CAUSES AND REMEDIES OF CONTROLLED FLIGHT INTO TERRAIN IN MILITARY AND CIVIL AVIATION

Major Michael L. Moroze and Dr. Michael P. Snow[1]
Air Force Research Laboratory
Wright-Patterson Air Force Base, Dayton OH

ABSTRACT

Controlled flight into terrain (CFIT) accidents continue to be a primary cause of fatalities and airframe losses in aviation. Alerting and automation technologies such as Ground Proximity Warning Systems (GPWS), Enhanced Ground Proximity Warning Systems (EGPWS), and Ground Collision Avoidance Systems (GCAS) are offered as partial solutions to this problem. This article reviews current accident data for CFIT accidents in both US Air Force and commercial aviation over the last 10 to 15 years. The magnitude of the CFIT problem, circumstances in which it occurs, and its causes are detailed based on these data. The differences and similarities between CFIT in the Air Force and CFIT in civil aviation are discussed. Finally, current and future remedies of CFIT accidents in both the civil and military aviation communities are described, compared, and contrasted. It is concluded that, in addition to warning and automatic collision avoidance systems, systems are needed to improve flight crew situation awareness, especially terrain awareness.

INTRODUCTION

Controlled flight into terrain (CFIT) accidents have occurred since the beginning of flight with the loss of life estimated at 30,000 passengers and crew since 1931 (Cooper, 1995). This paper explores CFIT accidents that occur in commercial and US Air Force aviation. Several measures are also described that are being taken to combat CFIT accidents. First, a definition of CFIT is presented along with some of the statistics associated with CFIT accidents. Then, we describe the current and future technologies that address CFIT accidents. Finally, the technology needs that would help reduce CFIT are discussed.

What is CFIT? Controlled flight into terrain accidents are typically described as those accidents in which a flight crew unintentionally flies an aircraft into the earth or a man-made obstacle under conditions in which the aircraft is flyable. Note that the critical distinction in these types of accidents is the fact that the aircraft is flyable and under control of the crew. Typically, mechanical or equipment malfunctions are not considered the immediate cause of the accident; rather the accident's probable and immediate causes are often attributed to pilot or human error.

Commercial Aviation CFIT Mishaps. CFIT accidents can be further broken down into two broad classes based on the phase of flight: Enroute or level flight -- in which the aircraft is flying straight and level at a steady altitude; and descent, approach, and landing -- in which the aircraft is decreasing its altitude and trying to land safely (Corwin, 1995). While the approach and landing phase of flight accounts for only 4% of the entire flight time, 50% of all accidents (not just CFIT accidents) occur during this phase of flight (Matthews, 1997). A study that analyzed commercial CFIT accidents between 1988-1994 found that almost 70% of these accidents occurred during the descent, approach, and landing phase, while 20% occurred during the enroute phase (Khatwa and Roelen in Scott, 1996A). While it is logical to think that the landing phase of flight would account for the majority of commercial CFIT accidents, it also is logical to think that the cause of these accidents is probably due to significant terrain features such as mountains. This is true in the majority of cases; however, a significant portion (40%) of the commercial CFIT landing-phase accidents involved no significant terrain features (Scott, 1996A). A clear majority (87%) of these accidents occur during Instrument Meteorological Conditions (IMC), with 20% occurring when the aircraft inadvertently transitions from Visual Meteorological Conditions (VMC) into IMC (Scott, 1996A).

Most (71%) CFIT accidents involve aircraft designed to carry no more than 9 passengers (Scott, 1996A). However, large aircraft with highly experienced pilots flying scheduled flights along known and familiar flight paths are not immune to CFIT, as evidenced by the crash on December 20,1995 of American Airlines Flight 965 flight from Miami, FL to Cali, Columbia with 167 passengers and crew aboard. One hundred and sixty-three people died in this crash. This crash is also significant because it was the first crash of a Boeing 757 that resulted in fatalities (NTSB, 1995). CFIT remains a significant problem: approximately 40% of all aircraft accidents are CFIT accidents and CFIT accidents account for "well over half of all aviation fatalities" (Matthews, 1997). In addition, the fatalities associated with CFIT are disproportionately high. Khatwa and Roelen report that three-quarters of all CFIT accidents result in the death of all passengers and crew on board the aircraft (in Scott, 1996A).

Air Force CFIT Mishaps. One would expect that the Air Force would experience a CFIT problem that is at least as

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[1] Point of contact for this paper is Michael P. Snow, AFRL/HECI, Wright-Patterson Air Force Base, OH, 45433-7521.

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great as the commercial sector, if not greater. This is due to the difference between the two sectors in their basic mission. In commercial aviation, the role of the aircraft is to move people or materials from point A to point B. The same is true for the role of parts of the Air Force. However, the Air Force also has additional roles such as fighter combat, search and rescue, offensive air operations and the like. The inherently more dangerous nature of these additional roles leads one to believe that there would be a significant amount of mishaps, including CFIT mishaps, in the Air Force. While training, safety interventions, and regulations help minimize the chance for the occurrence of CFIT mishaps, the number of CFIT mishaps remains quite high, as does their associated cost. Figure 1 (derived from Smith, 1997) depicts the size of the AF CFIT problem over the last 10 years.

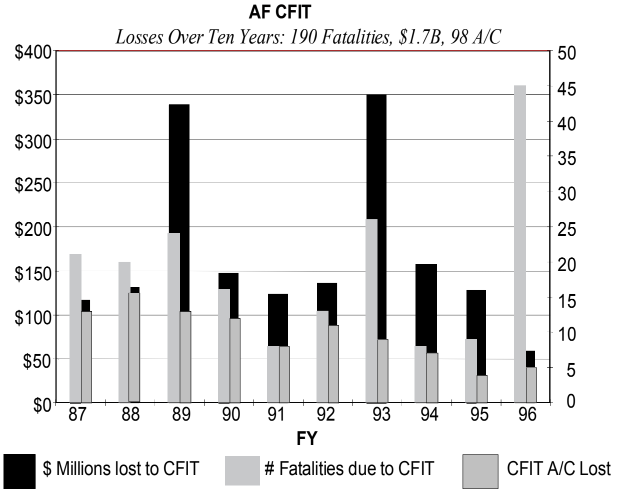

Figure 1. Air Force CFIT problem: 1987-1996.

As can be seen from the figure, the numbers depicting the costs of CFIT mishaps are staggering -- almost $2 Billion, 200 fatalities, and 100 aircraft lost over the last 10 years alone.

Krause (1994) investigated the extent of the CFIT problem in the Air Force from 1980 through January 1994 and classified the accidents on a variety of attributes. During this period there were 229 mishaps or incidents that were classified as CFIT. Most of these mishaps (172) fell into the Class A - Destroyed category, defined as a destroyed aircraft with or without a fatality. As can be expected, CFIT mishaps closely follow the flying patterns and population demographics of the Air Force.

CFIT and AF Flying Patterns. There appear to be no seasonal or monthly pattern in the data, although July, August, and September appear to have fewer CFIT accidents. The month of December has the fewest (possibly due to the fewest number of flying hours as well), although, interestingly, the low in December is followed by a high in January (Krause, 1994). A Chi-Square Goodness of Fit Test shows that there are no statistical differences in CFIT accident rates by month (χ^2 (11) = 7.69,$p > 0.05$). Looking at the differences between years, there is a statistically significant difference (χ^2 (13) = 20.66, $p < 0.05$) with 1983 and 1984 appearing to have more than expected CFIT mishaps and 1993 appearing to have fewer than expected CFIT mishaps. Reasons for these differences are unclear.

Krause (1994) also looked at the environmental conditions surrounding CFIT mishaps, and found that these attributes mirror the typical AF flying pattern. That is, most CFIT mishaps occur during day conditions and in VMC (visual meteorological conditions). His data are presented in Table 1.

Table 1. Visibility conditions and CFIT occurrence.

Day/Night Conditions	Meteorological Conditions
78% of CFITs occur during day conditions	72% of CFITs occur in VMC
21% of CFITs occur during night conditions	25% of CFITs occur in IMC

Air Force Pilot/Crew Experience. One would expect that the experience of the pilot and/or crew would have significant impact on the CFIT mishap occurrence. Krause (1994) reports that there is some connection between the general experience level of the pilot/crew and the likelihood of a CFIT mishap. With respect to rank, there appears to be a relationship between rank and the occurrence of CFIT mishaps with 1st Lieutenants and Majors having more than their fair share of CFIT accidents and Captains having less (χ^2 (5) = 25.3, $p < 0.05$).

When one looks at the flight hours, a similar pattern arises. Crews in which the most senior member has a UE (unit equipped) time of 100 - 300 hours have significantly more CFIT mishaps than would be expected. Compare this with crews in which the most senior member has a UE time of 1000 -2000 hours who have significantly fewer CFIT mishaps (χ^2 (11) = 22.3, $p < 0.05$). This again can relate to the behavior patterns associated with experience. When one looks at the crew's total flying time, crews that have between 300 - 500 flying hours have a disproportionate number of CFIT mishaps (χ^2 (11) = 61.3, $p < 0.05$). However, the data show that CFIT mishaps can happen to even the most experienced pilots/crews (those with over 4000 hours of UE or total time).

Air Force Aircraft. One of the most consistent findings across any of the reviews of the data is the types of aircraft that are involved in CFIT mishaps. This should not be surprising since certain types of aircraft (such as fighter, attack, or reconnaissance aircraft) perform more dangerous missions. However, even though most (71%) of the CFIT mishaps occur in fighter-type aircraft, a significant portion of the CFIT mishaps occur in other aircraft: transport (9%), trainer (5%), helicopter (12%), other (3%). (Data from 1980 to June 97, Krause, 1994).

Surprisingly, even though fighter aircraft account for most of the CFIT mishaps, most (85%) of the fighter mishaps occur off range (the range is the area where "combat" maneuvers are practiced). Fifteen percent of the mishaps occur on range and of these all were fighter type aircraft. (Krause, 1994)

The mission profiles for AF CFIT mishaps from 1980 through January 1994 show that the more aggressive and difficult flight profiles account for the majority of mishaps. Not surprisingly, a low-level flight profile is a major contributing factor in CFIT mishaps for all aircraft types. Additionally, the pattern for heavy transports is very similar to commercial aviation and points to the flight profile that is linked to commercial CFIT accidents as well. Another note is that these flight profiles take place during high task load on the operator and, in the fighter/attack case, high physiological load as well. It is not surprising, then, that we find that over 50% of CFIT mishaps have situational awareness components listed as contributing factors.

TECHNOLOGY REMEDIES

Ground Proximity Warning System (GPWS). It was clear during the early 1970s that the cost of CFIT accidents, especially with respect to commercial aviation, was too high. Therefore, the Federal Aviation Administration (FAA) required that airlines (and therefore aircraft manufacturers) install GPWS in the commercial aviation fleet. The FAA had a simple objective: "Build a system that would provide adequate warning of terrain contact, accounting for such items as crew recognition and reaction times, and take the flight crew out of the setting/interpretation loop." (Gurevich, 1991) The technology of the GPWS at this point (and currently) was to provide a look-down capability that would take into account the rise of terrain along with a projection of that terrain into the aircraft's flight path and combine that information with piloting information to provide an aural indication to the flight crew that a dangerous situation was imminent. One of the more significant drawbacks of this design as described by Gurevich (1991) and others (Cooper, 1995; Chazelle, 1995) is the number of nuisance alarms that are generated. Other issues associated with this design include late warnings (where the crew cannot react in time) or no warning at all (especially in certain configurations, such as landing). In the case of a false alarm, the aircraft will not impact terrain regardless of any avoidance maneuvers the crew may take. For this scenario, the cost of trying to avoid the terrain may be high in both aircraft damage (e.g., overstressing the aircraft) and passenger injuries due to evasive maneuvers. This behavior has the additional detriments of increasing crew reaction time as they try to better understand the situation leading to the alert, and habituating the crew to GPWS warnings so that warnings take on less and less meaning and therefore becomes less effective (Chazelle, 1995).

In another case, the GPWS can provide an alarm that the aircraft is approaching a dangerous situation, but the terrain's rise is so severe that it does not provide enough time for the crew to maneuver out of the situation. In this scenario, the aircraft will impact the terrain, regardless of any actions taken by the crew. Here, the pilot requires additional warning time to escape the terrain. Of course, increasing the warning time affects the number of false alarms, and therefore a trade-off needs to be made. The pilot, typically, performs this trade-off. Here the pilot attempts to determine the actual state of possible threat terrain, losing valuable seconds when impact is imminent, but saving potential damage and injury when it is not.

The reaction time of the pilot is critical to the success of the evasive maneuver. Typically, the generation of a GPWS warning provides 10-30 seconds advance warning of impact (Up in the Air, 1997). However, Gurevich (1991) reports that the average time from a GPWS warning to impact is 15 seconds. Gurevich reports that a study of data from Flight Data Recorders from two carriers' GPWS-initiated go-arounds showed an average pilot reaction time of 5.4 seconds, at a rotation rate of 1.4 degree/second to an 8.2-degree nose-up rotation. Some of the pilots took up to 13 seconds to react or rotated to only 4.1 degrees. Gurevich also reports that Boeing has found that maximum performance for large aircraft in a pull up or climb maneuver is a 15-degree body angle. These data clearly demonstrate that crews usually do not attain optimal flight characteristics to avoid terrain in response to a GPWS alert. In addition, these statistics come from pilots on carriers whose management policies clearly state that an immediate and unquestioned go-around should be executed as soon as a hard GPWS alert is sounded. While the GPWS provides for some warning, in many cases it is not enough.

Enhanced GPWS (EGPWS). Before GPWS was mandated in the mid 1970s for commercial aircraft by the FAA, pilots relied on piloting skills to determine if terrain encroached on the flight path. The GPWS mandate reduced CFIT accidents from about 9 per year in the seven years immediately preceding the mandate to about 4 per year after (Gurevich, 1991; but see also Proctor, 1997). This rate has remained fairly constant. In 1997, the Gore

Commission on Aviation and Safety (Gore, 1997) stated that CFIT remains a significant aviation safety issue. One of the recommendations of the Gore Commission was that both commercial and military passenger aircraft should have EPGWS installed. EGPWS includes all the same features as the current GPWS but also includes a predictive component. This predictive component would enable the EGPWS to provide more warning time -- up to 60 seconds -- in cases where impact into precipitous terrain is imminent (Proctor, 1997). In addition to this look-ahead capability, the EGPWS also incorporates the use of a worldwide digital terrain elevation database and a color-coded display of threat terrain.

Auto-GCAS. The Air Force has developed a system that has a great deal of potential in reducing CFIT accidents. In its Advanced Fighter Technology Integration (AFTI) F-16 program, the Air Force has been testing an automatic ground collision avoidance system (Auto-GCAS). Through the use of many of the same technologies -- digital terrain elevation database, radar altimeter, integration with navigation systems -- the Air Force has demonstrated a capability to reduce CFIT. This technology, though, goes one step further than the technologies employed in commercial EGPWS. The Auto-GCAS system has the ability to take control of the aircraft and execute a recovery to avoid terrain impact. The system is 3-dimensional and can execute a recovery through either a vertical or lateral maneuver (Scott, 1996B).

The Auto-GCAS system works by providing the pilot with an indication of his descent toward terrain. When the system is activated, horizontal chevrons (> <) appear at the side of the pilot's Heads-Up Display (HUD) as the aircraft maneuvers toward the ground or at low altitude. If the system determines that a fly-up maneuver within the next five seconds is needed to avoid terrain, the chevrons begin to move toward each other. When the chevrons meet, forming an "X," the pull-up maneuver is initiated. A head-down display flashes a "Break X" one second before the pull-up is initiated. Over 1,000 auto-recovery flights have been conducted. The results suggest that an automatic recovery system should be included as a final life-saving line of defense against CFIT.

In his paper discussed earlier, Krause (1994) performed an analysis to determine whether a GCAS system would have affected the outcome in the mishaps surveyed. In looking at each accident report (total of 229), he projected what the effect would have been if a GCAS system had been available. As shown in Table 2, a significant number (23% or 31%) of CFIT accidents would still have occurred even if avoidance or warning systems were employed.

Table 2. Projected effects of GCAS on CFIT.

	Auto Recovery GCAS		**Warning GCAS**	
	Number	Percent	Number	Percent
Probably Prevented	165	72%	129	56%
Possibly Prevented	3	1.3%	21	9.1%
Probably Not Prevented	53	23%	71	31%

Note: 8 (3.5%) unknown

SITUATION AWARENESS

Situation awareness (SA) is loosely defined as the perception, understanding, and ability to forecast the factors affecting the aircraft at any moment in time (Wickfield, 1996). Although not a new concept, it is very difficult to determine all the factors that comprise it. The general sense is that it is made up of those factors that allow the pilot and crew to safely pilot the aircraft, and in that sense then, it is the essence of the human-machine interface. As Cooper (1995) relates, situation awareness is the ability to "make and retain an accurate mental model of the outside world." Several authors suggest that one of the most common attributes of CFIT accidents is pilot or crew lack of situation awareness (Cooper, 1995; Scott, 1996B; Gore, 1997; Wickfield, 1997). Other authors investigating this issue more specifically identify this behavior as a lack of terrain situation awareness or terrain awareness (Kuchar & Hansman, 1993; Rate, Probert, Wright, Corwin, & Royer, 1994). In any case, it is the overall lack of the crew's understanding of where they are and where they are going in 3-dimensional space that enables CFIT to occur.

Why does a lack of SA occur? In some cases it's due to ambiguous or conflicting information. In others it can be due to weather conditions or inadequate planning. In still others it could be due to overload or task saturation. Cooper (1995) relates that automation may contribute to the lack of situation awareness. His thesis is that automation has reduced pilot workload for the majority of a flight but still leaves relatively intense periods of activity when pilot actions are required. It is well known that vigilance and monitoring tasks leave human operators susceptible to loss of contact with the state of the system being monitored.

We reviewed the data from Krause (1994) and found that factors related to spatial awareness accounted for a high percentage of CFIT mishaps. The data included the time spanned from 1980 through June of 1997, which included another 25 CFIT mishaps, for a total of 254 CFIT mishaps. By looking at the accident reports, we categorized the data into several groups. One group was the group in which spatial disorientation (SDO) was specifically mentioned in the accident report as a contributing or possibly contributing factor. The other groups were broken out to include other factors that may influence situation awareness (SA). These factors included channelized attention, task saturation, and/or visual illusion. The mention of these factors in the accident reports suggests that the pilot/crew had SA that contributed to the mishap. Figure 2 portrays these data and shows that over half of these accidents had some component of lost situation awareness listed as a contributing factor (note that one or more factors may have contributed to the CFIT mishap).

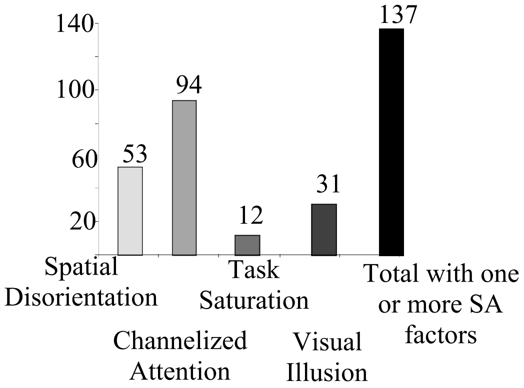

Figure 2. Situation awareness factors contributing to CFIT.

WARNINGS ARE NOT SUFFICIENT

The use of technology as it applies to CFIT reduction generally follows the model of "warn - act". That is, the technologies described above provide a warning to the crew when a dangerous situation is imminent. Implicitly, this means that the crew has already lost situation awareness (or they wouldn't be flying towards terrain), and that they must immediately (and typically without question) perform an escape maneuver. This strategy may not be optimal given the reaction times "both physically" - the time it takes to initiate and execute a control movement and "situationally" - the time it takes to assess the situation and plan an action to execute.

There are technologies in the laboratories and some commercially available that are designed, at least in part, to increase overall situation awareness of the crew. These technologies take advantage of available digital terrain data and incorporate this information into flight displays. The advantage to this strategy is that the crew/pilot is continually informed about the overall aircraft situation as it applies to terrain and navigation points. One would assume then, in an emergency situation, the crew already has a better understanding of the emergency then would be provided during a warning-only situation. For military aircraft, this has the added advantage of assisting in high workload flight profiles such as terrain following when the aircraft flies very close to the ground.

Kuchar and Hansman (1993) conducted two studies to better understand how varying display parameters could improve pilots' situation awareness concerning aircraft vertical position. In the first study they found that plan and perspective displays were preferred over a profile display, with the plan display being the most preferred. Another finding of this study was that pilots appeared to take different evasive actions depending on the type of display format. This suggests that display formats did not provide the same lateral information to pilots.

In their second study, which used only the plan display format, Kuchar and Hansman (1993) found that subjects preferred having information portrayed relative to their aircraft instead of with respect to the absolute mean sea level. In addition, subjects were able to determine if their route was clear of obstacles faster using the relative mode. Displaying information relative to current aircraft position may reduce the overall mental workload of pilots by reducing the number of translations that must be accomplished to determine the aircraft's position in space relative to surrounding hazards.

Another technology that has been shown to improve situation awareness, at least concerning the intended flight path, is the "pathway-in-the-sky." The pathway format provides the pilot with a graphic depiction of the commanded flight path, giving the pilot information regarding current state as well as information about the desired future state of the aircraft. Reising, Liggett, Solz, & Hartsock (1995) compared a traditional head-up display with a pathway head-up display to fly a curved instrument approach. Their results suggest that a pathway format provides the information needed for better flight performance in this task. They report that pilots describe the major benefit of this technique as being "instant situation awareness."

CONCLUSION

While providing enhanced warning or avoidance systems will certainly curtail a significant portion of CFIT mishaps in military as well as commercial aviation, an additional reduction could be made by enhancing the overall situation awareness of the pilot/crew. As described above, more than 50% of AF CFIT mishaps involve at least one situation awareness component as a contributing factor to the accident. Taking this fact into consideration, along with the assumption that CFIT mishaps usually occur during high workload flight profiles, we suggest that providing the pilot/crew with a better understanding of the aircraft's situation with respect to the earth, the flight profile, and aircraft performance would help to reduce the overall CFIT mishap rate. In addition, there appears to be a relationship between pilot experience and proficiency and CFIT mishaps. Improving situation awareness for pilots/crews with less experience or proficiency in a given aircraft type may be especially beneficial.

Controlled Flight Into Terrain (CFIT) has been a major aviation safety issue for several decades. Even with technologies such as Ground Proximity Warning Systems (GPWS), CFIT remains a significant safety issue. While newer technologies such as Enhanced GPWS, and Ground Collision Avoidance Systems (GCAS) will certainly reduce the number of CFIT accidents, a broader perspective must be taken. Technologies that are based on "warn - act" strategies primarily treat symptoms that occur once a dangerous situation has arisen. Increasing situation awareness and addressing other issues such as training and communication have an equally important role to play in reducing CFIT. By implementing systems that focus on these latter strategies, cockpits can be designed to lessen dependency on warning systems and reduce the likelihood of entering into dangerous situations in the first place.

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REFERENCES

Chazelle, X. (1995). A new concept for combating controlled flight into terrain. *Terrain Databases and their use in Navigation and Collision Avoidance, Colloquium by Professional Group 15 (Radar, sonar, and navigation systems),* April 4, 1995.

Cooper, J. (1995). Controlled Flight into terrain. *Aerospace 22(2),* 16-19. February 1995.

Corwin, W. (1995). Controlled flight into terrain avoidance: why the ground proximity warning system is too little, too late. *Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting.* Santa Monica CA: Human Factors and Ergonomics Society.

Gore, A. (1997). White House Commission on Aviation Safety, February 12, 1997.

Gurevich, A. (1991). Pull up pull up - The when and how of GPWS pull ups. *British Airways Flight Deck - Issue 1, Autumn 1991.* www.natcavoice.org/av/avs/pullup.htm

Krause, N. (1994). Controlled flight into terrain (CFIT), USAF History 1980-1993. Unpublished data. US Air Force Safety Center, Kirtland AFB, NM

Kuchar, J and Hansman, J. (1993). Part-task Simulator Evaluations of Advanced Terrain Displays. *Education, Training, and Human Engineering in Aerospace*, 1993

Matthews, S. (1997). Proposals for Improving Aviation Safety and Changing the System. *Remarks to the White House Commission on Aviation Safety and Security, International Conference on Aviation Safety and Security in the Twenty-first Century*, Washington D.C., U.S., January 13, 1997.

NTSB, (1995). Colombian Press Release--Factual Data. *National Transportation Safety Board,* Washington D.C., December 28, 1995.

Proctor, P. (1997). Major Airlines Embrace Enhanced GPWS. *Aviation Week & Space Technology*, April 21, 1997.

Rate, C., Probert, A., Wright, D., Corwin, W., and Royer, R., (1994) Subjective Results of a Simulator Evaluation Using Synthetic Terrain Imagery Presented on a Helmet Mounted Display. *SPIE, Vol. 2218*, pp 306 - 315.

Reising, J., Liggett, K., Solz, T., and Hartsock, D. (1995). A comparison of two head up display formats used to fly curved instrument approaches. In *Proceedings of the 39th Annual Meeting of the Human Factors and Ergonomics Society* (pp. 1-5). Santa Monica, CA: Human Factors and Ergonomics Society.

Scott, W. (1996A). New Research Identifies Causes of CFIT. *Aviation Week & Space Technology*, June 17, 1997.

Scott, W. (1996B). New Technology, Training Target CFIT Losses. *Aviation Week & Space Technology*, November 4, 1997.

Smith, E. (1997). Unpublished data on Air Force Accidents. US Air Force Flight Safety Center, Kirtland AFB, NM.

Up in the Air. (1997). New ground-avoidance system uses Cold War Technology. http://whyfiles.news.wisc.edu/027plane_crash/ground_avoid1.html.

Wickfield, E. (1997). Cockpit Leadership: Losing the "Big Picture". *Printed in National Aeronautic Association's Newsletter, For the Record*, September/October 1996.