional view or a bird's eye display using color codes to depict terrain height in relation to the aircraft's current altitude. The four dimensional system would also give the pilots a graphical representation of approaching terrain, as well as flight path projections (Goyer, 1998).

Air traffic controllers also have the ability to help prevent CFIT. If ATC systems are working correctly and controllers are able to interpret the information, such accidents could be prevented. The MSAW system was created for just that reason. There are two main reasons that the system has not prevented such high profile accidents such as the American Airlines in Cali, Columbia and the Korean Air in Guam. First, the system has to be installed. Currently, only the U. S., Japan and Israel have the system (Phillips, 1999). The second reason is the system has to be working correctly. The MSAW system was installed, but not covering the area when the crash occurred in the Korean Air disaster in Guam.

Another interesting statistic suggests that execution of non-precision approaches increase the rate of CFIT accidents. A study by the Approach and Landing Accident Reduction Task Force (ALAR) found that 50% of the CFIT accidents occurred during the approach and landing phase of the flight and 75% of those occurred at airports that did not have precision approach navigation aids. The ALAR Task Force was formed by the Flight Safety Foundation and studied 156 CFIT accidents from 1988-1994 (Phillips, 1999). The study goes to suggest that replacing non-precision approach systems with precision approaches, may reduce the CFIT accident rate.

Concerns and Potential Problems

One concern that has been mentioned is the integration of the advanced avionics and the human machine. Although systems aboard the aircraft are designed to help the pilot avoid CFIT scenarios, if the aircrew is not sensitized and trained to use and interpret the avionics correctly, it literally makes the equipment useless. The investigation in Guam of the Korean Air B-747, indicated that the altitude alert systems aboard the aircraft were working correctly, but the aircrew chose to ignore the appropriate warnings and continue the descent and impacted the ground. Improper training and lack of aircrew coordination contributed to this accident and has been a major factor in many more.

Another example of this involved a Southwest Airlines B-737 performing a hard landing at the Burbank-Glendale-Pasadena Airport on March 5, 2000. The aircraft skidded off the runway and slightly injured fifteen people. Preliminary investigations indicated that the aircraft was flying an unstable approach. An unstable approach is one in which an aircraft;

1. is not aligned with the runway at a sufficient height,
2. is not descending at a steady rate,
3. fails to capture the glideslope or correct vertical profile,
4. does not attain the desired speed, or
5. does not establish the desired configuration

https://commons.erau.edu/jaaer/vol10/iss3/4
DOI: https://doi.org/10.15394/jaaer.2001.1282

(Slatter, 1997).

Further investigation of the Southwest Airlines accident indicated the aircraft had a steeper than normal glidepath of up to six degrees caused by a late descent past the FAF (Phillips, 2000). The "sink rate, pull up" voice warning alarm from the GPWS system sounded several times during the approach and the aircraft approach speed was almost 60 MPH faster than the normal approach speed (Phillips, 2000). This recent accident illustrates the problem that is still present with avionics and crew integration.

General Aviation (GA) and corporate aircraft are not required to have such systems aboard their aircraft. Since those type of aircraft do most of the flying in the U.S., CFIT is a major concern for them. Although studies for the CFIT accident rate for GA and corporate aircraft are not noted in this paper, we can assume that it is a problem. So why not install these warning devices in the aircraft? Cost is the prohibiting factor for putting a system like GPWS in these aircraft.

Regional carriers also have concerns about more advanced systems. The industry has spent millions in recent years installing the GPWS in their fleet of aircraft. Now the FAA is threatening to have all commercial aircraft install the EGPWS in their aircraft by year 2001 (Commercial/Regional Airline News, 1998). Currently, U.S. major airlines are under a voluntary program to install EGPWS by 2003. The Regional Airline Association is lobbying for a volunteer program similar to the majors for installing the EGPWS by 2003. Estimated cost of installing the EGPWS system would be $23,900 for an aircraft that already has the GPWS installed and $40,000 for a complete system that would include a display in the cockpit (Commercial/Regional Airline News, 1998). The time line set forth by the FAA may be unreasonable. As indicated above, if the FAA gets its way, all commercial aircraft will have EGPWS by 2001. According to Stuart Matthews, president of the Flight Safety Foundation, it would take twenty years before it's installed in every commercial aircraft in the U.S. (Marks, 1998).

Conclusion

The first part in finding a solution to CFIT accident prevention seems to be a comprehensive plan of proper aircrew training in the following:

1. The use and coordination of avionics systems that help prevent CFIT accidents.
2. Integrating CFIT scenarios into CRM in the initial and recurrent training of aircrew.
3. Encourage open communication between flight crew where pilots check each other in critical phases of flight such as approach and landing.
4. Perform approach briefings to increase situational awareness in the cockpit.

The second part of the solution deals with aircraft systems in the aircraft. The proper use of altitude warning systems is the key to accident prevention. Plans are being developed for new systems, however, the FAA should take into account the time and cost to effectively integrate these systems into the airline industry. Estimated total cost for upgrades to the EGPWS system for the regional airline industry would be in excess of $115 million (Commercial/Regional Airline News, 1998). This could adversely impact the smaller airlines significantly. It is unrealistic to assume that if a new system is developed (like the EGPWS), that it will immediately be put into use. By utilizing the proper integration of aircrew training and current altitude avoidance systems, the CFIT reduction rate can be reduced. New and improved systems should continue to be developed and installed, but at a reasonable pace that will not impede the growth of the airline industry.□

Roger C. Matteson is an Assistant Professor of aviation at Central Washington University. He holds an MBA in Aviation and a Bachelor of Science in Aeronautical Science from Embry-Riddle Aeronautical University. He is a retired Air Force pilot and has earned Master CFI designation from the National Association of Flight Instructors.

REFERENCES

Air Safety Center $_{a}$, (1999), Abstract of the NTSB accident report. Hibbing, Minnesota. December 1993. Aviation Week home page [On-line] http://www.aviationweek. com/safety/ ntsbhib.htm.

Air Safety Center $_{b}$, (1999, November 22), Safer skies effort progressing on CFIT initiatives. December 1993. Aviation Week home page [On-line] http://www.aviationweek. com/safety/ news/nz991122.htm.

AlliedSignal Aerospace Corporation, (1996, May 13). AlliedSignal enhanced GPWS product description, 7-9.

Commuter/Regional Airline News, (1998 April 20), Regional carriers face cost of new safety plan, 16, 1-2.

Dornhein, Michael A. (1996, September 9). Recovered FMC memory puts new spin on Cali accident. Aviation Week and Space Technology, 145, 58-62.

Evans, David (2000, January 27). Near exactness with EGPWS. Aviation Today home page [On-line] http://www.aviationtoday.com/reports/EGPWS.htm.

Flight Safety Foundation, (1999). Controlled flight into terrain and approach and landing accidents. Flight Safety Foundation home page [On-line]. Available: http://www. flightsafety.org/cfit.html.

Garrison, Peter (1997, December). Confusion at Cali. Flying, 124, 93-96.

Goyer, Robert (1998, January). Pilots want new CFIT technology. Flying, 125, 30-31.

Jackson, Robert L. & Malnic, Eric (1998, April 14). FAA addresses big safety issues--new radar mandated to prevent 'Controlled Flights into Terrain'. Seattle Times, A3-A4.

Katz, Peter (1999, August). Flying into the ground. Plane and Pilot, 35, 24-27.

Mancuso, Vince (1995, April-June). Managing crew situational awareness. Up Front, 22-26.

Marks, Alexandra (1998, February 5). Finding ways to curb "pilot disorientation'. This week's crash in the Philippines puts new emphasis on addressing a leading cause of airplane accidents. Christian Science Monitor, 3-5.

Maurina, Daniel (1993, May). Efforts to reduce CFIT accidents should address failures of the aviation system itself. ICAO Journal, 45, 18-19.

McKenna, James T. (1997, August 11). Guam crash underscores navaid, training concerns. Aviation Week and Space Technology, 147, 35-37.

McKenna, James T. (1998, March 30). Guam probe cites pilot, FAA errors. Aviation Week and Space Technology, 148, 59-64.

NTSB, Washington, D.C., Jim Hall, Chairman, (Jan 27, 2000), Safety Recommendation, A-00-7 through -18.

Phillips, Edward H. (1999, March 8). Industry aims to curb approach, landing crashes. Aviation Week and Space Technology, 150, 41-43.

Phillips, Edward H. (March 13, 2000). NTSB probe focuses on Southwest pilots. Aviation Week and Space Technology, 152, 40.

Picou, Gary (1999). A new approach using familiar radios. Avionics News [On-line] http://www. gaaavionics.com/tls.htm.

Reason, J. (1990). Human Error. Cambridge University Press.

Scott, William B. (1996, November 4). New technology, training target CFIT losses. Aviation Week and Space Technology, 145, 73-77.

Slatter, R. J. (1997, March). Technique and criteria for a stabilized approach need to be spelled out in the operations manual. ICAO Journal, 52, 15.

Weiner, E. L. (1977). CFIT: System industry Accidents. Human Factors Journal, 19.

https://commons.erau.edu/jaaer/vol10/iss3/4

DOI: https://doi.org/10.15394/jaaer.2001.1282