# CFIT Operators Guide
# Table of Contents

3

| Section | | Page |
|---|---|---|

# Operators Guide



## 3.0 Introduction

This Operators Guide is Section 3 of the five-section Controlled Flight Into Terrain (CFIT) Education and Training Aid. Other sections include the Overview for Management, Decision Makers Guide, Example CFIT Training Program, and CFIT Background Material.

For the purposes of the CFIT Education and Training Aid, the term "operators" refers to the people involved in all operations functions required for the flight of commercial airplanes carrying at least 10 passengers, including airplanes involved in cargo operations. "Operators" is a broad term that includes such functions as air traffic systems, flight crew, flight dispatch, flight scheduling, flight training, and other supporting flight operations functions.

The goal of this training aid is to reduce the number of CFIT accidents. This can be accomplished by improving the knowledge and decision making of those who manage and fly within the international aviation system. This Operators Guide targets these people.

The material and recommendations provided in the CFIT Education and Training Aid were developed through an extensive review process to achieve consensus within the international aviation industry.

Portions of the data used in this aid came from the NASA Aviation Safety Reporting System (ASRS). While these are not objective reports, they are an excellent source of CFIT factors that can and have occurred. Even though ASRS reports may contain some unintentional inaccuracy, the CFIT Industry Team has included the information because its value exceeds the risk of editorial comment or inaccurate conclusions.

### 3.0.1 Operators Guide Objectives

The objective of the Operators Guide is to summarize and communicate key information that is relevant to operators. This Operators Guide:

- Indicates the magnitude of CFIT accidents.
- Identifies the causes of CFIT accidents.
- Identifies factors that contribute to CFIT accidents.
- Provides solutions and recommendations that, when implemented, can prevent CFIT accidents.

### 3.1 CFIT Accidents

***A CFIT accident is defined as an event where a mechanically normally functioning airplane is inadvertently flown into the ground, water, or an obstacle.*** These accidents have a history as old as flight itself. In the early days of reciprocating engine commercial airplanes, fully half of all accidents were attributable to CFIT. Since the beginning of commercial jet operations, more than 9,000 people have died worldwide because of CFIT.

***Figure 1***
***Hull-Loss Accidents for Worldwide Commercial Jet Fleet***

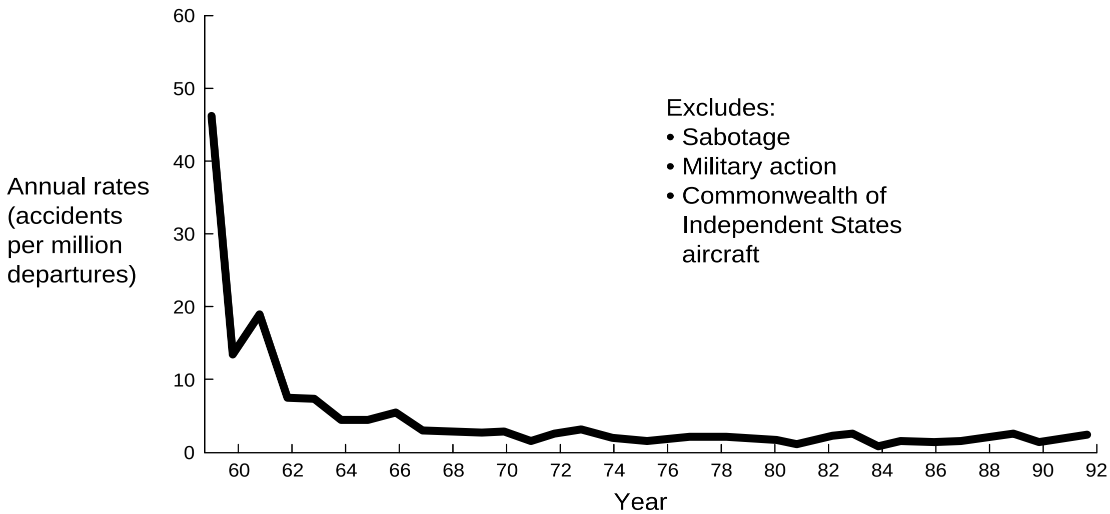
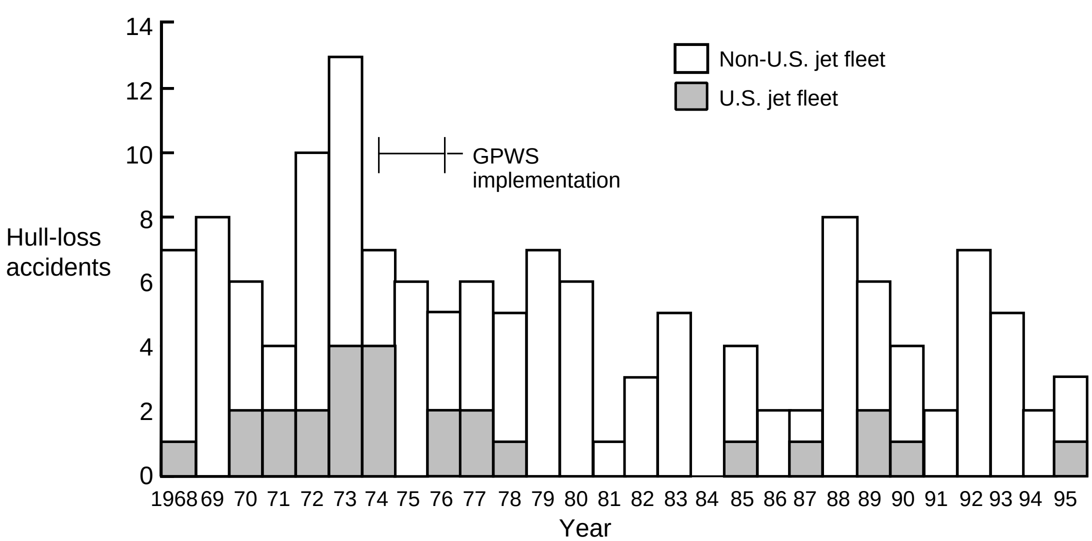



***Figure 2***
***CFIT Hull-Loss Accidents for Worldwide Commercial Jet Fleet***



The worldwide accident rate (which includes CFIT) for the commercial jet fleet decreased significantly in the 1960s and 1970s. This rate stabilized at that time and remains fairly stable today (Figure 1). Operators can be very satisfied with this accomplishment, but let's look at the actual number of CFIT accidents that are included in this accident rate. Figure 2 shows hull losses attributed to CFIT for the U.S. fleet as well as the rest of the world's fleet. The reduction in CFIT accidents that started in 1975 will be discussed later. The important thing to understand about these accidents is that they happened with normally functioning airplanes. These are accidents that operators could have prevented! From 1991 through 1995 there were more CFIT accidents than any other type (Figure 3). These accidents led to almost 1,000 fatalities, and in 1995 there were more fatalities attributed to CFIT than to any other type of accident (Figure 4). From November 1994 through December 1995, there were five CFIT accidents and 336 fatalities. CFIT is still happening.

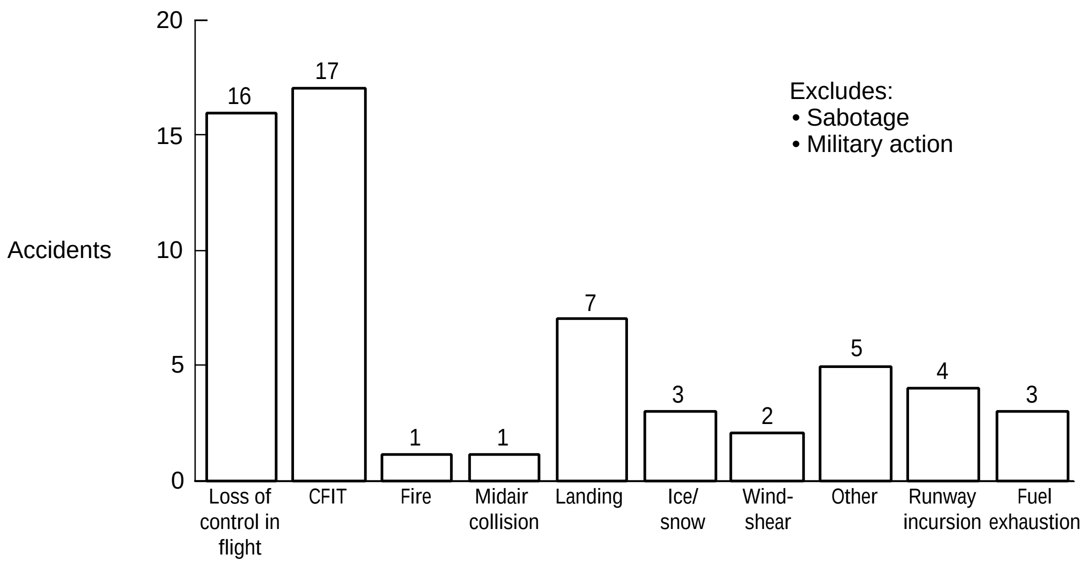



*Figure 3 Worldwide Airline Accidents Classified by Type - 1991 Through 1995*

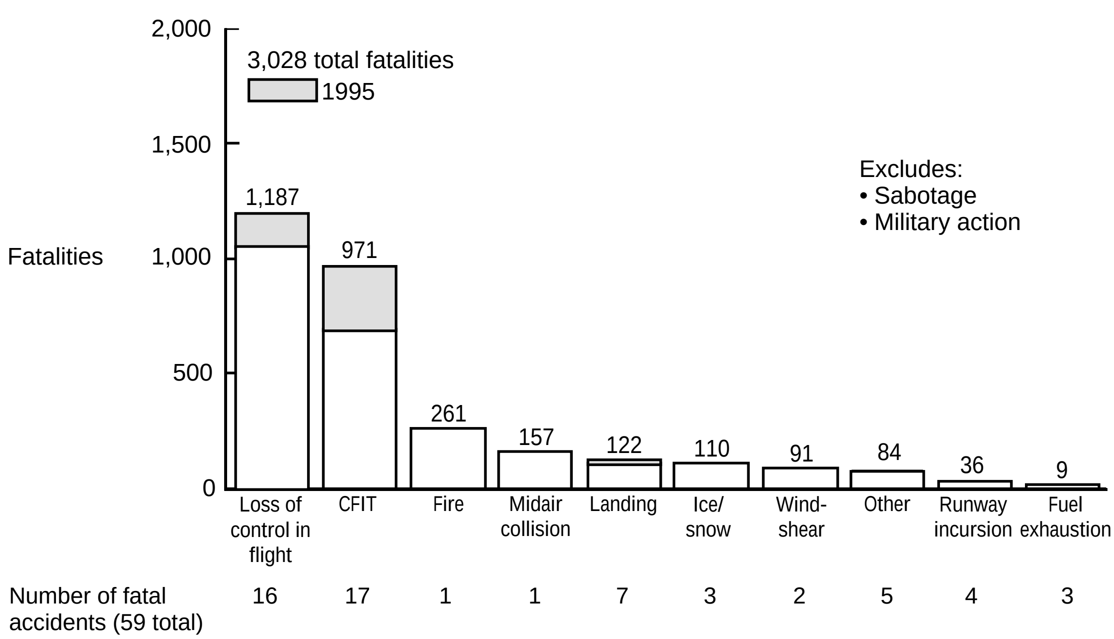


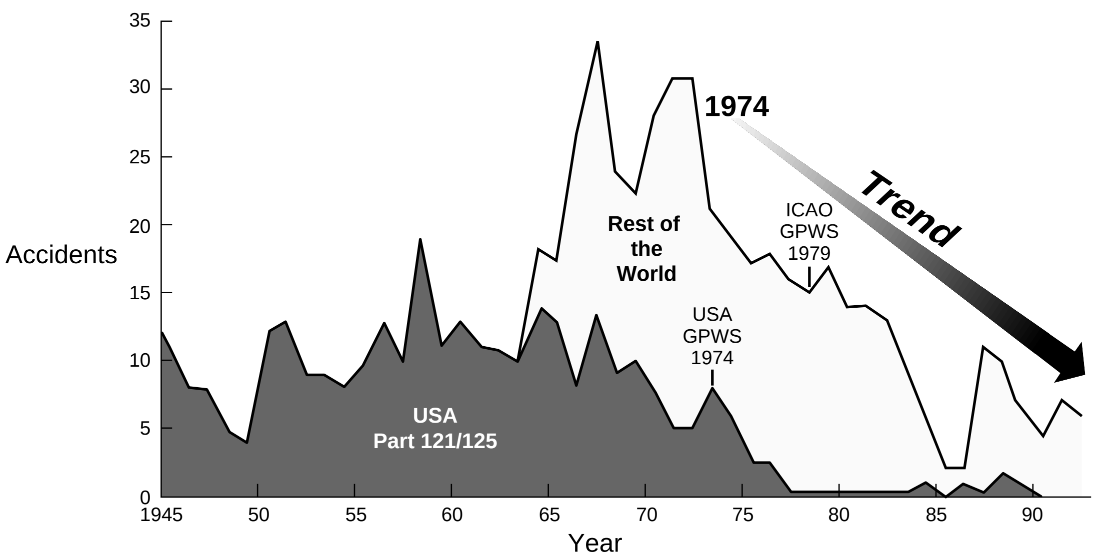

*Figure 4 Worldwide Airline Fatalities Classified by Type of Accident - 1991 Through 1995*

### 3.1.1 The Positive Results of the Ground Proximity Warning System (GPWS)

The number of CFIT accidents reached a historical high in 1973 (Figure 2). In the United States, starting in 1975, large jet transport accidents attributable to CFIT fell to an average of only one every 2 years. A major reason for this was the advent of the GPWS. In the early 1970s, Scandinavian Airlines System originated the concept of a warning system that would alert flight crews of imminent flight into terrain. Using the existing radio altimeter and air data computers, AlliedSignal (formerly Sundstrand Data Control) developed this cost-effective and practical device for installation in airplanes. An aural warning tone that was used in the original equipment to warn the flight crew was quickly replaced by a "pull up" command that was triggered by the airplane's flight path in relation to terrain characteristics.

In 1973, some airplane manufacturers and airlines recommended that GPWS be installed on their airplanes (Figure 5). During the following year, GPWS became standard equipment on most new airplanes. The United States Federal Aviation Administration (FAA) issued a Proposed Rule requiring that GPWS equipment be installed on all airplanes that operated under Part 121 and Part 125 regulations. The FAA still had some doubts concerning the effectiveness of GPWS in preventing CFIT, and it did not want the industry to rely only on GPWS for the prevention of CFIT accidents. In fact, in early 1974, the FAA issued a statement noting that "Present instrumentation and inflight procedures provide for safe and adequate terrain clearance as long as proper flight crew members discipline is maintained and appropriate flight operations procedures are followed."

*Figure 5*
*CFIT Accidents Per Year—USA and World Carriers*



Late in 1974 in the United States, a CFIT accident resulted in more rapid reaction by the FAA. A 727 flying a VOR/DME approach to runway 12 struck a hill 50 ft below the crest 20 mi from Dulles Airport in Washington, D.C. There were more than 90 fatalities. Subsequent to this accident, the FAA enacted FAR 121.360, which required all large jet and turbo-prop airplanes to be equipped with GPWS by the end of 1975. The short response time imposed by this ruling was met with initial reluctance by the airline community. Even with this reluctance and some technical problems that accompanied the regulatory requirement for GPWS, CFIT losses began a very significant and continuous drop. In the United States, accidents that were attributable to CFIT fell from the previous eight per year to only one per 5 years (Figure 2). In addition to GPWS, there were other initiatives that also helped reduce CFIT accidents. Expansion and upgrading of the air traffic control (ATC) radar within the United States, Air Route Traffic System III Minimum Safe Altitude Warning System (MSAWS), approach lighting, Visual Approach Slope Indicator (VASI) and precision approach path indicators (PAPI) systems, and Instrument Landing Systems (ILS) all had a positive effect in reducing the CFIT problem.

The United Kingdom Civil Aviation Authority conducted an evaluation using actual airline flight data. As a result of this, in 1975 it followed the FAA lead and also mandated the installation of GPWS by issuing Specification 14 as the technical standard. The International Civil Aviation Organization (ICAO) established GPWS standards in 1979. All of these actions resulted in the reduction of the number of worldwide CFIT accidents (Figure 2).

Regional carriers in the United States were not required to have the GPWS installed on their airplanes until recently. It is interesting to note that during the time that CFIT accidents for the large carriers decreased to about one hull loss every other year, the regional carriers without GPWS were experiencing CFIT accidents that resulted in an average of three hull losses per year.

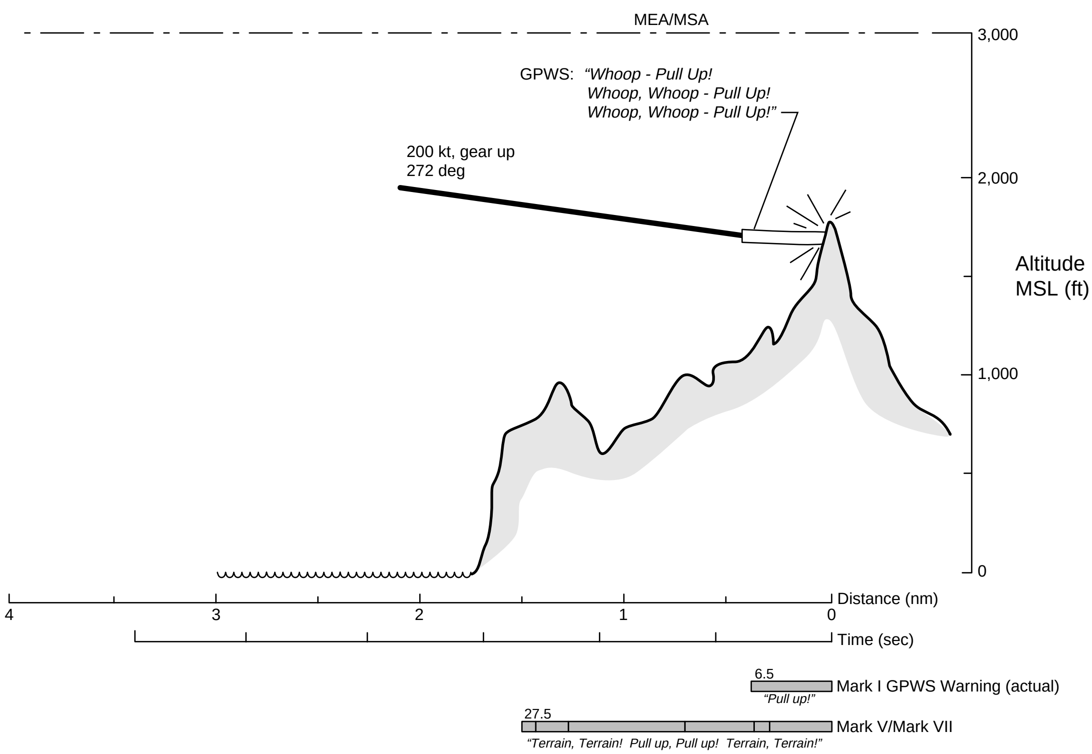
### 3.1.2 GPWS Initial Reliability and Follow-On Improvements

The first GPWS model, the Mark I, was not as reliable as anticipated, because of the rush to meet regulatory installation time requirements. It was plagued with false and nuisance warnings. This led to these prophetic remarks from the Air Transport Association of America in late 1975: “Pilots will quickly lose confidence in this system if this continues for even a short period of time. Once they lose confidence, it will be practically impossible to regain. Then, the efforts of both the FAA and industry to realize the safety benefits which this system promises will have gone for nothing. We will have spent thousands of man-hours and millions of dollars on a black box that nobody trusts.” In a survey conducted soon after the GPWS installation requirement, 83% of the pilots surveyed expressed concerns about false or nuisance alerts. These concerns included the potential for having a midair collision while performing a mandatory pull-up, losing control of the airplane while distracted, ignoring a valid warning because of system credibility problems, and ignoring a valid warning through a misunderstanding of the cause of the warning.

Now, 20 years later, we still may be living with these concerns. We are still trying to regain flight crew confidence in GPWS. Flight crew recognition and subsequent response is still being influenced by GPWS warning integrity. Many CFIT accidents have been attributable to flightcrews failing to respond properly to valid GPWS warnings even though modifications and improvements were made to the system. (Refer to Sec. 5, AlliedSignal Aerospace Report). The Mark I was improved in 1975, and the Mark II version was on the line in 1976. The Mark II allowed higher sink rates at lower altitudes; provided for better high-speed warnings; and added specific reasons for warnings such as “Too Low-Gear” and “Terrain, Terrain.” The latest versions of the GPWS, the Mark V and VII, are tailored for terrain around specific airports, and they are easily reprogrammed, if needed. Although false alerts still occur and are a cause for concern, there is no evidence that an accident has been caused by these nuisance alerts.

With the early Mark I GPWS, the frequency of pull-up warnings was about one per 750 sectors. (A sector is that portion of an airplane flight that consists of one takeoff and one landing.) Recent data show that pull-up warnings now average about one for each 5,000 sectors for short-haul carriers and once per 7,000 sectors for long-haul carriers. Along with better validity in the GPWS warnings came earlier warnings to the flight crew. With the first versions of GPWS there was as little as 5 sec warning and no warning if the projected impact point was on a relatively steep slope of a mountain. Now, after continual upgrade modifications, the warning time has increased to almost 30 sec, and improvements are still in progress. The significance of this improved warning time can be seen by reviewing the flight path profile of a CFIT accident that happened in Azores, Portugal (Figure 6).

*Figure 6*
*Flight Path Profile: 707-300, Santa Maria, Azores, February 8, 1989*



### 3.1.3 Industry Support Required for GPWS

Installation of GPWS on all airplanes should be the goal of the international aviation industry. It is estimated that over the next 15 years, half of the current unequipped airplanes will be retired from service. However, this still leaves nearly 200 airplanes that do not have GPWS installed. Currently, less than 5% of the world's commercial airplane fleet is not equipped with GPWS; however, these unequipped airplanes are involved in nearly 50% of CFIT accidents (Figures 7 and 8).

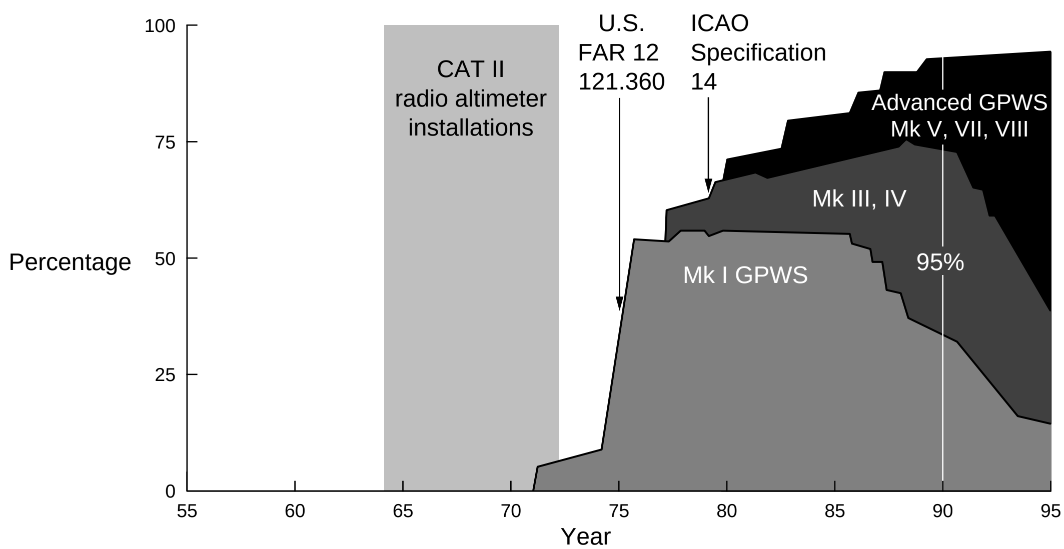



*Figure 7*
***World Airline Jet Fleet Equipped With GPWS***

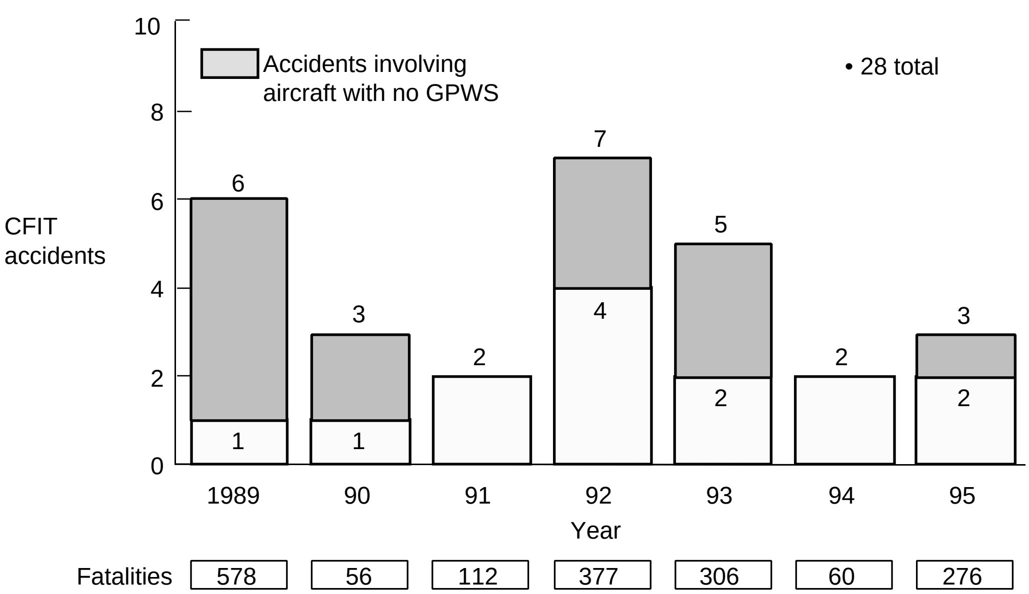



*Figure 8*
***Commercial Jet CFIT Accidents: 7-Year Period - 1989 Through 1995***

## 3.2 CFIT and the Flight Crew

The most prevalent primary factor for hull losses with known causes is the flight crew (Figure 9). For worldwide airlines from 1991 to 1995, there were more CFIT accidents than any other type (Figure 3). What are the causes and contributing factors for these accidents, and why do they occur? The answers lie in two areas. One set of factors is found primarily in the operations area and will be addressed in this section. Of equal importance are the factors that are present in the corporate, management, government, and regulatory area. These factors are covered in Section 2 of this CFIT Education and Training Aid.

### 3.2.1 Causes for CFIT Accidents

There are two basic causes of CFIT accidents; both involve flight crew situational awareness. One definition of situational awareness is an accurate perception by flight crews of the factors and conditions currently affecting the safe operation of the aircraft and the crew. The causes for CFIT are the flight crews' lack of vertical position awareness or their lack of horizontal position awareness in relation to the ground, water, or obstacles. More than two-thirds of all CFIT accidents are the result of altitude error or lack of vertical situational awareness. Simply stated, flight crews need to know where they are and the safe altitude for flight. The underlying assumption is that a flight crew is not going to knowingly fly into something. It follows then that CFIT accidents occur during reduced visibility associated with instrument meteorological conditions (IMC), darkness, or a combination of both conditions.

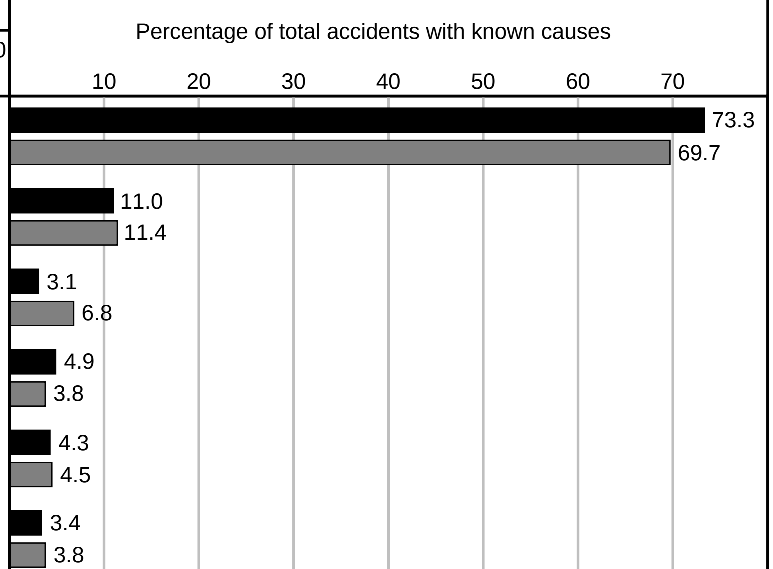
### 3.2.2 Factors That Contribute to CFIT

There are many factors that lead to CFIT accidents. We all accept that the flight crew has the final responsibility for preventing a CFIT accident, but if many of the factors normally associated with these accidents were eliminated, or at least mitigated, the potential for flight crew errors would be lessened.

- In the following sections, abbreviated solutions to counter CFIT factors and prevent CFIT accidents are indicated by a bullet (solid dot) shown here. More detailed discussion of CFIT prevention strategies can be found in Section 3.3.

***Figure 9 Primary Cause Factors for Hull-Loss Accidents for Worldwide Commercial Jet Fleet***

| Primary factor | Number of accidents: Total | Number of accidents: Last 10 years |
|---|---|---|
| Flight crew | 327 | 92 |
| Airplane | 49 | 15 |
| Maintenance | 14 | 9 |
| Weather | 22 | 5 |
| Airport/ATC | 19 | 6 |
| Miscellaneous | 15 | 5 |
| Total with known causes | 446 | 132 |
| Unknown or awaiting reports | 90 | 54 |
| Total | 536 | 186 |




Excludes:
- Sabotage
- Military action

Legend:
- 1959 to 1994
- Last 10 years (1985 to 1994)

### 3.2.2.1 Altimeter Setting Units of Measurement Factors

Accidents and numerous incidents have been recorded that involved the aircraft altimeter! Errors associated with the use of the barometric altimeter and its settings remain a problem that is compounded by language, nonstandard phraseology, and the use of different units of measurement. While there is an international standard, it is not adhered to by all states. Altimeter settings may be given in inches of mercury (inHg), hectoPascals (hPa), or millibars (mbars). Note: HectoPascals replaced millibars (metric) as a unit of measurement term for altimeter settings. Some air traffic systems use meters and some use feet for altitude reference. Most airplanes are only equipped with altimeters that use feet as a reference. The unit of measurement used depends on the area of the world in which the flight crew is flying. A problem can arise when a flight crew has been trained and primarily operates in one area of the world and only periodically operates elsewhere.

The following is an example of what can happen. An ATC controller, who speaks English as a second language, hurriedly advises the flight crew to descend and maintain 9,000 ft using an altimeter setting of "992." The flight crew begins the letdown and dutifully sets 29.92, not 992 hectoPascals that the controller was expecting to be set. Throughout the approach the airplane will be approximately 600 ft below the altitude indicated on the altimeters. The airplane will prematurely descend to the next lower altitude on a nonprecision approach and level approximately 600 ft below the MDA. This can make the difference between a normal landing at the destination and a CFIT accident just short of the runway.

- Know what altimeter units of measurement are used for the area in which you are flying.
- Be especially vigilant during radio transmissions of altimeter settings. If in doubt, verify whether the setting was given in inches of mercury or hectoPascals/millibars.
- Be prepared for the conversion of feet and meters.

### 3.2.2.2 Altimeter Settings Factors

The QNH altimeter setting is obtained by measuring the existing surface pressure and converting it to a pressure that would theoretically exist at sea level at that point. This is accomplished by adding the pressure change for elevation above sea level on a standard day. This QNH altimeter setting is the standard used throughout most of the world. ***Some states, however, report or use QFE.***

The QFE altimeter setting is the actual surface pressure, and it is not corrected to sea level. The QFE altimeter setting results in the altimeter indicating height above field elevation, while the QNH setting results in the altimeter indicating altitude above mean sea level (MSL).

There have been incidents in which a QNH setting has been erroneously used as a QFE setting. This results in the airplane being flown lower than the required altitude (Source: Pilot report from Peoples Republic of China).

The QNE altimeter setting is always 29.92 inHg, or 1013 hPa/mbars. QNE is set when operating at, climbing through, or operating above the transition altitude. Transition altitudes are not standardized throughout the world, which increases the potential for flight crews to make errors.

Extreme atmospheric anomalies, such as low temperatures or low pressures, can affect altimeters and result in reduced altitude margins of safety. This incident was reported by a Jetstream 31 Captain: "The First Officer got the ATIS. Passing FL180, the First Officer called the transition, altimeters 29.82. I questioned that setting, and he recounted, stating the setting of 29.82. We executed the VOR RWY 25 via the arc. Turning onto the inbound course, the minimum alt is 800 feet, to which I started to descend. We had been in and out of clouds with a ragged ceiling and low light conditions. My focus was inside the cockpit. At about 1,400 feet, out of the side of my eye, I noticed that the waves on the water looked awfully close. I looked out the window and got the immediate feeling something was horribly wrong. I told the First Officer to verify altimeter setting, and tower came back with 28.84. We were actually at 400 feet, not 1,400 feet! I added max power and climbed up to 800 feet and we continued to a landing on RWY 36 without further incident. I thank God that conditions were not just a little worse, or there had been less light, because we would have descended into the water at 180 knots." (Source: ASRS report 257947.)

- Know what altimeter setting units of measurements are used for your areas of operation.
- Know the phase of flight in which to apply the

appropriate altimeter settings.
- Establish and use altimeter setting cross-check and readback cockpit procedures.
- Cross-check radio altimeter and barometric altimeter readings.
- Operate at higher than minimum altitudes when atmospheric anomalies exist.

### 3.2.2.3 Safe Altitudes

Vertical awareness implies that flight crews know the altitude relationship of the airplane to the surrounding terrain or obstacles. Obviously, during IMC and reduced-visibility flight conditions, it is necessary to rely on altitude information provided by other than visual means. To assist flight crews, instrument flight rule enroute charts and approach charts provide Minimum Safe Altitudes (MSA), Minimum Obstruction Clearance Altitudes (MOCA) Minimum Enroute Altitudes (MEA), Emergency Safe Altitudes (EAS), and in most terminal areas, actual heights of the terrain or obstacles. Traditional maps, such as Sectional or Operational Navigation Charts, are available for more detailed study. The potential for CFIT is greatest in the terminal areas. Detailed altitude information is provided to assist the flight crews in maintaining situational awareness.

A flight crew on a flight to Portland, Oregon, USA, made this report: “The area below us was like a ‘black hole’… The city lights were off the right wing—a beautiful night. After being cleared for a visual approach, I began descent so as to arrive... at the recommended 3,000 feet mean sea level. ...at 4,100 feet MSL the GPWS went ‘Whoop, whoop! Pull up! Terrain.’ For a split second we thought it was a false warning, since we were still looking at the airport/city. Then I noticed both radio altimeters go from 2,500 feet to 400 feet in 1-2 seconds. I immediately applied full power and initiated a max climb until over the city’s outskirts (lights). Our whole crew serves this city daily and knows the airport well. Simple fact is that most pilots going into a familiar airport use the approach plate and do not often refer to the area chart. ...We were stupid and very lucky.” (Source: ASRS report 216837.)
- Make sure that adequate charts are available.
- Study the altitude information.
- Know and fly at or above the safe altitudes for your area of operation.

### 3.2.2.4 Air Traffic Control Factors

The inability of air traffic controllers and pilots to properly communicate has been a factor in many CFIT accidents. There are multiple reasons for this problem. With the growth of the aviation industry throughout the world, the use of English as a common language is more difficult to support. The lack of English language proficiency can make understanding controller instructions to the flight crews and airborne information or requests from the flight crews to the controllers much more prone to errors. Heavy workloads can lead to hurried communications and the use of abbreviated or nonstandard phraseology. The potential for instructions meant for one airplane to be given to another is increased. Unreliable radio equipment still exists in some areas of the world, which compounds the communication problems.

The importance of good communications was pointed out in a report by an air traffic controller and flight crew of an MD-80. The controller reported that he was scanning his radar scope for traffic and noticed that the MD-80 was descending through 6,400 ft and immediately instructed a climb to at least 6,500 ft. The pilot responded that he had been cleared to 5,000 ft and then climbed to... The pilot reported that he had “heard” a clearance to 5,000 ft and read back 5,000 ft to the controller and received no correction from the controller. After almost simultaneous GPWS and controller warnings, the pilot climbed and avoided the terrain. The recording of the radio transmissions confirmed that the airplane was cleared to 7,000 ft and the pilot mistakenly read back 5,000 ft and attempted to descend to 5,000 ft. The pilot stated in the report: “I don’t know how much clearance from the mountains we had, but it certainly makes clear the importance of good communications between the controller and pilot.” (Source: ASRS report 96032.)

ATC is not always responsible for safe terrain clearance for the airplanes under its jurisdiction. Many times ATC will issue enroute clearances for flight crews to proceed off airway direct to a point. When flight crews accept this clearance, they also accept responsibility for maintaining safe terrain clearance.

Airspace constraints that are most prevalent in the terminal areas many times require air traffic controllers to radar vector airplanes at minimum vectoring altitudes that can be lower than the sector MSA. Proper vertical and horizontal situational awareness is vital during this critical phase of flight. Humans make errors. From time to time ATC may issue flawed instructions that do not ensure adequate terrain clearance. While it may be difficult for flight crews to know that an error has been made, it is possible that mistakes can be detected with good flight crew position and altitude awareness.

The following is a report of an incident that took place in El Paso, Texas, USA: “El Paso clearance Delivery: cleared to Salt Lake City Airport, full route clearance, radar vectors TCS, direct GUP, direct HVE, direct SLC, maintain 7,000 feet, expect FL350 10 minutes after departure...After takeoff, fly heading 070 degrees. I read the above clearance back as written above. El Paso clearance delivery responded: readback correct. Runway 08 in use at the time. Winds reported calm. Several minutes later, I requested if runway 04 would be available (while still at the gate) El Paso clearance delivery replied: ‘Affirmative, I'll forward your request for runway 04.’ No amendments or changes to the original clearance were issued until receiving takeoff clearance from tower. Approximately 25 minutes later we departed runway 04 with the following instruction from El Paso tower: ‘After takeoff, turn left heading 330 degrees. Cleared for takeoff.’ While in a left turn to 330 degrees after takeoff, combined tower/departure controller said: ‘radar contact, turn left heading 300 degrees.’ We responded by acknowledging the heading and ‘leaving 6 for 7,000 feet.’ Aircraft was leveled off at 7,000 feet MSL. Captain asked controller the elevation of the terrain below us. Tower replied: ‘5,800 feet.’ After approximately one minute level at 7,000 feet MSL, the radar altimeter light came on, indicating terrain less than 2,500 feet. A climb was immediately initiated when the GPWS warned: ‘Terrain, Terrain.’ ATC was advised we’re climbing. ATC replied: ‘Verify you’re climbing to 17,000.’ Captain replied that were issued 7,000 feet. ATC replied: ‘Climb and maintain 17,000.’...The controller said he was the new shift replacement for the controller who had given us the clearance.” (Source: ASRS 95474.)

- Exercise good radio communication discipline.
- Know the height of the highest terrain or obstacle in the operating area.
- Know your position in relation to the surrounding high terrain.
- Challenge or refuse ATC instructions when they are not clearly understood, when they are questionable, or when they conflict with your assessment of airplane position relative to the terrain.

### 3.2.2.5 Flight Crew Complacency

Complacency can be defined as self-satisfaction, smugness, or contentment. You can understand why, after years in the same flight deck, on the same route structure to the same destinations, a flight crew could become content, smug, or self-satisfied. Add to this equation a modern flight deck with a well-functioning autopilot, and you have the formula for complacency.

Here is an example of flight crew complacency. The flight crew is flying an arrival. They get a nonstandard clearance to descend to a lower altitude, in an unfamiliar sector. Suddenly, the GPWS warning sounds: “Pull up! Pull up!” The flight crew is not sure what to do, because they have never experienced this before. They may hesitate to pull up, or they may ignore the warning—with disastrous results.

In this scenario, the GPWS warning may not have registered with the flight crew. They have flown into this airport hundreds of times, but because of complacency, their brains may very well have disregarded aural and visual cockpit warnings. At the other extreme, flight crews may also be exposed to continued false GPWS warnings because of a particular terrain feature and a GPWS database that has not been customized for the arrival. The flight crew becomes conditioned to this situation since they have flown the approach many times. This can also lull the flight crew into complacency, and they may fail to react to an actual threat. Note: The newer versions of GPWS can be programmed by the manufacturer for specific airfield approach requirements, so that these nuisance warnings are eliminated.

- Know that familiarity can lead to complacency.
- Do not assume that this flight will be like the last flight.
- Adhere to procedures.

### 3.2.2.6 Procedural Factors Associated With CFIT

Many studies show that operators with established, well thought out and implemented standard operating procedures (SOP) consistently have safer operations. It is through these procedures that the airline sets the standards that all flight crews are required to follow. CFIT accidents have occurred when flight crews did not know the procedures, did not understand them, and did not comply with them or when there were no procedures established. More than one CFIT accident has occurred when the flight crew delayed its response to a GPWS warning during IMC. If an SOP had addressed this situation and provided the flight crew with specific guidance, maybe an accident could have been avoided. In the absence of SOPs, flight crews will establish their own to fill the void in order to complete the flight. Some crews think the weather is never too bad to initiate an approach! It is the responsibility of management to develop the comprehensive procedures, train the flight crews, and quality control the results. It is the responsibility of the flight crew to learn and follow the procedures and provide feedback to management when the procedures are incorrect, inappropriate, or incomplete.

*Figure 10*
*Percentage of All Accidents by Phase of Flight and the Percentage of Flight Time That the Flight Crew Is Exposed During That Phase*

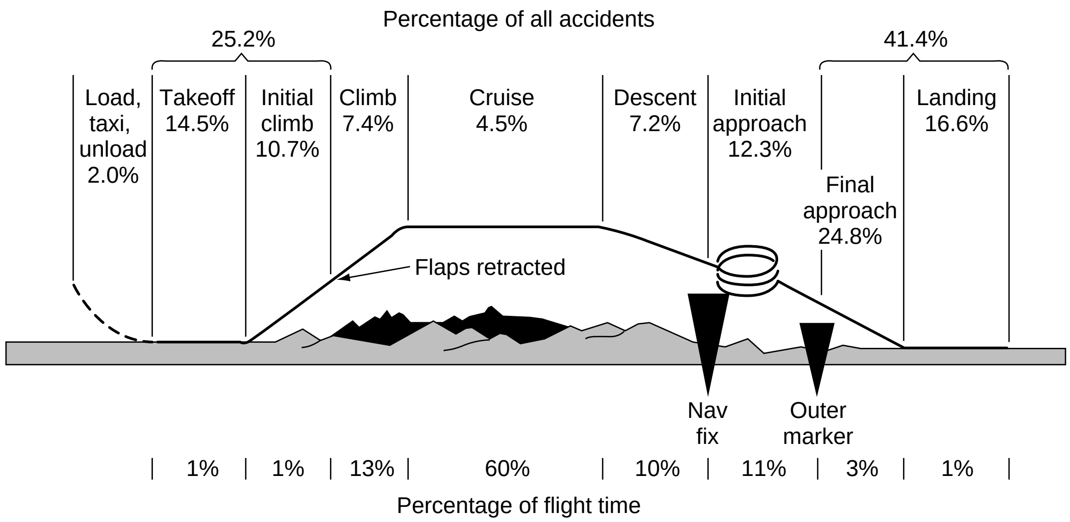
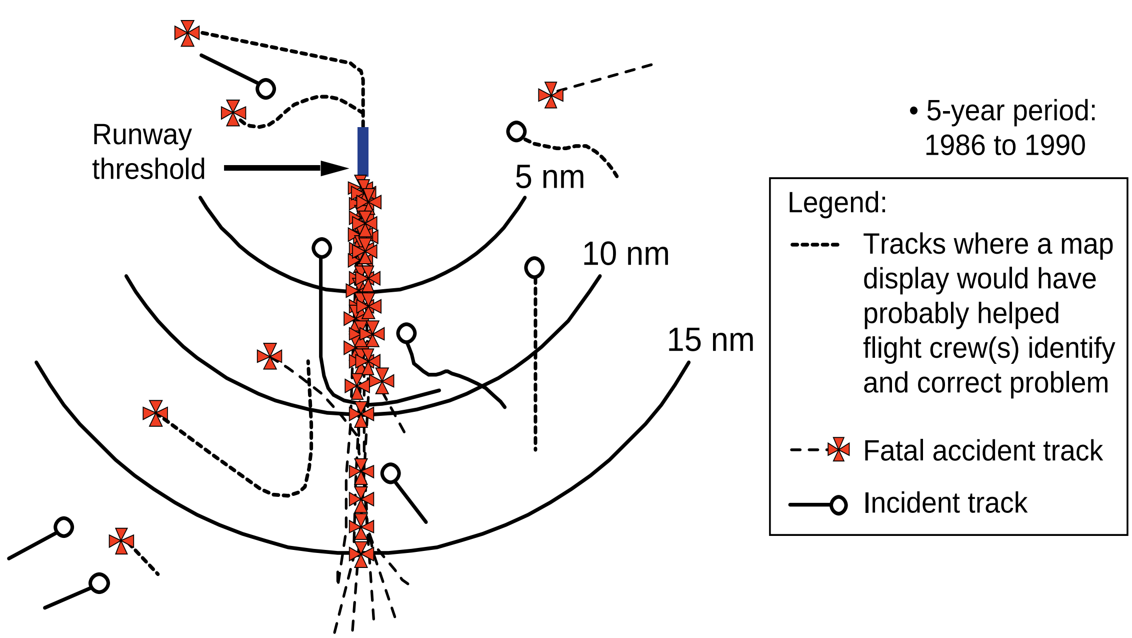



*Figure 11*
*Map Location of CFIT Accidents/ Incidents*



- Do not invent your own procedures.
- Management must provide satisfactory SOPs and effective training to the flight crew.
- Comply with these procedures.

### 3.2.2.7 Descent, Approach, and Landing Factors

CFIT accidents have occurred during departures, but the overwhelming majority of accidents occur during the descent, approach, and landing phases of the flight (Figure 10). CFIT accidents make up the majority of these accidents. An enlightening analysis of 40 CFIT accidents and incidents was accomplished for a 5-year period, 1986 to 1990. The airplanes' lateral position in relation to the airport runway and the vertical profile were plotted. (Figures 11 and 12). One of the interesting things is that almost all the position plots in Figure 11 are on the runway centerline inside of 10 mi from the intended airport. The vertical profiles shown in Figure 12 are also significant. The flight paths are relatively constant 3-deg paths—right into the ground! Most of the impacts are between the outer marker and the runway.

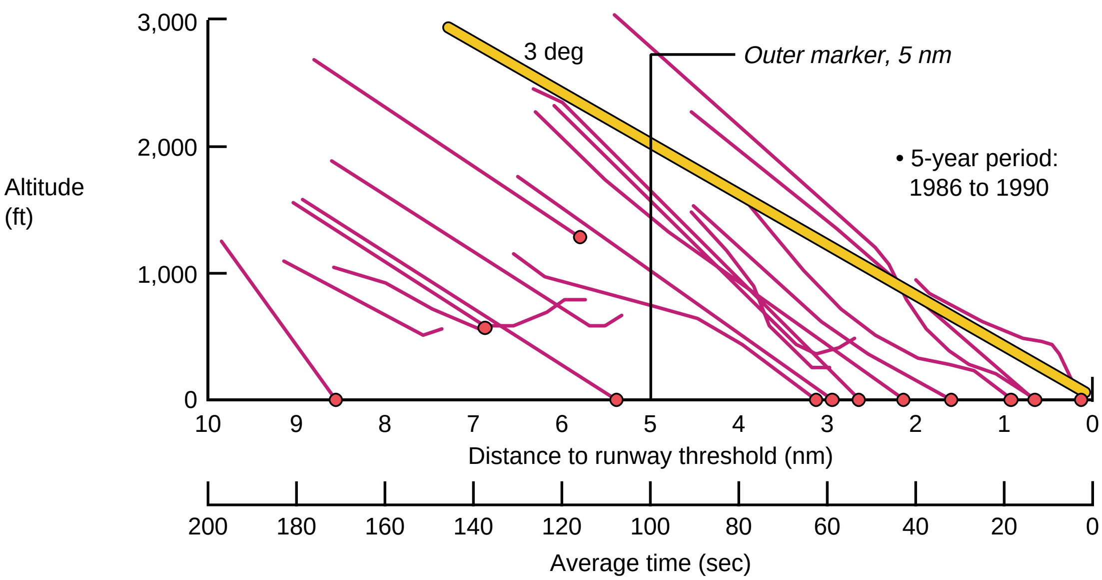



*Figure 12*
*Primary Cause Factors for Hull-Loss Accidents for Worldwide Commercial Jet Fleet*

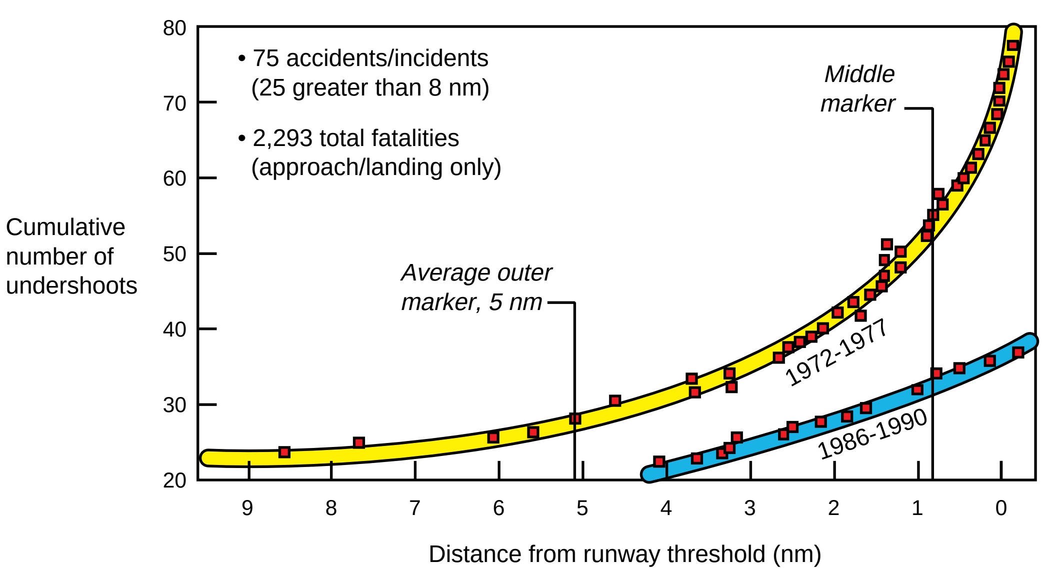



*Figure 13*
*Geographical Location of CFIT Accidents*

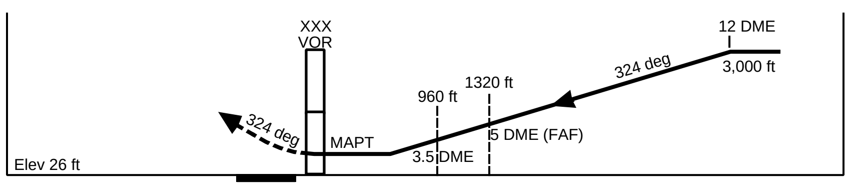
The geographical locations of CFIT accidents during the 1970s show a different pattern than those in the late 1980s and 1990s (Figure 13). During the 5-year period from 1972 through 1977, there were 75 CFIT accidents or incidents. Twenty-five of these accidents/incidents were greater than 8 nm from the runway. The preponderance of the remaining accidents/incidents were inside the middle marker. However, for the period 1986 to 1990, the distribution of accidents/incidents was relatively even. This difference may be the result of improvements made in runway approach aids that took place during this time period. Additional ILS were installed, as well as runway approach lighting systems. Continued capital investment in runway precision approach and lighting systems needs to be made worldwide.

- Know what approach and runway aids are available before initiating an approach.
- Use all available approach and runway aids.
- Use every aid to assist you in knowing your position and the required altitudes at that position.

Most CFIT accidents occur during nonprecision approaches, specifically VOR and VOR/DME approaches. Inaccurate or poorly designed approach procedures coupled with a variety of depictions can be part of the problem. Figure 14 is an example of an approach procedure produced by different sources. There are documented cases that the minimum terrain clearances on some published approach charts have contributed to both accidents and incidents. For more than a decade, a worldwide effort has been under way to both raise and standardize the descent gradient of nonprecision approaches. There are gradients as little as 0.7 deg in some VOR approach procedures. ASRS report 254276 illustrates the hazard of shallow approaches coupled with other confusion associated with the procedure design (Figure 15). In addition to the shallow approach gradients, many approaches use multiple altitude step-down procedures. This increases flight crew workload and the potential for making errors.

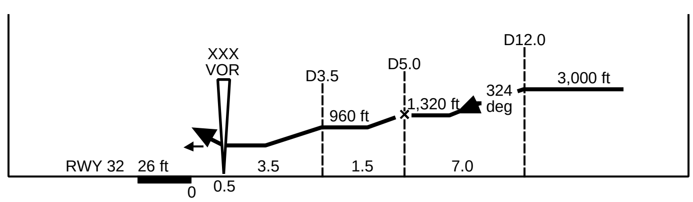
- Study the approach procedure(s) before departure.
- Identify unique gradient and step-down requirements.
- Review approach procedures during the approach briefing.
- Use autoflight systems, when available.

***Figure 14***
***Approach Procedure Design***

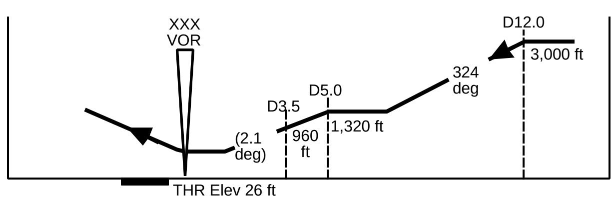



**State AIP**

- Many ways to present the descent profile
- Comparison of profiles for the same nonprecision approach




**Commercial Source A**




**Commercial Source B**

There is more than one standard for approach procedures in the world. The U.S. standard is Terminal Instrument Procedures (TERPS). The ICAO standard is Procedures for Air Navigation Services—Aircraft Operations (PANS-OPS), and the Russian Federation uses still another. Flight crews, therefore, may be exposed to different standards and different margins of terrain clearances.

- Study anticipated approach procedures before departure.
- Know that there are different approach design standards.

Different approach procedure charting requirements and printing can also make it more difficult for flight crews to safely fly an approach. High-elevation obstacles and terrain surrounding airports have been annotated on charts for years, but the actual terrain has not been depicted. Slowly, the publishing and printing organizations for

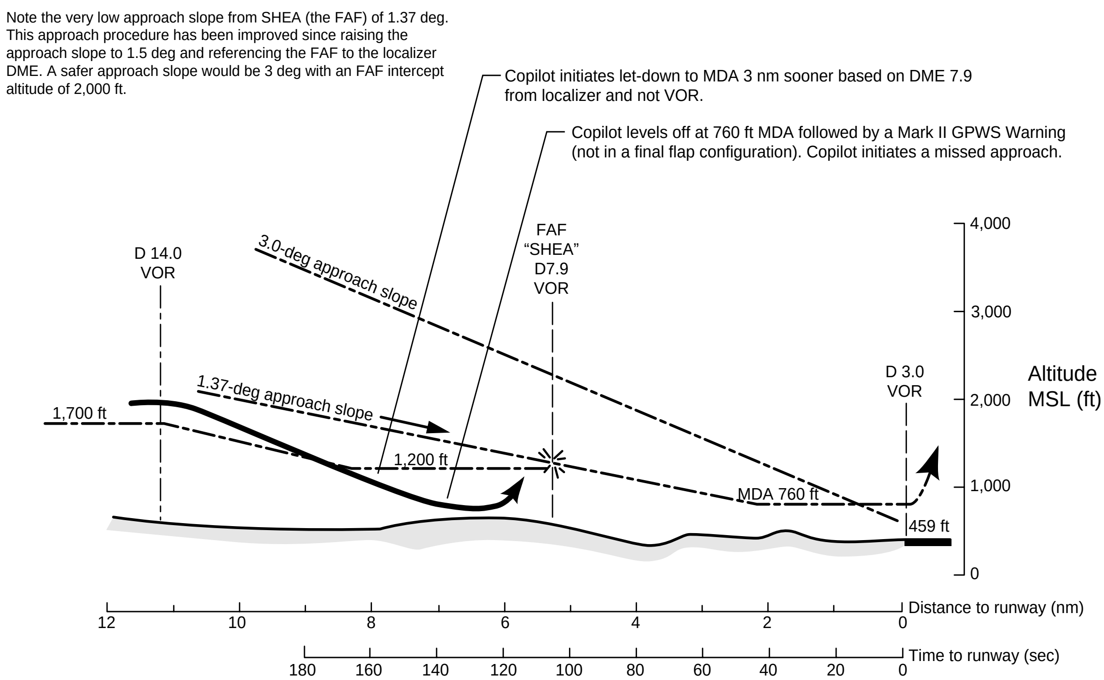
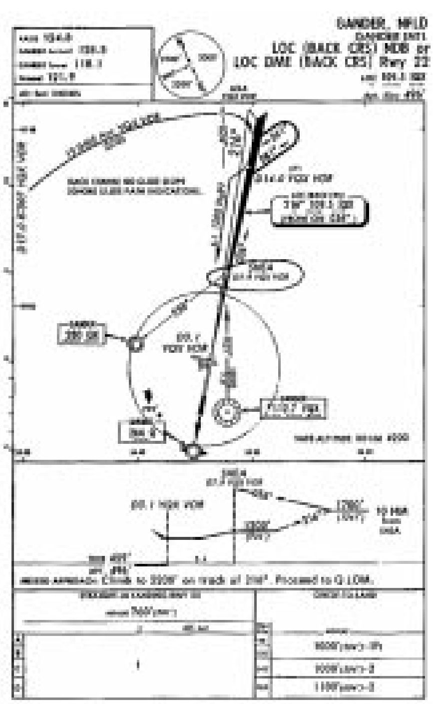



*Figure 15*
*Flight Path Profile—ASRS Report 254276*



aeronautical and approach charts have begun to use color and depict terrain or minimum safe altitude contours. Recently, some of the larger international operators have started printing their own customized charts that include these features. This greatly helps the flight crews to recognize the proximity of high terrain to the approach courses. Hopefully, this will result in fewer accidents.

Unstable approaches contribute to many CFIT accidents or incidents. Unstable approaches increase the possibility of diverting a flight crew's attention to regaining better control of the airplane and away from the approach procedure. A stabilized approach is defined by many operators as a constant rate of descent along an approximate 3-deg flight path with stable airspeed, power setting, and trim, with the airplane configured for landing.

- Fly stabilized approaches.
- Execute a missed approach if not stabilized by 500 ft above ground level or the altitude specified by your airline.

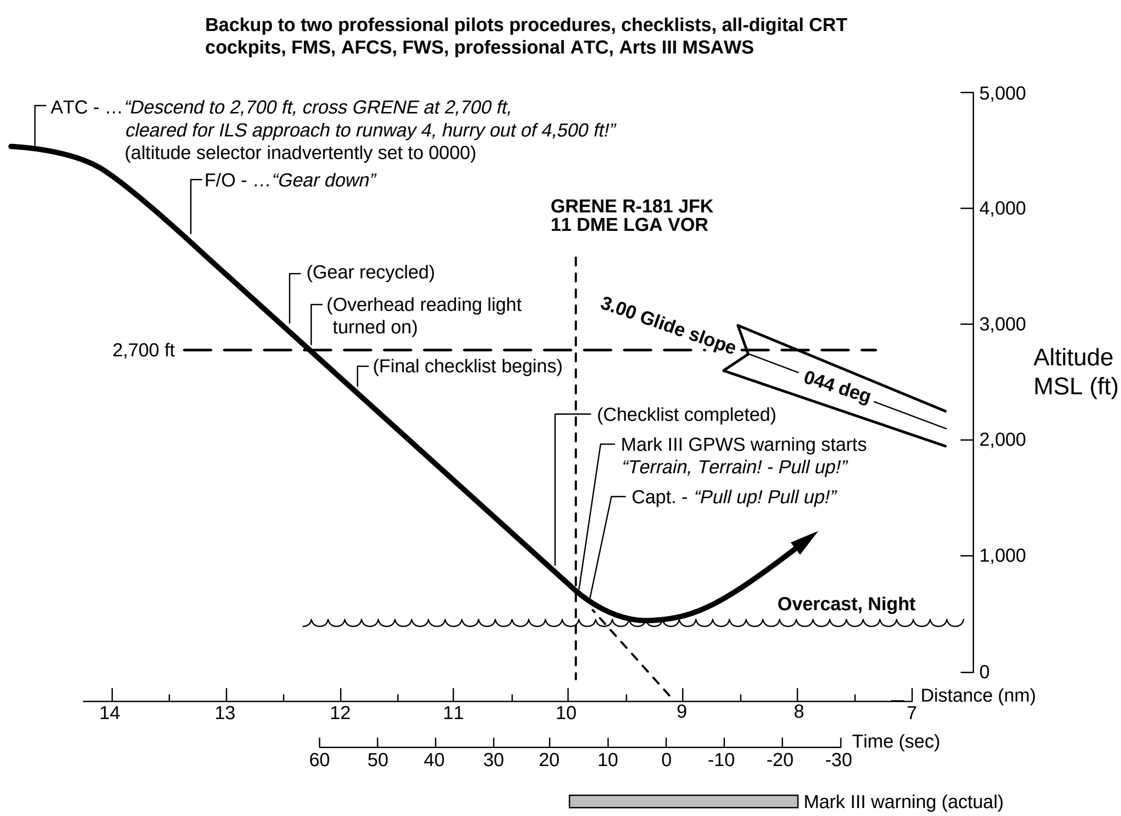
In some modern glass-cockpit aircraft, the flight guidance system has the capability to display flight path vector / flight path angle. Use of this mode enables a stabilized approach to be flown at the required slope during a nonprecision approach, with automatic correction for the effects of wind.

Flight management systems also have the capability to provide a computed profile for a nonprecision approach. Required conditions for the use of lateral and vertical navigation functions for this purpose are that the approach profile is included in the database, that it is verified in accordance with obstacle clearance criteria, and that the FMS accuracy is confirmed to be high.

The use of these techniques, in conjunction with the autoflight system, reduces crew workload and should ensure a higher level of safety. Procedures specific to the airline type are given in the applicable Flight Crew Operating Manual. Crews should be adequately trained, either in the simulator or in flight, to use the procedures associated with these features.

- If a nonprecision approach is necessary, use the recommended flight guidance system function to fly a stabilized profile at the required angle whenever possible.
- Continuously monitor position and track by reference to the basic approach aid(s).

***Figure 16***
***The Last "Safety Net": 767 La Guardia, February 1983***



### 3.2.2.8 Autoflight System Factors

"On final approach into La Guardia Airport, New York, USA, with the weather 400 foot overcast, the descent was made below the minimum maneuvering altitude. I feel that a dangerous situation existed this time, and I will try to give a history of the events (Figure 16).

"Our clearance was 'descend to 2,700 feet, cross GRENE at 2,700 feet, cleared for the ILS approach to runway 4, hurry out of 4,500 feet'. Using the flight level change mode on the mode control panel we descended to 2,700 feet. The first officer was flying and asked for flaps 20, gear down. Acting as copilot and doing the copilot duties, I put the gear handle down and the flaps at 20 degrees. The gear amber light was on, so it was necessary to recycle the landing gear.

"Three green lights appeared after cycling. It was night time, so I turned on the overhead reading light and completed the landing checklist. As I was replacing the checklist to the card holder, the GPWS sounded two pull-up warnings, and I said 'Pull up, pull up.' The autopilot was disengaged and maximum power was added. At about this point, we crossed the LOM. An attempt was then made to get back on the localizer and glide slope, but we were not able to do so. A missed approach was made and another approach and landing was uneventful. On the missed approach, the altitude select on the mode control panel indicated 0000. Neither of us know how it got there.

"The aircraft was descending below the glide slope all the way down and did not capture, but was going to 0000 feet as asked for by the altitude selector.

"I feel that there was some failure in the system as well as in the coordination of the flight crew. I feel that we all must be more cognizant of the fact that the monitoring of... instruments must be absolutely primary by both pilots. We may have been saved by the GPWS and I feel that closer monitoring by both pilots would have prevented this situation. The only reason I write this is to once again alert each of us to the many traps these new concepts and the new instrumentation can lead us into. Heads up is the answer." (Source: ASRS report PAN AM Flight OPS magazine.)

A minimum of three to five autoflight-related near-collision with the terrain incidents occur each year. Not all incidents are reported. The actual number of incidents may be much greater. The advancement of technology in today's modern airplanes has brought us flight directors, autopilots, autothrottles, and flight management systems. All of these devices are designed to reduce flight crew workload. They keep track of altitude, heading, airspeed, and the approach flight path, and they tune navigation aids with unflagging accuracy. When used properly, this technology has made significant contributions to flight safety. But technology can increase complexity, and it can also lead to unwarranted trust or complacency. ***Autoflight systems can be misused, may contain database errors, or may be provided with faulty inputs by the flight crew. These systems will sometimes do things that the flight crew did not intend for them to do.***

Imagine this situation. You are descending, and the autoflight system is engaged and coupled to fly the FMC course. It is nighttime, and you are flying an instrument arrival procedure in mountainous terrain. The FMC has been properly programmed, and the airplane is on course when ATC amends the routing. In the process of programming the FMC, an erroneous active waypoint is inserted. While you and the first officer are reconciling the error, the airplane begins a turn to the incorrect waypoint! It does not take very long to stray from the terrain altitude protected routing corridor.

- Monitor the autoflight system for desired operation.
- Avoid complacency.
- Follow procedures.
- Cross-check raw navigation information.

### 3.2.2.9 Training Factors

Most of the factors that have been identified are the result of deficiencies in flight crew training programs. Therefore, training becomes a significant factor that contributes to CFIT. Well-designed equipment, comprehensive operating procedures, extensive runway approach aids, and standardized charting or altimeter setting procedures and units of measurement will not prevent CFIT unless flight crews are properly trained and disciplined.

- Develop and implement effective initial and recurrent flight crew training programs that include CFIT avoidance.
- Implement Flight Operations Quality Assurance Programs.

## 3.3 CFIT Prevention

In Section 2 of this document (the Decision Makers Guide) we point out that CFIT prevention encompasses more than operator-related actions. There are system-related problems that, when solved, will help operators avoid situations that may lead to CFIT. Some progress has been made in solving the systemic problems, but much more needs to be done. ***In the meantime, operators can also do much more to prevent CFIT accidents.***

### 3.3.1 Minimum Safe Altitude Warning System (MSAWS)

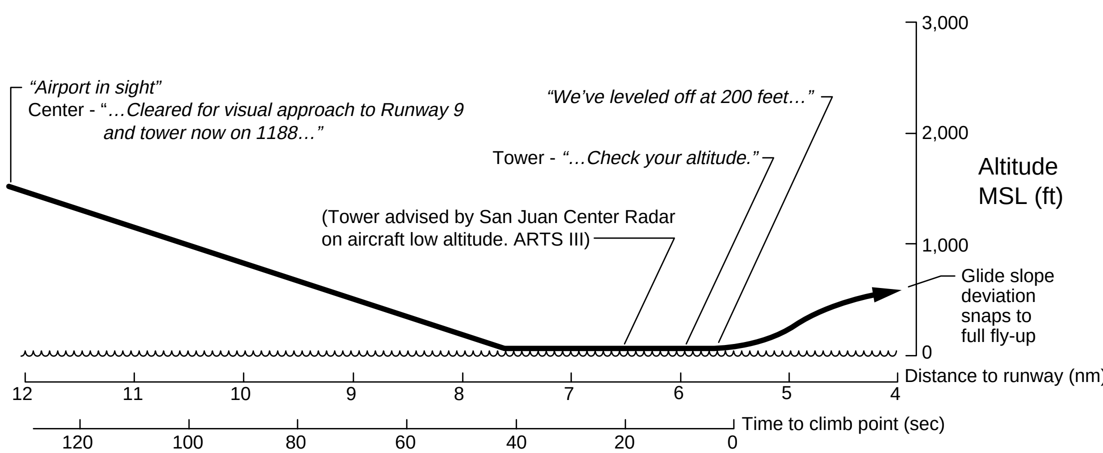
The Minimum Safe Altitude Warning System became operational in the United States in 1976. MSAWS alerts the air traffic controller with both visual and aural alarms when an airplane penetrates, or is predicted to penetrate, a predetermined MSA in the protected terminal area. It operates in two modes: surveillance in all sectors of the terminal area and a mode tailored to monitor airplane altitude versus position on the final approach course. This capability is especially valuable when airplanes are being radar vectored and it is more difficult for the pilots to maintain situational awareness. While MSAWS is an excellent aid in preventing CFIT, it is not widely available outside the United States.

This report was extracted from a 1986 Pan American Flight Operations magazine. The airplane was on a very short flight and never got above 5,000 ft. The time was 0145 local. Approaching destination, the airplane was cleared for a visual approach and was handed off to the tower for landing. The flight crew then descended below a cloud deck in order to keep the airfield in sight. The approach briefing was short, and there was a mention of the short runway during the briefing. The crew continued to descend by flying on the ILS glide slope to an altitude of 200 ft. The Captain later reported that the airplane seemed unusually low in spite of an on-glide-path indication. During this time, the radar at the ATC center noticed the airplane getting unusually low; in fact, the radar reported the airplane below 50 ft at times! The center contacted the destination tower operator and reported its observations. The tower operator immediately contacted the inbound flight and warned the flight crew of the situation.

When asked about their altitude, the flight crew reported "level at 200 ft." Actually, they were 50 ft above the water and had been for almost a minute! Just after the query the airplane climbed to 600 ft. The ILS glide slope, that was previously centered, snapped to the full fly-up position. The airplane completed a normal landing.

***Figure 17***
***Flight Path Profile***

| | |
|---|---|
| Circumstances: | During visual night approach to Runway 9, the aircraft inadvertently descended well short (7 nm) of the runway before error was detected. Aircraft was well right of localizer in possible false lobes. No ILS flags. No GPWS below "Glide slope alert." |
| Configuration: | Landing |
| Weather: | 17? 11?, visibility: 30 mi |



The GPWS never alerted the crew to the low glide slope because the ILS had locked on to a false lobe, and it had never alerted the flight crew to the altitude deviation because the gear was down and the flaps were in the landing position. The GPWS was operating normally, because it used inputs from the Captain's instruments that reflected an on-glide-slope condition. The GPWS never reached a limit that was considered out of tolerance.

The flight crew noticed the low altitude, but paid little attention; the tower operator could not see the airplane, but the MSAWS on the ATC center radar noticed and saved the flight! (Figure 17)

### 3.3.2 Crew Briefings

Many of the CFIT accidents show a lack of flight crew communication. For example, while one pilot flew the approach, the other did not know or understand the intentions of the flying pilot. This lack of communication can lead to breakdowns in flight crew coordination and cross-checking. ***One of the best ways to let the nonflying pilot know what to expect is to conduct a briefing before each takeoff and each approach.*** While this seems elementary, many flight crews simply ignore the obvious safety implications of the briefings.

Accident statistics show that the vast majority of accidents occur during the approach at the destination airport. Is it not logical then to prepare carefully and properly for the arrival, approach, and landing? ***The approach briefing sets the professional tone for your safe arrival at the destination.*** The flying pilot should discuss how he or she expects to navigate and fly the procedure. This will not only solidify the plan for the approach, but it will inform the nonflying pilot of the flying pilot's intentions, which provides a basis for monitoring the approach. Deviations from the plan now can be more readily identified by the nonflying pilot. The approach briefing should be completed before arriving in the terminal area so that both pilots can devote their total attention to executing the plan.

Operators should require briefings by the flight crew. As operations vary from country to country, some briefing items may be more important than others and some unique items may be added, but there are some items that should always be covered. ***Use the following briefing guidelines if other guidance is not provided by standard operating procedures or the airplane manufacturer.***

Takeoff briefing:

- Weather at the time of departure.
- Runway in use, usable length (full length or intersection takeoff).
- Flap setting to be used for takeoff.
- V speeds for takeoff.
- Expected departure routing.
- Airplane navigation aids setup.
- Minimum sector altitudes and significant terrain or obstacles relative to the departure routing.
- Rejected takeoff procedures.
- Engine failure after V1 procedures.
- Emergency return plan.

Approach briefing:

- Expected arrival procedure to include altitude and airspeed restrictions.
- Weather at destination and alternative airports.
- Anticipated approach procedure to include:
  - Minimum sector altitudes.
  - Airplane navigation aids setup.
  - Terrain in the terminal area relative to approach routing.
  - Altitude changes required for the procedure.
  - Minimums for the approach DA/H or MDA/H.
  - Missed approach procedure and intentions.
- Communication radio setup.
- Standard callouts to be made by the nonflying pilot.

### 3.3.3 Autoflight Systems

Proper use of modern autoflight systems reduces workloads and significantly improves flight safety. These systems keep track of altitude, heading, airspeed, and flight paths with unflagging accuracy. Unfortunately, there are a great number of first-generation airplanes that are still operating that do not have the advantages associated with well-designed, integrated systems. There are also some flight crews whose airplanes do have modern autoflight systems, that do not take full advantage of these systems to manage the progress of the flight and reduce workload. ***To assist in preventing CFIT, the proper use of autoflight systems is encouraged during all approaches and missed approaches, in IMC, when suitable equipment is installed.*** It is incumbent upon operators to develop specific procedures for the use of autopilots and autothrottles during precision approaches, nonprecision approaches, and missed approaches and to provide simulator-based training in the use of these procedures for all flight crews.

### 3.3.4 Route and Destination Familiarization

Flight crews must be adequately prepared for CFIT critical conditions, both enroute and at the destination. ***Flight crews must be provided with adequate means to become familiar with enroute and destination conditions for routes deemed CFIT critical.*** One or more of the following methods are considered acceptable for this purpose:

- When making first flights along routes, or to destinations, deemed CFIT critical, Captains should be accompanied by another pilot familiar with the conditions.
- Suitable simulators can be used to familiarize flight crews with airport critical conditions when those simulators can realistically depict the procedural requirements expected of crew members.
- Written guidance, dispatch briefing material, and video familiarization using actual or simulated representations of the destination and alternatives should be provided.

### 3.3.5 Altitude Awareness

It is essential that flight crews always appreciate the altitude of their airplane relative to terrain and obstacles and the assigned or desired flight path. Flight crews need to receive and use procedures by which they will monitor and cross-check assigned altitudes as well as verify and confirm altitude changes. As a minimum, in the absence of SOPs or airplane manufacturer guidance, use the following procedures:

- Ascertain the applicable MSA reference point. Note: The MSA reference point for an airport may vary considerably according to the specific approach procedure in use.
- Know the applicable transition altitude or transition level.
- Use a checklist item to ensure that all altimeters are correctly set in relation to the transition altitude/level. Confirm altimeter setting units by repeating all digits and altimeter units in clearance readbacks and intracockpit communications.
- Call out any significant deviation or trend away from assigned clearances.
- Include radio height in the pilot instrument scan for all approaches.
- Upon crossing the final approach fix, outer marker, or equivalent position, the pilot not flying will cross-check actual crossing altitude/height against altitude/height as depicted on the approach chart.
- Follow callout procedures (refer to The Use of Callouts, Section 3.3.6).

### 3.3.6 The Use of Callouts

Callouts are defined as aural announcements by either flight crew members or airplane equipment of significant information that could affect flight safety. These callouts are normally included in an airline's SOP. In the absence of other guidance, use these callouts to help prevent CFIT accidents. A callout should be made at the following times:

- Upon initial indication of radio altimeter height, at which point altitude versus height above terrain should be assessed and confirmed to be reasonable.

- When the airplane is approaching from above or below the assigned altitude (adjusted as required to reflect specific airplane performance).
- When the airplane is approaching relevant approach procedure altitude restrictions and minimums.
- When the airplane is passing transition altitude/level.

### 3.3.7 GPWS Warning Escape Maneuver

The GPWS warning is normally the flight crew's last opportunity to avoid CFIT. Incidents and accidents have occurred because flight crews have failed to make timely and correct responses to the GPWS warnings. The available time has increased between initial warning and airplane impact since the first version of the GPWS; however, this time should not be used to analyze the situation. React immediately. With the early versions, there was as little as 5 sec warning, and none at all if the impact point was on a relatively steep slope of a mountain. There may be as much as 30 sec for newer and future versions.

***In the absence of standard operating procedures or airplane manufacturer guidance, execute the following maneuver in response to a GPWS warning, except in clear daylight VMC when the flight crew can immediately and unequivocally confirm that an impact with the ground, water, or an obstacle will not take place:***

- React immediately to a GPWS warning.
- Positively apply maximum thrust and rotate to the appropriate pitch attitude for your airplane.
- Pull up with wings level to ensure maximum airplane performance.
- Always respect stick shaker.

***Continue the escape maneuver until climbing to the sector emergency safe altitude or until visual verification can be made that the airplane will clear the terrain or obstacle, even if the GPWS warning stops.***

### 3.3.8 Charts

Flight crews must be provided with and trained to use adequate navigation and approach charts that accurately depict hazardous terrain and obstacles. These depictions of the hazards must be easily recognizable and understood. On modern-technology airplanes, the electronic displays should resemble printed chart displays to the maximum extent feasible.

### 3.3.9 Training

Flight crew training can be a contributing factor to CFIT. It is also the key to CFIT accident prevention. Modern airplane equipment, extensive standard operation procedures, accurate charts, improved approach procedures, detailed checklists, or recommended avoidance techniques will not prevent CFIT if flight crews are not adequately trained. The cause of CFIT is the flight crew's lack of vertical and/or horizontal situational awareness. We know the solutions to these causes: a proper support infrastructure and a trained and disciplined flight crew. An example CFIT training program is provided in Section 4 of this training aid.

## 3.4 CFIT Traps

In the previous sections, the causes of CFIT and contributing factors are identified, along with recommendations and strategies that may be used to avoid CFIT accidents and incidents. It could be misleading to the reader when causes and factors are discussed separately. Accidents and incidents do not normally happen because of one decision, or one error. They rarely happen because the flight crew knowingly disregarded a good safety practice. Accidents and incidents happen insidiously. Flight crews fall into traps—some of their own making and some that are systemic. Let's look at some examples of traps that could happen when a flight crew employs one recommendation, but disregards another.

Go To Next Section

We have identified that nonprecision VOR instrument approaches are especially hazardous when they include shallow approach paths and several altitude step-down points. We recommend that the autoflight system be used, if available, to reduce the workload. While this technique may mitigate the problem with the approach procedure, it can create another trap if the flight crew becomes complacent and does not properly program the computer, monitor the autoflight system, make the proper cockpit callouts, etc.

In another situation, flight crews are encouraged to use the displays that modern cockpits provide to assist them in maintaining situational awareness. However, if they disregard the raw navigational information that is also available, they can fall into a trap if any position inaccuracies creep into the various electronic displays.

The importance of takeoff and arrival briefings is stressed as a means to overcome some of the factors associated with departures and arrivals. However, if the briefings do not stress applicable unique information or become rote or are done at the expense of normal outside-the-cockpit vigilance, their value is lost and the flight crew can fall into another trap.

It should be evident that there is no single solution to avoiding CFIT accidents and incidents. All the factors are interrelated, with their level of importance changing with the scenario. Be aware, the traps are there! Section 5, CFIT Background Material, provides many more examples of traps that can happen to you.