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Killers in Aviation:

FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents

Special FSF Report

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In This Issue

Killers in Aviation: FSF Task Force Presents Facts about Approach-and-landing and Controlled-flight-into-terrain Accidents **1**

This special report includes the most recent versions of working-group reports from the FSF Approach-and-landing Accident Reduction (ALAR) Task Force, as well as previously published reports that also include data about controlled -flight-into-terrain (CFIT) accidents. These combined reports present a unique and comprehensive review of ALAs and CFIT.

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Cover: Wreckage of Korean Airlines Flight 801, a Boeing 747-300, lies near the top of Nimitz Hill, three miles from Guam International Airport in Agana, Guam, on Aug.6, 1997. The flight crew was conducting a localizer approach to Runway 6L in instrument meteorological conditions when the aircraft, in a wings-level and slightly nose-high attitude, struck terrain and trees, and came to rest 2,100 feet (641 meters) from the initial impact point. Twenty-nine of the 254 people aboard the aircraft survived the accident.

Photo: U.S. National Transportation Safety Board

Flight Safety Foundation (FSF) is an international membership organization dedicated to the continuous improvement of flight safety. Nonprofit and independent, FSF was launched in 1945 in response to the aviation industry's need for a neutral clearinghouse to disseminate objective safety information, and for a credible and knowledgeable body that would identify threats to safety, analyze the problems and recommend practical solutions to them. Since its beginning, the Foundation has acted in the public interest to produce positive influence on aviation safety. Today, the Foundation provides leadership to more than 700 member organizations in 76 countries.

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Flight Safety Foundation Approach-and-landing Accident Reduction Task Force Final Reports

Preface

This special issue of *Flight Safety Digest* (*FSD*) presents several unique reports about approach-and-landing accidents (ALAs) and controlled-flight-into-terrain (CFIT) accidents — the primary causes of fatalities in aviation. The reports, some new and some previously published by the Foundation, combine to present a powerful image of two killers that remain at large in the international aviation community, despite their worldwide recognition.

Flight Safety Foundation (FSF) has targeted these two causes of accidents, as well as accidents caused by airplane upset and human factors, as the foremost challenges in commercial aviation safety.

The Foundation is not alone in its recognition of these accident causes, or in its efforts to gather and disseminate information to help prevent them. The International Air Transport Association (IATA) and the International Civil Aviation Organization (ICAO) are but two among many organizations and other FSF members that have worked earnestly with the Foundation in supporting two FSF-led international task forces that have focused, respectively, on the reduction and prevention of CFIT and ALAs.

Moreover, the difficult and time-consuming work of these task forces has involved a wide variety of volunteers who not only have presented factual data to further substantiate the seriousness of the issues, but have also recommended actions that could prevent accidents. (See “International Air Carrier Establishes Guidelines for Preventing CFIT Accidents” beginning on page 249 of this issue.)

The FSF Approach-and-landing Accident Reduction (ALAR) Task Force, created in 1996 as another phase of CFIT accident reduction launched in the early 1990s, presented its final working-group reports in November 1998; the reports were highlighted at the joint meeting of the FSF 51st International Air Safety Seminar, International Federation of Airworthiness 25th International Conference and IATA, at Cape Town, South Africa. Further refined since that meeting, the reports are reprinted in this *FSD* and provide compelling data.

None of this extraordinary work by the FSF ALAR Task Force could have been produced without the unselfish efforts of volunteers (listed on the following pages) and the support of their respective organizations, and we — all of us in the aviation community — owe them a heartfelt “Thank you!”

Together, we are making a safe transportation system even safer.

Stuart S Matthews.

Stuart Matthews
Chairman, President and CEO
Flight Safety Foundation

January 1999

FSF Approach-and-landing Accident Reduction Task Force Members

The success of this international effort was made possible by the volunteers who comprised the following working groups:

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Flight Safety Foundation
Approach-and-landing Accident Reduction Task Force

Analysis of Critical Factors During Approach and Landing in Accidents and Normal Flight

Data Acquisition and Analysis Working Group

Final Report (Version 2.0)

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Contents

Executive Summary

This document is the final report of the Data Acquisition and Analysis Working Group (DAAWG) of the Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force (Appendix D contains the complete listing of participants). The DAAWG was established in August 1997 to independently analyze data that may lead to the identification and/or resolution of approach-and-landing safety issues. Activities pursued by the DAAWG included: high-level analyses of 287 fatal accidents; detailed case studies of 76 accidents and serious incidents; and the assessment of key crew behavioral markers isolated in the occurrences and in the line audits of about 3,300 flights. The DAAWG is also conducting an economic analysis of the cost of approach-and-landing accidents (ALAs) to the industry (in progress).

Analysis of Fatal Approach-and-landing Accidents

The following conclusions emerged from the analyses of 287 fatal ALAs, involving jet and turboprop aircraft (maximum takeoff weight [MTOW] above 12,500 pounds/ 5,700 kilograms) and occurring between 1980 and 1996 (inclusive):

1. There were 287 ALAs resulting in 7,185 fatalities to passengers and crewmembers;
2. The average ALA rate is 14.8 fatal accidents per year for non-Commonwealth of Independent States (C.I.S.) aircraft. If the trend observed continues, 23 fatal accidents per year can be expected by the year 2010;
3. The world average accident rate for Western-built jets is 0.43 accidents per million flights. The fatal-accident rate for Western-built jets was highest for Africa (2.43 accidents per million flights) and South America and Central America (1.65 accidents per million flights). Australasia did not have any fatal accidents involving Western-built jets;
4. The fatal-accident rate involving Western-built jets for Europe's 18 full-member Joint Aviation Authorities (JAA) states is 0.16 accidents per million flights, 10 times lower than the rate for the other 26 European states;
5. The ALA rate for freight, ferry and positioning flights (no passengers carried) is possibly eight times higher than the rate for passenger flights;
6. Among occurrences where data were available, three-fourths of the accidents happened where a precision-approach aid was not available or was not used;
7. Fifty percent of the accidents occurred during daylight, 39 percent during night and two percent during twilight. The accident rate at night is estimated to be close to three times the accident rate during daylight;
8. "Omission of action/inappropriate action" by a flight crewmember was identified as the most common *primary* causal factor. This usually referred to the crew continuing descent below the decision height (DH) or minimum descent altitude (MDA) without adequate visual reference;
9. The second most common primary causal factor was "lack of positional awareness in the air," generally resulting in controlled flight into terrain (CFIT);
10. When all causal factors (*primary* and *contributory*) are considered, the most frequent are those referred to above as primary causes, plus "slow and/or low on approach," "flight handling" and "poor professional judgment/ airmanship";
11. Aircraft built and operated in the C.I.S. had "press-on-itis" as the most frequent causal factor; this factor was sixth in the overall ranking. ("Press-on-itis" refers to continuing an approach when conditions suggest otherwise.);
12. The most frequent *circumstantial factors* were "nonfitment of [not being equipped with] presently available safety equipment" (generally ground-proximity warning system [GPWS]) and "failure in crew resource management (CRM)." Inadequate CRM practices were seen as circumstantial factors in nearly half of the accidents. "Lack of ground aids" was cited in at least 25 percent of all accidents; and,
13. The most frequent *consequences* were "collision with terrain/water/obstacle" and "CFIT." These were followed by "loss of control in flight," "postimpact fire" and "undershoot." For Eastern-built (C.I.S.) jets, fatal overruns were the most frequent consequence; this consequence ranked sixth overall.

Analysis of Approach-and-landing Accidents and Serious Incidents

The following conclusions emerged from the analyses of 76 ALAs and serious incidents (occurrences) that occurred during the period 1984–1997 (inclusive):

1. Fifty-nine percent of the aircraft were equipped with an operating cockpit voice recorder (CVR) and 52 percent with a flight data recorder (FDR). Many of the high-quality occurrence data available to the DAAWG were associated with those occurrences;
2. The study sample is biased because of the disproportionate number of occurrences associated with

North America and Europe (71 percent). This was a result of difficulties obtaining data from many other geographical areas;

3. CFIT, landing overruns, loss of control, runway excursion and nonstabilized approaches accounted for 76 percent of all occurrences;

4. Freight operations accounted for 17 percent of the sample, and 83 percent involved passenger operations — thus the accident rate for freight operations is potentially significantly higher;

5. Nonprecision approaches primarily were associated with CFIT accidents;

6. Sixty-seven percent of CFIT occurrences were in hilly or mountainous-terrain environments, and 29 percent were in areas of flat terrain. This suggests that significant terrain features are not necessarily a prerequisite for CFIT;

7. Almost 60 percent of the occurrences were in poor-visibility conditions, about half in precipitation and almost one-third in the presence of adverse winds;

8. Seventy-one percent of the CFIT occurrences were during poor-visibility conditions. Seventy-three percent of overruns/excursions occurred on wet runways and in precipitation, and 67 percent involved adverse wind conditions;

9. When data for dual-pilot operations are considered, the captain was the pilot flying (PF) in 74 percent of those occurrences. (This is not a measure of risk because exposure data are required.);

10. The most frequent causal factor (74 percent) was poor "professional judgment/airmanship" (i.e., decision making). Another form of poor decision making, "press-on-itis," accounted for 42 percent of all occurrences;

11. "Omission of action/inappropriate action" (*inadvertent* standard operating procedures [SOPs] deviation) was the second most frequent causal factor (72 percent). The "*deliberate* nonadherence to procedures" accounted for 40 percent of the sample;

12. "Failure in CRM (cross-check/coordinate)" was the third most frequent causal factor (63 percent);

13. The fourth most frequent causal factor (51 percent) was "lack of positional awareness." This generally implied lack of vertical-position awareness, resulting in CFIT;

14. Poor "aircraft handling" was a causal factor in 45 percent of all occurrences. Poor energy management was an associated factor in many occurrences. Although low-energy approaches (36 percent "slow and/or low") resulted in some loss-of-control occurrences, CFIT was the primary consequence. Thirty percent of all occurrences involved high-energy approach conditions;

15. "Slowed/delayed crew action" was a causal factor in 45 percent of the study-sample occurrences;

16. "Incorrect or inadequate ATC instruction/advice/service" was a causal factor in 33 percent of all occurrences. Consequences included increased cockpit workload, reduced levels of both crew coordination and situational awareness, and a breakdown in CRM between the flight crew and air traffic control (ATC);

17. Formal occurrence reports documented both controllers and flight crewmembers using nonstandard phraseology;

18. Occurrences involving ambiguous communication of an onboard emergency by flight crews, without an ATC request for clarification/verification, were identified. In other occurrences, aspects of ATC handling of the aircraft during emergency situations may have confused or distracted flight crewmembers;

19. Fatality resulting from postimpact fire was a factor in 26 percent of all occurrences. Associated factors included confusion during the rescue arising from poorly defined procedures, and communication among aircraft rescue and fire-fighting (ARFF) services, airport authorities, ATC and the operator;

20. "Lack of qualification/training/experience" on aircraft type or type of operation being conducted was a causal factor in 22 percent of all occurrences;

21. "Disorientation and illusions" was a causal factor in 21 percent of the study-sample occurrences;

22. "Automation interaction" was a causal factor in 20 percent of all occurrences. Evidence suggests that crew unawareness of systems or unfamiliarity with systems was a factor. The autopilot, autothrottle, flight director, flight management system and radio altimeter were typical subsystems cited;

23. On average, 10 causal factors (out of 64) were involved per occurrence, with a maximum of 24. For the 22 crew-related causal factors, the average was 6.9, with a maximum of 17. Crew-related causal factors were implicated in 93 percent of the accidents and serious incidents. Crew-related causal factors constituted 68 percent of the total causal-factor ratings;

24. The causal factor "failure in CRM (cross-check/coordinate)" was significantly correlated with nine of the other 22 causal factors. Thus, 10 of the 22 crew factors were associated with CRM;

25. The most frequent circumstantial factor was "poor visibility" (59 percent). Contaminated "runway condition" was a factor in 18 percent of all occurrences;

26. "Failure in CRM (cross-check/coordinate)" was the second most frequent circumstantial factor (58 percent) and the third most frequent causal factor;

27. "Incorrect or inadequate crew procedures" was attributed to 47.4 percent of all occurrences, the third most frequent circumstantial factor;

28. "Company management failure" was identified as a circumstantial factor in 46 percent of all occurrences;

29. "Inadequate/inappropriate training" was a circumstantial factor in 37 percent of all occurrences;

30. "Inadequate regulation" accounted for 30 percent of the study-sample occurrences, and "inadequate regulatory oversight" was involved in 25 percent of the occurrences;

31. The "nonfitment of presently available safety equipment" (generally GPWS) was a circumstantial factor in 29 percent of all occurrences;

32. "Lack of/inadequate ATC" (12 percent) and "lack of/inadequate ground aids" (21 percent) were the two circumstantial factors related to ground infrastructure; and,

33. A high proportion of occurrences involved postimpact fire (42 percent), and 16 percent of all occurrences also involved emergency-evacuation difficulties.

Analysis of Crew Behavioral Markers during Line Audits

1. The analysis of crew errors during line audits found that the highest percentage of errors (49.4 percent) occurred during the approach-and-landing phase of flight. This confirms the greater risk associated with this phase;

2. In order of importance, the most frequently cited negative behavioral markers were failure to stay "ahead of the curve" (80 percent), poor vigilance (70 percent), poor leadership (49 percent), failures of inquiry (49 percent), inadequate assertion (38 percent), poor briefings (37 percent) and inadequate teamwork (26 percent);

3. The two automation markers were "failure to use the technology at the appropriate level" (42 percent), followed by "failure to verbalize flight management computer inputs" (33 percent); and,

4. Line-audit data provide organizations information needed to take proactive steps for safety, and to design training that addresses critical issues.

Key Recommendation Areas

Recommendations were derived from the results of the data analyses for specific industry groups: regulatory authorities; operators; flight crew; air traffic services (ATS); controllers; airport authorities; accident-investigation bodies; and manufacturers (airplane and equipment). Key recommendation areas include (not in any order of priority):

1. **Improved audit and surveillance** of operators by regulatory authorities;

2. **Terrain awareness and airplane-energy awareness** — Use of terrain-awareness and warning systems (TAWS), radio altimeters, navigation charts with colored contours depicting either terrain or minimum flight altitudes, head-up displays, and application of new flight deck technologies;

3. **Approach procedures** — Design of nonprecision approaches and use of global navigation satellite system (GNSS)/required navigation performance (RNP)/barometric vertical navigation (VNAV) approach procedures;

4. **Provision of terminal-area facilities** — Use of precision-approach guidance, approach and runway lighting, visual approach guidance and minimum safe altitude warning system (MSAWS);

5. **Flight-crew training** – Environment (adverse weather, light conditions, illusions, etc.); CRM including error management, risk assessment and decision making; nonprecision approaches; automation management; aircraft minimal control criteria; missed approaches; GPWS/TAWS and crew-ATC interaction and communication;

6. **Air traffic controller procedures and training** — Crew-ATC interaction and communication, aircraft automation capabilities, and handling of aircraft during abnormal/emergency situations;

7. **Joint emergency training programs** — Emergency procedures and common phraseology for operators, airports, ATS and emergency services;

8. **Standard operating procedures** — Establishing routine standard operating procedures (SOPs), go-around policy, approach ban, pilot flying during abnormal/complex conditions and automation use;

9. **Adoption of flight-data monitoring and safety-reporting programs** such as flight operational quality assurance (FOQA) by operators, ATS and airports;

10. **Provision of flight data recorders and cockpit voice recorders**;

11. **Investigation of accidents and serious incidents** — States' compliance with International Civil Aviation Organization (ICAO) Annex 13;

12. **Safety information** — Global coordination of the sharing and distribution of safety data; and,

13. **Operating standards**.

1. Introduction

Data from many safety studies show that approach-and-landing phase accidents account for a significant proportion of air transport accidents. Approximately 56 percent of the world jet-fleet accidents to date occurred in these flight phases and accounted for 44 percent of all fatalities.[1] In contrast, the duration of the approach-and-landing phase is typically 16 percent of total flight time.[1] One of Flight Safety Foundation's (FSF's) recent priorities has been reducing the approach-and-landing accident (ALA) rate.

The escalating costs of each accident in human-life and financial terms are significant and are not tolerable by the industry or traveling public. As most ALAs occur in the vicinity of airports, public awareness is bound to increase. Intense media coverage of these accidents maintains this high public awareness.

Abbreviations and Acronyms

AAG	Accident Analysis Group — U.K. CAA
AAIB	U.K. Air Accidents Investigation Branch
ADREP	ICAO Accident/Incident Data Reporting Systems
AIG	ICAO Accident Investigation and Prevention Division
ALA	Approach-and-landing accident
ALAR	Approach-and-landing accident reduction
ALPA	Air Line Pilots Association, International
AP	Autopilot
ARFF	Aircraft Rescue and Fire Fighting
ASAP	FAA Aviation Safety Action Program
AT	Autothrottle
ATC	Air traffic control
ATS	Air traffic services
BAe	British Aerospace
BASI	Australian Bureau of Air Safety Investigation
BASIS	British Airways Safety Information System
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication (U.K. CAA)
CFIT	Controlled flight into terrain
C.I.S.	Commonwealth of Independent States
CRM	Crew resource management
CVR	Cockpit voice recorder
DAAWG	Data Acquisition and Analysis Working Group
DH	Decision height
ECCAIRS	European Coordination Center for Aircraft Incident Reporting Systems
EGPWS	Enhanced ground-proximity warning system
FAA	U.S. Federal Aviation Administration
FD	Flight director
FDR	Flight data recorder
FOQA	Flight operational quality assurance
FSF	Flight Safety Foundation
FMS	Flight management system
GAIN	Global Analysis and Information Network
GNSS	Global navigation satellite system
GPWS	Ground-proximity warning system
HUD	Head-up display
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFALPA	International Federation of Air Line Pilots' Associations
IFR	Instrument flight rules
IMC	Instrument meteorological conditions
ISASI	International Society of Air Safety Investigators
JAA	Joint Aviation Authorities
LLC	Line/LOS checklist
LOFT	Line-oriented flight training
LOS	Line-oriented simulation
MCTM	Maximum certified takeoff mass
MDA	Minimum descent altitude
MSAWS	Minimum safe altitude warning system
MTOW	Maximum takeoff weight
NASA	U.S. National Aeronautics and Space Administration
NLR	National Aerospace Laboratory (NLR)–Netherlands
NM	Nautical mile
NTSB	U.S. National Transportation Safety Board
PAPI	Precision approach-path indicator
PF	Pilot flying
PNF	Pilot not flying
RA	Radio altimeter
RNP	Required navigation performance
SARPS	Standards and Recommended Practices (ICAO)
SOPs	Standard operating procedures
SWAPA	Southwest Airlines Pilots Association
TAR	Terminal approach radar
TAWS	Terrain-awareness and warning system
TSBC	Transportation Safety Board of Canada
VASI	Visual approach-slope indicator
VMC	Visual meteorological conditions
VFR	Visual flight rules
VNAV	Vertical navigation
WG	Working group

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

The Foundation established the FSF Approach-and-landing Accident Reduction (ALAR) Task Force in 1996. This global effort is a follow-up activity of the FSF Controlled-flight-into-terrain (CFIT) Task Force, and is supported by the International Civil Aviation Organization (ICAO), the International Federation of Airline Pilots' Associations (IFALPA), the International Air Transport Association (IATA) and the International Society of Air Safety Investigators (ISASI). The FSF ALAR Task Force goal is a 50 percent reduction in the ALA rate in five years.

The FSF ALAR Task Force comprises the following working groups (WGs):

- Aircraft Equipment WG;
- ATC Training and Procedures/Airport Facilities WG;
- Data Acquisition and Analysis WG; and,
- Operations and Training WG.

This final report documents the activities of the Data Acquisition and Analysis Working Group (DAAWG). The role of the DAAWG has been central to the FSF ALAR Task Force activities, and the main focus has been safety-data analyses to identify problem areas and solutions to reduce the accident risk.[2] DAAWG's results also have been used extensively by the other WGs.

Both accident data and operational experience suggest that factors associated with the descent phase can influence the safety of the approach-and-landing phase, for example, thoroughness of crew preparation for approach. Consequently, events occurring after initiation of the descent define the scope of the DAAWG's interests, and the following phases were considered:

- Approach and landing;
- Circling maneuvers; and,
- Missed approach.

The term "occurrence" denotes accidents and serious incidents in this report.

1.1 Objectives of the Data Acquisition and Analysis Working Group

The DAAWG was established in August 1997. The goals of the DAAWG were to:

- Independently analyze data that may lead to the identification and/or resolution of approach-and-landing safety issues;
- Support data requests from other WGs; and,
- Generate data that clearly demonstrate to the industry the cost (both human-life and financial) of ALAs.

The DAAWG conducted four studies to meet these objectives:

- An analysis of 287 fatal ALAs;
- Detailed case studies of 76 ALAs and serious incidents;
- Assessment of crew performance in line audits, yielding a database of about 3,300 flights; and,
- Economic analysis of ALAs (in progress).

CFIT continues to be a significant contributor to ALAs and therefore was included within the work program, but repetition of FSF CFIT Task Force activities was avoided.

Each of the above DAAWG studies is described in detail in subsequent sections of this report. The Operations and Training WG and the Aircraft Equipment WG also have used the results to generate their recommendations.

1.2 Previous Related Activities

Analysis of approach-and-landing safety issues in itself is not unique. The results of a literature survey of ALAs are presented in separate National Aerospace Laboratory (NLR)–Netherlands and FSF documents.[3,4] The review confirmed that there is no shortage of available literature and that over the years, much credible work has been performed by many organizations. The knowledge gained from such a review is important to prevent repetition of previous credible work. Some references date back to the 1960–1970 time frame and therefore may not necessarily reflect the current operational environment. Many of the recent studies have involved the FSF CFIT Task Force. The FSF ALAR Task Force used much of that work as a useful starting point for its own activities. The NLR also has studied the CFIT problem[4] as well as the influence of terminal area facilities on approach-and-landing safety.[5]

The DAAWG activities differ from other similar studies because data from accidents, serious incidents and line audits gathered from routine flights were employed in the analyses. Analytical methods employing taxonomies developed by the U.K. Civil Aviation Authority (CAA), NLR and The University of Texas at Austin were employed. In addition, the composition of the study team (highly multidisciplinary) and its international membership were unique to the DAAWG investigation. The FSF ALAR Task Force efforts built on the experience of the FSF CFIT Task Force work, and duplication of efforts was avoided as several task-force members participated in both activities.

2. Working Group

The DAAWG membership was multidisciplinary (flight crew, test pilots, human factors specialists, flight-deck designers, aeronautical engineers, researchers, controllers, regulators, accident investigators and safety analysts). Industry-wide participation and global support greatly aided the progress made. The following organizations supported the DAAWG:

Accident-investigation Bodies

U.K. Air Accidents Investigation Branch (AAIB), Australian Bureau of Air Safety Investigation (BASI), Transportation Safety Board of Canada (TSBC), U.S. National Transportation Safety Board (NTSB), ISASI

Airlines

American Airlines, Aviacsa Aeroexo, Continental Airlines, KLM Cityhopper

Airports

Amsterdam Airport Schiphol

Air Traffic Control

ATC Netherlands

Academia

Cranfield University Safety Centre, The University of Texas at Austin

Airplane Manufacturers

Airbus Industrie, Boeing Commercial Airplanes Group, British Aerospace Airbus

Avionics Manufacturers

Honeywell, Rockwell Collins

Pilot Unions

Air Line Pilots Association, International (ALPA), Southwest Airlines Pilots Association (SWAPA), IFALPA

Research Organizations

National Aerospace Laboratory (NLR)–Netherlands

Regulatory Bodies

U.K. CAA, ICAO

Training Organizations

FlightSafety Boeing

A list of individual DAAWG members is presented in Appendix D.

3. Approach-and-landing Fatal-accident Review

3.1 Introduction

Early in 1996, a group of specialists was set up within the U.K. CAA to systematically review global fatal accidents. The group was called the Accident Analysis Group (AAG). The AAG analyzed 621 fatal accidents that occurred between 1980 and 1996 (inclusive), and the analysis resulted in the publication of *Global Fatal Accident Review*.[6] From these 621 fatal accidents, 287 were judged to have occurred in the approach-and-landing phase of flight. Those fatal accidents formed the basis of part of the current study — see Appendix B.

3.2 Description of Accident Sample

The study included global approach-and-landing fatal accidents involving jet and turboprop airplanes with greater than 12,500 pounds/5,700 kilograms maximum takeoff weight (MTOW) that occurred between 1980 and 1996 (inclusive) — during public transport, business flights, commercial training flights and ferry/positioning flights. The following types of accidents were excluded from the study:

- Helicopter accidents;
- Piston-engine-aircraft accidents;
- Accidents resulting from acts of terrorism or sabotage;
- Fatalities to third parties not caused by the aircraft or its operation;
- Eastern-built aircraft and operators from the Union of Soviet Socialist Republics (U.S.S.R.) or Commonwealth of Independent States (C.I.S.) prior to 1990 (because information from these countries was unavailable or limited at that time); and,
- Military operations or test flights.

3.3 Sources of Data

Summaries of the accidents were obtained from the *World Aircraft Accident Summary*.[7] The summaries were usually brief and were supplemented with other information when required and available. Numbers of flights also were obtained from Airclaims and other sources when available.

3.4 Methodology

The review process by the AAG involved reaching consensus views to establish which causal factors, circumstantial factors and consequences occurred in each accident, together with an assessment of the level of confidence in the information available. In addition, a single primary causal factor was selected from the causal factors identified.

3.5 Taxonomy

3.5.1 Causal Factors

A causal factor is an event or item judged to be directly instrumental in the causal chain of events leading to the accident. An event may have been cited in the accident summary as having been a causal factor or it may have been implicit in the text. Whenever an official accident report was quoted in the accident summary, the AAG used any causal factors stated in the report for consistency; additionally, as noted in Section 3.4, the AAG selected one primary causal factor for each accident (though this proved to be difficult for some accidents). Where the choice of factor was contentious, the group agreed to decide a particular approach as a matter of policy, and then applied this policy consistently for all other similar occurrences.

The causal factors are listed in generic groups such as "aircraft systems" and then broken down into specific factors such as "system failure affecting controllability." The full list is in Appendix C.

An accident may have been attributed to any number of causal factors from any one group and any combination of groups. The highest number of causal factors recorded was 10, attributed in an accident in which an aircraft undershot the runway.

3.5.2 Circumstantial Factors

A circumstantial factor is an event or item that was judged not to be directly in the causal chain of events but could have contributed to the accident. These factors were present in the situation and were felt to be relevant to the accident, although not directly causal. For example, it was useful to note when an aircraft was involved in CFIT and was not equipped with a ground-proximity warning system (GPWS). Since GPWS was not mandatory for all aircraft in the study and an aircraft may be flown safely without GPWS, the nonfitment of (not being equipped with) GPWS in a CFIT accident was classed as a circumstantial factor rather than a causal factor.

Circumstantial factors, like causal factors, were listed in generic groups and then broken down further into specific factors. The full list is in Appendix C. Just as for causal factors, any number of circumstantial factors may have been attributed to an accident from any one group and any combination of groups. The highest number of circumstantial factors recorded was seven.

3.5.3 Consequences

A list of consequences was used to record the circumstances of the fatal accidents in terms of collisions, structural failure, fire, fuel exhaustion and other events. It was important to keep a record of the consequences, as all fatal accidents consist of a chain of events with a final outcome resulting in fatalities. In some occurrences, knowing what happened is just as important as knowing why or how that occurrence happened, because a particular combination of causal factors in one occurrence may lead to a fatal accident, but in another case may result in only a minor incident. In many occurrences, the consequence is all that is known about a particular accident. The consequences used are listed in Appendix C. The highest number of consequences recorded was five.

3.5.4 Level of Confidence

The AAG also recorded a level of confidence for each accident. This could be "high," "medium" or "low" and reflected the group's confidence in the accident summary and the factors assigned. The level was not a measure of confidence in the allocation of individual factors, but of the group's analysis of the accident as a whole. Alternatively, if the group believed that there was not enough substantive information in the accident summary (and there was no possibility of obtaining an official accident report), then the fourth level of confidence was "insufficient information." For these accidents, no attempt was made to attribute causal factors, although there may have been circumstantial factors such as "poor visibility" that may have appeared to be relevant. Accidents with insufficient information were included in the analysis with attributed consequences (and sometimes circumstantial factors), even though there were no primary or other causal factors.

There were 64 possible causal factors, 15 possible circumstantial factors and 15 possible consequences, and each accident was attributed to as many factors and consequences as were considered relevant. The group could attribute any combination of factors, although some factors naturally were mutually exclusive. For example, factor A2.3 ("failure to provide separation in the air") and factor A2.4 ("failure to provide separation on the ground") would not be attributed to the same accident, as the aircraft involved was either in the air or on the ground.

The recording of factors was based on judgments of the evidence available, to ascertain the cause of the accident rather than to apportion blame.

3.5.5 Accident Rates

Absolute numbers of accidents are not necessarily a good indication of safety standards and are of no comparative value until they are converted to accident rates. For this purpose, it is possible to present the number of accidents per hour, per passenger-kilometer, per metric ton-kilometer, etc., but the rate per flight was considered to be the most clearly useful indicator and has been used in this study.[8]

3.6 Assumptions and Limitations

The AAG decided to assess all global fatal accidents, unlike other studies in which only accidents with substantial information available were reviewed. This was done to reduce any bias in the analysis towards accidents that have occurred where detailed investigations were carried out and formal reports were issued.

As with all statistics, care should be taken when drawing conclusions from the data provided. Only fatal accidents have been included in this study and therefore important events including nonfatal accidents, serious incidents and reports of insufficient separation between aircraft during flight (air proximity [AIRPROX] reports or near mid-air collision [NMAC] reports) have not been covered. It is important to recognize these limitations when using the data.

In this report, the analysis of the data has been performed on groups of accidents rather than individual accidents, so that the aggregation of the data will help to mask any random errors introduced by inaccurate coding.

3.7 Results

3.7.1 Worldwide Results

Because of the lack of information on the number of flights worldwide, accident rates have not been included in this section. Nevertheless, utilization data were available for Western-built jets, and accident rates are included in section 3.7.6.

Fatal accidents by year. The group studied 287 global fatal accidents during approach and landing, which occurred between 1980 and 1996 (inclusive). The number of fatal accidents is shown by year in Figure 3–1.

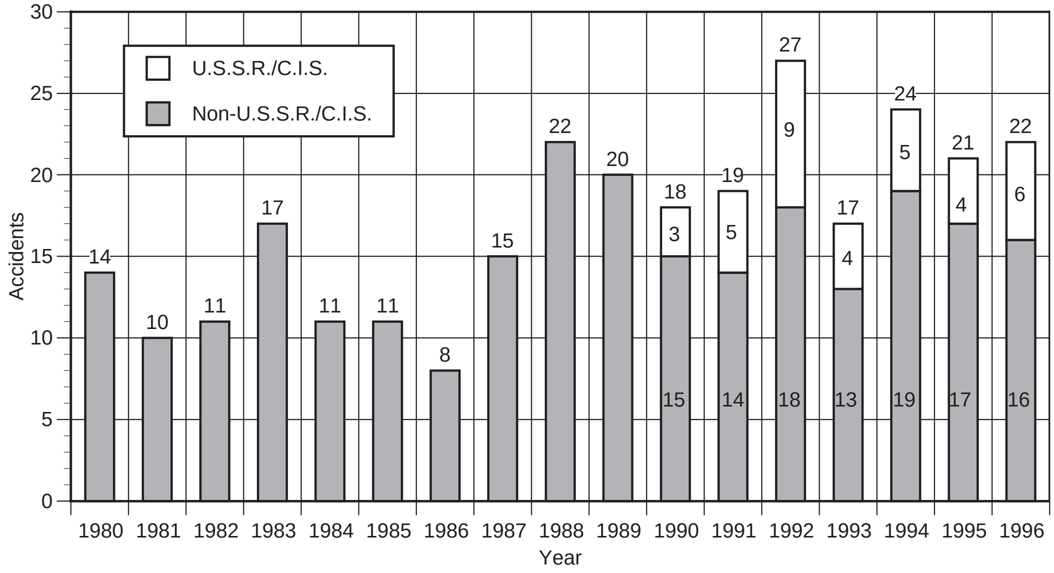
There was an average of 12.1 accidents per year for the non-C.I.S. aircraft and operators in the first eight years of the study and 16.6 in the last eight years; this shows a marked growth in the number of accidents. The average growth (best mean line) is 0.37 accidents per year; if this growth continues, one can expect 23 fatal accidents to Western-built and operated turbojets and turboprops (including business jets) annually by the year 2010.

Fatalities by year. The total accidents considered resulted in 7,185 fatalities to passengers and crewmembers, an average of 25 fatalities per accident, or 63 percent of aircraft occupants (Figure 3–2, page 12).

In 1992 there were 970 fatalities, almost twice the annual average of 540 for the years 1990 to 1996 (where C.I.S. data are included).

In the first eight years of the study period, there was an average of 300 fatalities per year for the non-C.I.S. accidents compared

287 Fatal ALAs Worldwide, by Year
1980-1996

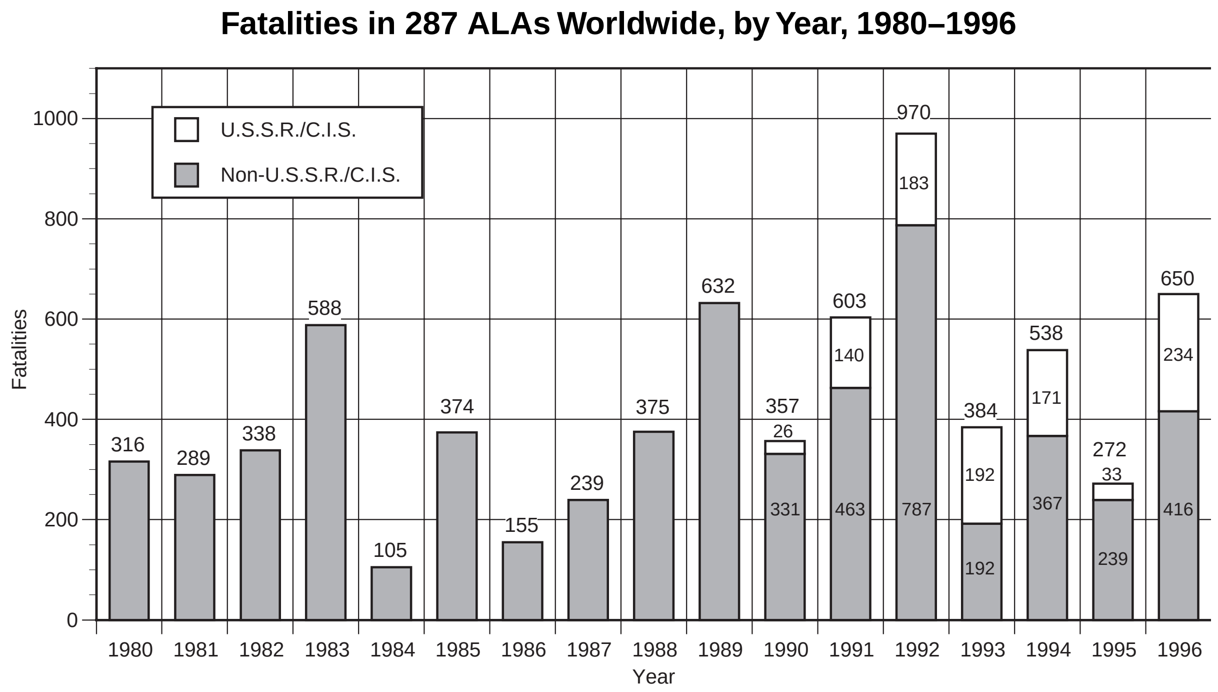


ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/ 5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3–1



ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/ 5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3–2

with 428 for the last eight years. The “best mean line” growth was 6 percent per year. Though continuing such growth would lead to an annual average of 495 fatalities by 2010, there is some reason to hope that the figures since 1992 indicate improvement.

Phase of flight. The group attributed one of 14 phases of flight in its analysis of global accidents.[6] This study looks more closely at accidents in three of these phases of flight; the selection of flight phase was based on judgment rather than precise criteria (Table 3–1).

Accidents that occurred in other closely related phases, i.e., descent, holding and go-around, were not included. Data show that the accidents are fairly evenly distributed among the three phases of flight considered.

Accident locations by region. The number of accidents during approach and landing in each of the world regions in which the 287 fatal accidents occurred is shown in Table 3–2 (page 13). The figures in the third column show the percentage of the fatal accidents in all phases of flight in the region that occurred during the three approach-and-landing flight phases.

The regions are defined by Airclaims; definitions can be found in Appendix A.

To appreciate the full significance of these data, knowledge of the number of relevant flights carried out in each region is required to calculate the accident rates; those data are not currently available. (See section 3.7.6 for more comprehensive data on Western-built jets.)

Table 3–1
287 Fatal ALAs Worldwide, By Phase of Flight 1980–1996

Phase of Flight	Fatal ALAs
Approach	108
Final approach	82
Landing	97
Total	**287**

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Accidents by region of operator. The accidents are shown by region of operator in Table 3–3. Because of the marked difference in regulatory arrangements between the two groups, Europe has been divided into the Joint Aviation Authorities (JAA) full-member countries (Appendix A) and the "rest of Europe."

Table 3–2
287 Fatal ALA Locations, by Region*
1980–1996

Region	Fatal ALAs	Percent of Region's Fatal Accidents
North America	74	44
South/Central America	67	49
Asia	43	35
Africa	34	49
Europe	62	57
Australasia	7	50
Total	**287**	

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

*Regions defined by Airclaims and shown in Appendix A.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 3–3
287 Fatal ALAs Worldwide, By Region* of Operator
1980–1996

Region	Fatal ALAs
North America	78
South/Central America	67
Asia	42
Africa	31
Europe	64
JAA full-member countries	30
All other European countries	34
Australasia	5
Total	**287**

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms.

U.S.S.R. = Union of Soviet Socialist Republics
C.I.S. = Commonwealth of Independent States

JAA = Joint Aviation Authorities

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

* Regions defined by Airclaims and shown in Appendix A.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Data show that the distribution of fatal accidents by region of operator is not markedly different from the distribution of accident locations by region.

Again, the data for numbers of flights flown by the classes of aircraft covered and by region are not currently available, so it was not possible to estimate accident rates.

Service type. The 287 fatal accidents occurred during the types of service shown in Table 3–4.

Table 3–4
287 Fatal ALAs Worldwide, By Type of Service
1980–1996

Service	Fatal ALAs	Percent of 287 Fatal ALAs
Passenger	177	62
Freight/ferry/positioning	73	25
Business/other revenue	30	10
Training/other nonrevenue	7	3
Total	**287**	**100**

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms.
U.S.S.R. = Union of Soviet Socialist Republics
C.I.S. = Commonwealth of Independent States
Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Although the actual number of flights for all classes of aircraft is not available, it is estimated that there is a much higher accident rate on freight/ferry/positioning flights than on passenger flights. During the period 1990–1996 (inclusive), 3.6 percent of the international and domestic flights during scheduled services of IATA members involved all-cargo flights.[9] U.K. CAA's data on fixed-wing air transport movements at U.K. airports from 1986 to 1996 for aircraft with MTOW greater than 12,500 pounds showed that an average of 5 percent were all-cargo flights; there was a steady increase in this period from 4.4 percent in 1986 to 5.6 percent in 1996.[10] The average for the period covered in this study (1980 to 1996) therefore was estimated to be about 4.6 percent for U.K. airports.

These indications suggest that, overall, the freight/cargo operations — together with ferry and positioning flights — represent about 5 percent of the number of flights in commercial transport operations. This indicates that the fatal accident rate on freight, ferry and positioning flights (i.e., when no passengers are aboard the aircraft) is potentially eight times higher than the rate for passenger flights. This is a surprising and important conclusion considering that the safety and operational standards that should be applied to such flights are generally not different.

Earlier NLR work showed that 26 percent of 156 CFIT accidents (during 1988–1994) analyzed involved freight operations.[4] Another NLR/FSF study of 132 ALAs showed a similar trend, i.e., freighter operations accounted for 24 percent of the total accident sample.[3] These data are consistent with the DAAWG findings.

Aircraft classes. The classes of aircraft involved in the accidents are shown in Table 3–5.

Accidents involving Western-built jets are reviewed in more detail in section 3.7.6.

Type of approach. In 169 (59 percent) of the accidents, the type of approach used was not known. The distribution for the remainder is shown in Table 3–6.

Of those accidents where the type of approach was known, only 25 percent occurred during approaches and landings where a precision landing aid was available. It is suspected that precision-landing aids were not available in some of the accidents where no information on the type of approach was found; if this assumption is correct, then more than 75 percent of ALAs occurred when a precision-approach aid was not available or not used.

A recent joint study by the NLR and the Foundation concluded that, on a worldwide basis, there appears to be a fivefold increase in accident risk for commercial aircraft flying nonprecision approaches compared with those flying precision approaches.[3,5] When stratified by ICAO region, the risk increase associated with flying nonprecision approaches compared with flying precision approaches ranges from threefold to almost eightfold, depending on the region. That study used both accident and movement data to reach these conclusions.

Table 3–5
287 Fatal ALAs Worldwide, By Class of Aircraft 1980–1996

Class	Fatal ALAs	Percent of 287 Fatal ALAs
Western-built jets	92	32
Eastern-built jets	16	6
Western-built turboprops	84	29
Eastern-built turboprops	19	7
Business jets	76	26
Total	**287**	**100**

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms.

U.S.S.R. = Union of Soviet Socialist Republics
C.I.S. = Commonwealth of Independent States

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 3–6
118 Fatal ALAs Worldwide,* By Type of Approach 1980–1996

Type of Approach	Fatal ALAs	Percent of 118 Fatal ALAs
Visual	49	41
ILS or ILS/DME	30	25
VOR/DME	16	13
NDB	11	9
VOR	10	8
Other (SRA or DME)	2	4
Total	**118**	**100**

*Where the type of approach was known.

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms.

U.S.S.R. = Union of Soviet Socialist Republics
C.I.S. = Commonwealth of Independent States
ILS = Instrument landing system
DME = Distance measuring equipment
VOR = Very high frequency omnidirectional radio
NDB = Nondirectional beacon
SRA = Surveillance-radar approach

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Night, day, twilight. There might be an assumption that night approaches may result in more difficulties caused by factors such as reduced visual cues or spatial disorientation. Similarly, it is possible that the twilight hours could present particular problems. Where known, the ALAs have been allocated to “day,” “night” or “twilight” categories — the latter being broadly defined as times close to local sunrise and sunset. The results are shown in Table 3–7 (page 15).

Global data for the percentage of landings at night were not available, but discussions with airlines and airport operators suggest that the figure is approximately 20 percent to 25 percent. If this is correct, then the rate for ALAs at night is close to three times the rate for day. No conclusion can be drawn from the twilight data.

When broken down by aircraft class, the data show that business jets were involved in an even higher proportion of accidents at night than ALAs at night among all classes; of those where the lighting conditions were known (87 percent), 55 percent occurred at night and 41 percent occurred daylight.

Level of confidence. The level of confidence shows the group’s confidence in the completeness of the accident summary and the consequent factors to which each accident was attributed,

Table 3–7
287 Fatal ALAs Worldwide, by Time of Day
1980–1996

Time of Day	Fatal ALAs	Percent of 287 Fatal ALAs
Day	143	50
Night	112	39
Twilight	5	2
Not known	27	9
Total	**287**	**100**

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms.
U.S.S.R. = Union of Soviet Socialist Republics
C.I.S. = Commonwealth of Independent States
Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

as detailed in section 3.5. Of the 287 fatal ALAs, a high level of confidence was attributed to 152 ALAs, as shown in Table 3–8.

Causal factors were attributed in all but the eight accidents (3 percent) where there was considered to be insufficient information. The factors from all of the other accidents (279) were used in the analysis. There was little difference in the proportions of accidents for which a given level of confidence was attributed for each aircraft class, e.g., high levels of confidence were attributed to 53 percent and 61 percent of accidents involving Western-built jets and turboprops, respectively.

3.7.2 Analysis of Primary Causal Factors

Primary causal factors overall. In the accident review carried out by the AAG, any number of causal factors may have been attributed, of which one was identified to be the primary causal factor. Of the 287 ALAs, eight were judged to have insufficient information available, leaving 279 for which causal factors were attributed.

The five most frequently identified primary causal factors in the overall sample of 279 accidents are shown in Table 3–9.

The five most frequently identified primary causal factors (out of a possible 64) account for 71 percent of the accidents. All five primary causal factors are from the "crew" causal group, indicating that crew factors were involved. The involvement of crew actions as a causal factor does not imply that crewmembers are sole agents. Rather it indicates that deficiencies and other systemic problems necessarily will be manifested in the crew's behavior.

Table 3–8
Level of Confidence in Completeness of Accident Summary of 287 Fatal ALAs Worldwide
1980–1996

Level	Fatal ALAs	Percent of 287 Fatal ALAs
High	152	53
Medium	104	36
Low	23	8
Insufficient information	8	3
Total	**287**	**100**

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms.
U.S.S.R. = Union of Soviet Socialist Republics
C.I.S. = Commonwealth of Independent States
Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 3–9
Most Frequent Primary Causal Factors In 279 Fatal ALAs Worldwide
1980–1996

Primary Causal Factor*/**	Fatal ALAs	Percent of 279 Fatal ALAs
Omission of action/ inappropriate action	69	24.7
Lack of positional awareness in the air	52	18.6
Flight handling	34	12.2
"Press-on-itis"	31	11.1
Poor professional judgment/airmanship	12	4.3
Total	**198****	

*For which sufficient information was known to allocate causal factors.

**Some ALAs had primary causal factors not among the five most frequent primary causal factors.

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms.
U.S.S.R = Union of Soviet Socialist Republics
C.I.S. = Commonwealth of Independent States
Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

In these ALAs, the most common primary causal factor, "omission of action/inappropriate action," generally referred to the crew's continuing their descent below the decision height

(DH) or minimum descent altitude (MDA) without visual reference, or when visual cues were lost. The second most frequent factor, “lack of positional awareness in the air,” generally involved a lack of awareness of proximity to high ground, frequently when the aircraft was not equipped with a GPWS and/or when precision-approach aids were not available; these were generally CFIT accidents.

Considering the causal groups (as shown in the causal factors list, Appendix C) rather than individual factors, “crew” groups were allocated in 228 of the 279 accidents (82 percent), followed by “environmental” groups in 14 accidents (5 percent). Complete summaries of the attributed causal factors, including primary causal factors, are published in a separate report.[11]

Primary causal factors by aircraft class. When each aircraft class is considered separately, there are considerable differences in the most frequently identified primary causal factors. Table 3–10 shows the ranking of various primary factors for each class; the figures in parentheses are the percentages of the accidents for that aircraft class.

It is noteworthy that accidents involving aircraft built and operated in the C.I.S. have “press-on-itis” as the most frequent primary cause, whereas this is generally fourth in the ranking for other aircraft classes. Flight handling ranks first among the most frequent primary causes for Western-built turboprops, even though it is third overall.

3.7.3 Analysis of All Causal Factors

All causal factors overall. The AAG attributed each accident to any number of causal factors. Usually, an accident results from a combination of causal factors and it is important to view the complete situation rather than just the single primary factor. For this part of the analysis, primary factors have been included along with all others. The average number of causal factors attributed was 3.8. The largest number of causal factors attributed was 10.

Table 3–10
Ranking of Primary Causal Factors in 279 Fatal ALAs Worldwide, by Aircraft Class 1980–1996

Primary Causal Factor	Overall Ranking	Western-built Jets	Eastern-built Jets	Western-built Turboprops	Eastern-built Turboprops	Business Jets
Omission of action/ inappropriate action	1 (24.7%)	1 (27.4%)	= 2 (12.5%)	3 (17.1%)	2 (18.7%)	1 (31.1%)
Lack of positional awareness in the air	2 (18.6%)	2 (16.5%)	= 2 (12.5%)	= 1 (19.5%)	3 (12.5%)	2 (20.3%)
Flight handling	3 (12.2%)	= 3 (9.9%)	= 4 (6.3%)	= 1 (19.5%)	= 4 (6.3%)	3 (9.5%)
“Press-on-itis”	4 (11.1%)	= 3 (9.9%)	1 (31.2%)	4 (8.5%)	1 (37.5%)	= 4 (5.4%)
Poor professional judgment/airmanship	5 (4.3%)	5 (5.5%)	•	= 6 (3.7%)	•	= 4 (5.4%)
Deliberate nonadherence to procedures	6 (2.9%)	= 7 (2.2%)	•	= 8 (2.4%)	= 4 (6.3%)	= 6 (4.1%)
Wind shear/upset/ turbulence	7 (2.2%)	= 7 (2.2%)	= 4 (6.3%)	= 6 (3.7%)	•	•
Failure in CRM (cross-check/coordinate)	8 (1.8%)	= 14 (1.1%)	•	5 (4.9%)	•	•
Icing	= 9 (1.4%)	•	•	= 11 (1.2%)	= 4 (6.3%)	= 8 (2.7%)
System failure flight-deck information	= 9 (1.4%)	= 14 (1.1%)	= 4 (6.3%)	= 11 (1.2%)	•	=10 (1.4%)

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/ 5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States CRM = crew resource management • = No fatal ALAs were attributed to this primary causal factor in this class of aircraft.

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Note: The complete list of primary causal factors has been shortened for this table. Factors that ranked high in the overall list (first column) sometimes ranked lower for specific types of aircraft. In some instances, two or more primary causal factors occurred in equal numbers of accidents, and the factors were assigned equal rankings. For example, some columns may contain two 3s, three 4s, etc.
In several instances, a factor shown in the table occurred in equal numbers of accidents with a factor not shown because the factor not shown was not among those ranked 1 through 9 in the “overall ranking” column.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

The five most frequently identified causal factors in the sample of 279 accidents are shown in Table 3–11.

The data in the right-hand column indicate the percentage of the 279 accidents to which the particular causal factor was attributed; note that each accident usually is attributed to several different factors. As in the analysis of primary causal factors, the five most frequent factors were elements involving crew performance. These are generally the result of other systemic deficiencies.[12]

The three most frequently identified causal factors each appear in about 40 percent or more of all accidents.

All causal factors by aircraft class. The rankings of the most frequent causal factors for each aircraft class are shown in Table 3–12 (page 18).

As in the analysis of primary causal factors, "press-on-itis" appears as the most frequent, or equally most frequent, causal factor for aircraft built and operated in the C.I.S., whereas this factor ranked only sixth overall. Data show deliberate nonadherence to procedures to be notably more frequent for C.I.S. aircraft than for Western-built and Western-operated airliners; to a lesser extent, business jets also ranked higher on this factor.

Table 3–11
Most Frequent Causal Factors In 279 Fatal ALAs Worldwide 1980–1996

Causal Factor*	Cited in Fatal ALAs	Percent of 279 Fatal ALAs
Lack of positional awareness in the air	132	47.3
Omission of action/ inappropriate action	121	43.4
Slow and/or low on approach	109	39.1
Flight handling	81	29.0
Poor professional judgment/airmanship	68	24.3
Total	**511****	

* For which sufficient information was known to allocate causal factors.

**Most fatal ALAs had multiple causal factors.

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms.

U.S.S.R. = Union of Soviet Socialist Republics

C.I.S. = Commonwealth of Independent States

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

3.7.4 Analysis of Circumstantial Factors

Circumstantial factors overall. As stated in section 3.4, a circumstantial factor was an event or aspect that was not directly in the causal chain of events, but could have contributed to the accident. The average number of circumstantial factors was 2.7. The five most frequently identified circumstantial factors in the sample of 279 accidents are presented in Table 3–13 (page 19).

The "nonfitment of presently available safety equipment" referred, in the great majority of occurrences, to the lack of GPWS or, in some occurrences, enhanced GPWS (EGPWS) of the type that is now available (even if not available at the time of the accident); this factor was intended to assess how many accidents such equipment might have prevented.

"Failure in CRM" (failure of crewmembers to cross-check or coordinate) also was a causal factor, Table 3–11 (page xx). A judgment was made as to whether the lack of good CRM was actually one of the causes that led to the accident, in which case it was attributed as a causal factor, or whether inadequate CRM appeared to have been present and if CRM to a higher standard might have helped to prevent the accident, in which case "failure in CRM" was attributed as a circumstantial factor.

Circumstantial factors by aircraft class. The ranking of the most frequent circumstantial factors for each aircraft class is shown in Table 3–14 (page 19).

There is some consistency across aircraft classes, except for Eastern-built turboprop ALAs, in the ranking of the five circumstantial factors that occur most frequently. The "nonfitment of presently available safety equipment" (essentially GPWS) was judged to be a factor in 47 percent of the total ALAs. "Failure in CRM" was also seen to be a factor in 47 percent of the total ALAs. "Lack of ground aids" — basically the lack of a precision-approach aid — was an important factor in 29 percent of the total ALAs.

3.7.5 Analysis of Consequences

Consequences overall. Consequences are not seen as part of the causes of accidents, but are relevant to a complete understanding of an accident scenario. A full list of the 15 consequences considered is in Appendix C. The average number of consequences attributed was 1.9. Consequences were attributed even to the eight accidents considered to have insufficient information for the selection of causal or circumstantial factors. The five most frequently identified consequences in this sample of 287 ALAs are shown in Table 3–15 (page 20).

Table 3–12
Ranking of All Causal Factors in 279 Fatal ALAs Worldwide, by Aircraft Class 1980–1996

Causal Factor	Overall Ranking	Western-built Jets	Eastern-built Jets	Western-built Turboprops	Eastern-built Turboprops	Business Jets
Lack of positional awareness in the air	1 (47.3%)	1 (44.0%)	= 1 (43.7%)	2 (42.7%)	2 (37.5%)	1 (59.5%)
Omission of action/ inappropriate action	2 (43.4%)	1 (44.0%)	3 (37.5%)	1 (43.9%)	= 3 (31.2%)	3 (45.9%)
Slow and/or low on approach	3 (39.1%)	3 (35.2%)	4 (31.2%)	4 (39.0%)	= 3 (31.2%)	2 (47.3%)
Flight handling	4 (29.0%)	5 (27.5%)	= 6 (18.7%)	3 (40.2%)	= 5 (25.0%)	5 (21.6%)
Poor professional judgment/airmanship	5 (24.3%)	4 (30.8%)	= 9 (12.5%)	7 (19.5%)	= 7 (18.7%)	4 (25.7%)
“Press-on-itis”	6 (21.5%)	6 (17.6%)	= 1 (43.7%)	6 (20.7%)	1 (50.0%)	6 (16.2%)
Failure in CRM (cross-check/coordinate)	7 (15.8%)	7 (16.5%)	= 6 (18.7%)	5 (22.0%)	•	8 (10.8%)
Postimpact fire	= 8 (11.8%)	= 8 (14.3%)	= 9 (12.5%)	= 8 (13.4%)	= 10 (12.5%)	12 (6.8%)
Deliberate nonadherence to procedures	= 8 (11.8%)	= 17 (6.6%)	= 6 (18.7%)	10 (11.0%)	= 5 (25.0%)	7 (14.9%)

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/ 5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States
CRM = Crew resource management • = No fatal ALAs were attributed to this causal factor in this class of aircraft.

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Note: The complete list of all causal factors has been shortened for this table. Factors that ranked high in the overall list (first column) sometimes ranked lower for specific types of aircraft. In some instances, two or more factors occurred in equal numbers of accidents, and the factors were assigned equal rankings. For example, some columns may contain two 3s, three 4s, etc. In several instances, a factor shown in the table occurred in equal numbers of accidents with a factor not shown because the factor not shown was not among those ranked 1 through 8 in the “overall ranking” column.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

“Collision with terrain/water/obstacle” and “CFIT” were the most frequent consequences. The former implied that control of the aircraft had been lost (i.e., “loss of control in flight” also would have been attributed) or severe weather or some other factor had contributed to the impact; CFIT, on the other hand, was attributed when the aircraft was flown into terrain under the full control of the flight crew. Where the impact with terrain occurred in circumstances where it was not clear whether or not the aircraft was under control, the “collision with terrain/water/obstacle” consequence was attributed; this almost certainly underestimates the number of CFIT accidents.

“Postimpact fire” was known to have occurred in nearly one-fourth of the accidents (and probably occurred in more). “Postimpact fire” was recorded as a consequence whenever the fire was known to have occurred. “Postimpact fire” also appears for some accidents as a causal factor; this indicates that in these accidents the fire was judged to have contributed to the fatalities that occurred.

“Undershoots” were involved in several fatal accidents; “overruns” were involved in about half as many fatal accidents as undershoots, presumably because overruns are less often fatal, rather than because they occur less often.

Consequences by aircraft class. The rankings of the most frequent consequences for each aircraft class are shown in Table 3–16 (page 20).

The pattern is moderately consistent, but Eastern-built (C.I.S.) jets had fatal overruns at twice the frequency of the overall sample. The dominant consequence, as might be expected from the earlier results, is collision with terrain, generally CFIT.

3.7.6 Analysis of Western-built jets

This section presents an analysis of data for Western-built jet airliner operations, broken down into world regions. Airclaims has provided utilization data including numbers of flights flown annually for this category of aircraft. The fatal-accident rates are shown in relation to the number of flights, because flights are considered to provide the most useful and valid criterion to indicate safety standards.

(continued on page 20)

Table 3–13
Ranking of Most Frequent Circumstantial Factors in 279 Fatal ALAs Worldwide
1980–1996

Circumstantial Factor*	Cited in Fatal ALAs	Percent of 279 Fatal ALAs
Nonfitment of presently available safety equipment (GPWS, TCAS, wind-shear warning, etc.)	132	47.3
Failure in CRM (cross-check/coordinate)	131	47.0
Weather (other than poor visibility, runway condition)	103	36.9
Poor visibility	89	31.9
Lack of ground aids	81	29.0
Total	**536**	**

*For which sufficient information was known to allocate circumstantial factors.
**More than one circumstantial factor could be allocated to a single accident.

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/ 5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States
GPWS = Ground-proximity warning system TCAS = Traffic-alert and collision avoidance system CRM = Crew resource management

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 3–14
Ranking of Most Frequent Circumstantial Factors in 279 Fatal ALAs Worldwide, By Aircraft Class
1980–1996

Circumstantial Factor	Overall Ranking	Western-built Jets	Eastern-built Jets	Western-built Turboprops	Eastern-built Turboprops	Business Jets
Nonfitment of presently available safety equipment (GPWS, TCAS, wind-shear warning, etc.)	1 (47.3%)	1 (44.0%)	= 1 (50.0%)	2 (46.3%)	7 (12.5%)	1 (59.5%)
Failure in CRM (cross-check/coordinate)	2 (47.0%)	2 (41.8%)	= 1 (50.0%)	3 (45.1%)	= 3 (37.5%)	2 (56.8%)
Other weather (other than poor visibility, runway condition)	3 (36.9%)	4 (28.6%)	3 (43.7%)	1 (50.0%)	1 (50.0%)	5 (28.4%)
Poor visibility	4 (31.9%)	3 (31.9%)	= 5 (25.0%)	4 (30.5%)	6 (31.2%)	3 (35.1%)
Lack of ground aids	5 (29.0%)	= 5 (25.3%)	4 (31.2%)	= 5 (26.8%)	= 3 (37.5%)	4 (33.8%)
Inadequate regulatory oversight	6 (23.7%)	= 5 (25.3%)	= 5 (25.0%)	5 (26.8%)	2 (43.7%)	7 (13.5%)

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/ 5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States
GPWS = Ground-proximity warning system CRM = Crew resource management TCAS = Traffic-alert and collision avoidance system

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./ C.I.S. were not included for years before 1990.

Note: The complete list of most frequent circumstantial factors has been shortened for this table. Factors that ranked high in the overall list (first column) sometimes ranked lower for specific types of aircraft. In some instances, two or more factors occurred in equal numbers of accidents, and the factors were assigned equal rankings. For example, some columns may contain two 3s, three 4s, etc. In several instances, a factor shown in the table occurred in equal numbers of accidents with a factor not shown because the factor not shown was not among those ranked 1 through 6 in the “overall ranking” column.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 3–15
Most Frequently Identified Consequences in 287 Fatal ALAs Worldwide 1980–1996

Consequence	Cited in Fatal ALAs	Percent of 287 Fatal ALAs
Collision with terrain/water/obstacle	131	45.6
Controlled flight into terrain (CFIT)	120	41.8
Loss of control in flight	74	25.8
Postimpact fire	65	22.6
Undershoot	50	17.4
Total	**440***	

*Some fatal ALAs had multiple consequences.

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/ 5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R. and C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 3–16
Ranking of Identified Consequences in 287 Fatal ALAs Worldwide, by Aircraft Class 1980–1996

Consequence	Overall Ranking	Western-built Jets	Eastern-built Jets	Western-built Turboprops	Eastern-built Turboprops	Business Jets
Collision with terrain/water/ obstacle	1 (44.6%)	1 (48.9%)	= 2 (31.2%)	1 (50.0%)	1 (47.8%)	2 (39.5%)
Controlled flight into terrain (CFIT)	2 (41.8%)	2 (34.8%)	1 (56.2%)	2 (40.5%)	= 2 (31.6%)	1 (51.3%)
Loss of control in flight	3 (25.8%)	4 (22.8%)	= 6 (6.2%)	3 (38.1%)	= 2 (31.6%)	4 (18.4%)
Postimpact fire	4 (22.6%)	3 (27.2%)	= 4 (18.7%)	4 (17.9%)	= 5 (12.5%)	3 (26.3%)
Undershoot	5 (17.4%)	5 (18.5%)	= 2 (31.2%)	5 (16.7%)	= 5 (12.5%)	5 (15.8%)
Overrun	6 (9.8%)	6 (14.1%)	4 (18.7%)	6 (6.0%)	= 5 (12.5%)	= 6 (6.6%)
Ground collision with object/obstacle	7 (7.0%)	7 (10.9%)	= 6 (6.2%)	= 9 (2.4%)	= 5 (12.5%)	= 6 (6.6%)

ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/ 5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Note: The complete list of identified consequences has been shortened for this table. Identified consequences that ranked high in the overall list (first column) sometimes ranked lower for specific types of aircraft. In some instances, two or more identified consequences occurred in equal numbers of accidents, and the identified consequences were assigned equal rankings. For example, some columns may contain two 3s, three 4s, etc. In several instances, a factor shown in the table occurred in equal numbers of accidents with a factor not shown because the factor not shown was not among those ranked 1 through 7 in the "overall ranking" column.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

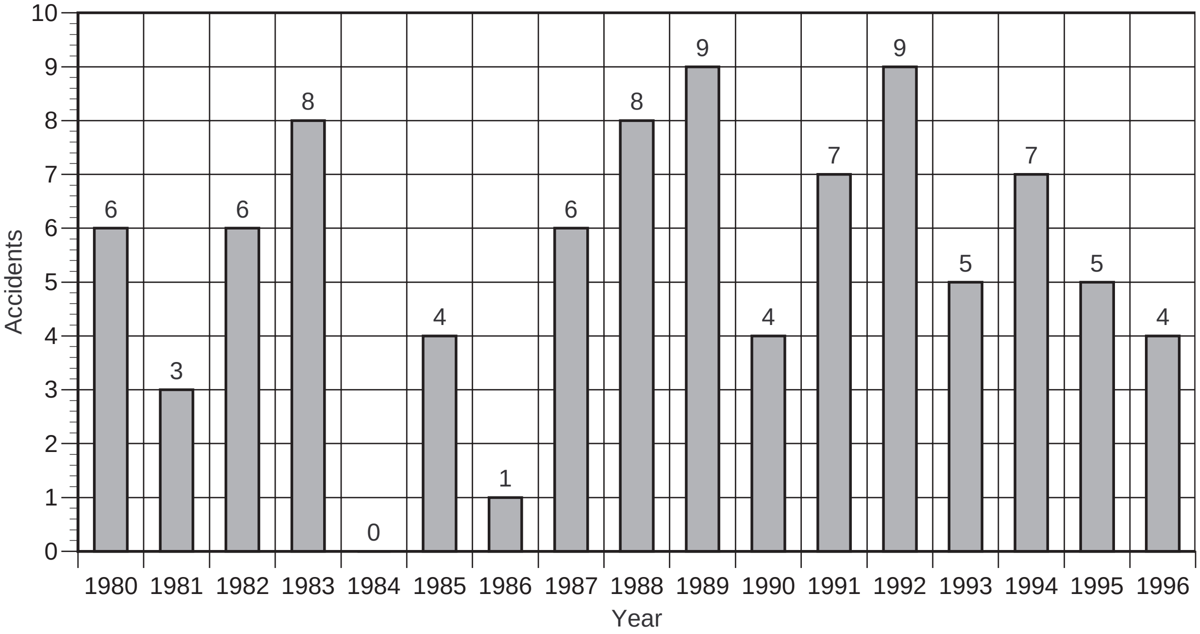
Ninety-two of the 287 fatal ALAs (32 percent) involved Western-built jets.

Fatal accidents by year. The 92 fatal accidents are shown by year in Figure 3–3 (page 21). The number of accidents per year involving Western-built jets averaged between five and six per year with an overall increasing trend for the period of the study; the average growth (best mean line) is 0.11 accidents per year.

Fatalities by year. The 92 fatal accidents during approach and landing to Western-built jets between 1980 and 1996 (inclusive) resulted in 4,696 fatalities to passengers and crewmembers (Figure 3–4, page 22) — yielding averages of 51 fatalities per accident and 276 fatalities per year. The ratio of the overall number of fatalities to the number of occupants (passengers and crew) in all the accidents gives a measure of average survivability; this figure is 61 percent.

In the first eight years of the 17-year study period, there were 1,804 fatalities, compared with 2,662 in the last eight years. The growth rate overall (best mean line) averages 4.5 additional fatalities per year. Both the number of accidents and the number

92 Fatal ALAs in Western-built Jets* Worldwide, by Year
1980–1996



*Excludes business jets. ALAs = Approach-and-landing accidents involving jet aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3–3

of fatalities are growing by between 1 percent and 2 percent per year. A continuing increase in both the number of accidents and the number of fatalities is likely to result in public concern that, for example, could lead to negative economic influences and inappropriate legislative/regulatory actions.

Fatal accidents by region of operator. The fatal ALAs for Western-built jets between 1980 and 1996 are shown in Figure 3-5 (page 23) by region of operator; there were no ALAs in Australasia. Europe is divided into 19 full member JAA states and the rest of the European states — Appendix A.

Fatal accident rates by region of operator. The numbers of flights were applied to compute the fatal-accident rates per million flights for ALAs. The results are in Figure 3-6 (page 23). Africa, South America/Central America and Asia have fatal accident rates above the world average — Africa by a factor of more than five. Australasia, North America and, to a lesser extent, Europe are below the world average. Data for Europe are divided into the 19 full-member JAA states and other states in the next section.

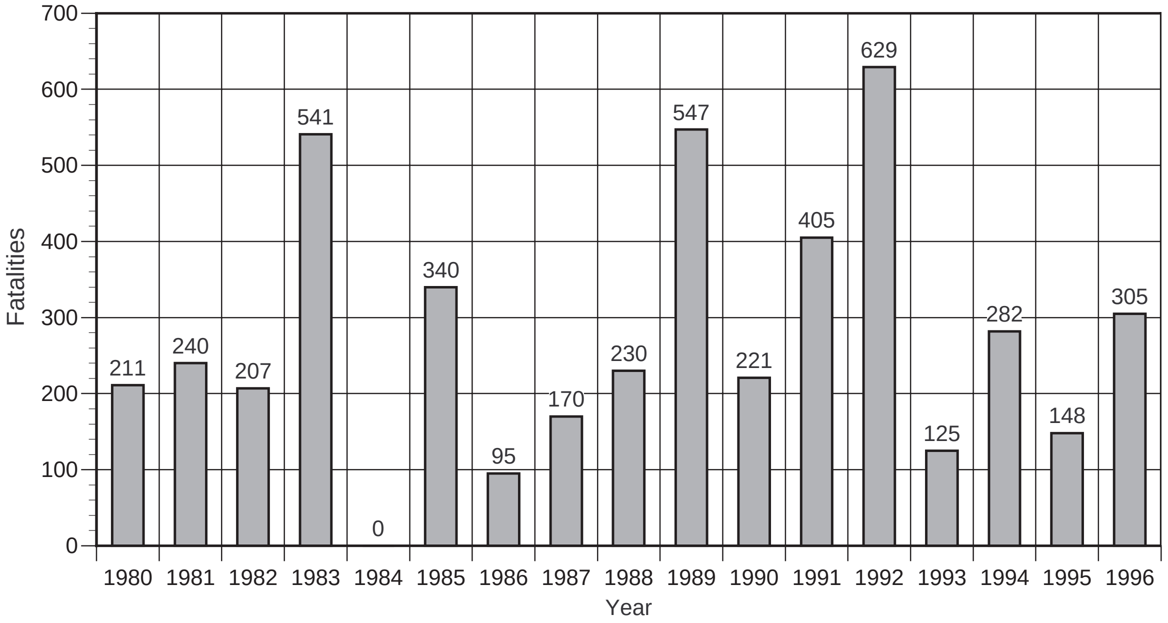
Australasia's record of zero fatal accidents in 5.3 million flights merits further consideration. This can be compared, for example, with the North American sample of 14 fatal accidents in 110.8 million flights. If Australasia had the same underlying accident rate as North America, on average, one accident could be expected every 7.9 million flights. No accidents in 5.3 million flights does not necessarily indicate that the Australasia is safer than North America. Without diminishing the favorable record in Australasia, readers must be very cautious in interpreting this result for reasons discussed in the next section.

Fatalities by region of operator. The number of ALA fatalities occurring in Western-built jets between 1980 and 1996 (inclusive) was 4,696. The data are shown by region of operator in Figure 3–7 (page 24).

Fatal accident rates for the JAA states and the rest of Europe. Europe is divided into the JAA member states (which use a common set of safety regulations and comprise 19 full-member states) and the rest of Europe (26 states). Of the 12 fatal ALAs involving European operators, seven were JAA operators and five were operators from other states. The numbers of flights for each group of countries were 42.8 million and 3.04 million, respectively. This gives the following fatal-accident rates for ALAs:

JAA full-member countries:	0.164 per million flights
Other European countries:	1.640 per million flights

Fatalities in 92 Fatal ALAs in Western-built Jets,* by Year 1980–1996



*Excludes business jets. ALAs = Approach-and-landing accidents involving jet aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3–4

The JAA full-member states therefore have an accident rate 10 times lower than the rest of Europe, and comparable with North America.

4. ALAs and Serious Incidents

A second study was initiated after completion of the analysis presented in section 3. The second study attempted to review individual occurrences (from a smaller sample) in greater depth using detailed information from final occurrence reports. A greater emphasis also was placed on the dynamic sequence of events leading to the occurrence and on the development of recommendations for industry.

4.1 Objectives

The objectives of this study were to use detailed information from final occurrence reports to:

- Identify and analyze factors related to ALAs and serious incidents; and,
- Identify measures (prevention strategies) that may mitigate the risk of approach-and-landing occurrences.

The major differences compared to the study presented in section 3 are:

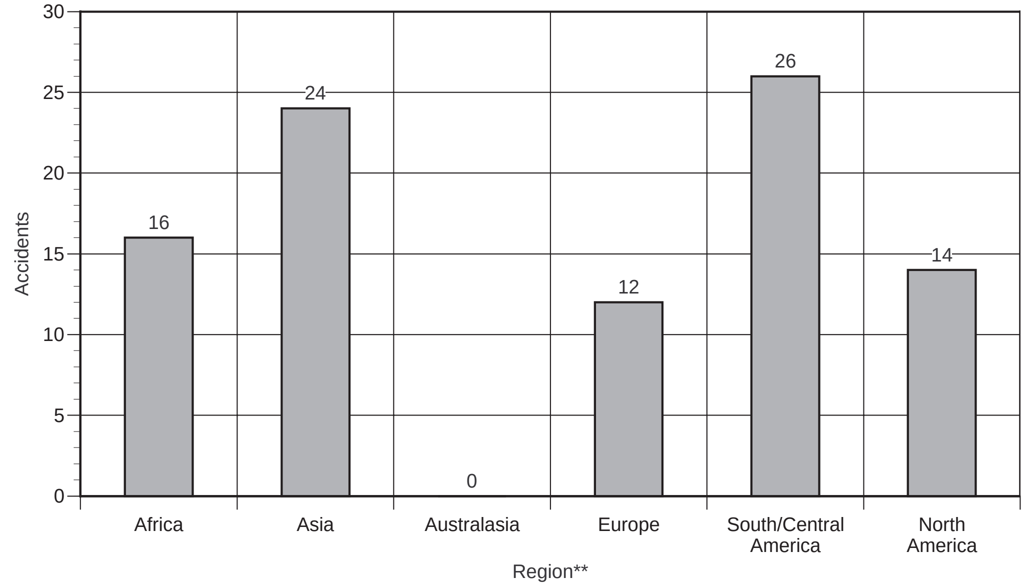
- Rates of occurrence were not evaluated in this analysis, as a smaller occurrence sample was adopted;
- Occurrence-variable data relevant to the DAAWG objectives were collected and analyzed;
- Higher-quality data were generally available for analyses of the individual occurrences;
- Great emphasis was placed on the dynamics of the occurrence sequence; and,
- Greater focus was placed on the identification of prevention strategies.

4.2 Study Approach

The methodology adopted is outlined below:

- Identify a sample of approach-and-landing occurrences appropriate to the study objectives;
- Develop or adopt a taxonomy for the collection and analysis of the data;
- Analyze the gathered information to determine factors associated with the occurrences in the study sample; and,

92 Fatal ALAs in Western-built Jets,* by Region of Operator 1980–1996



*Excludes business jets. ALAs = Approach-and-landing accidents involving jet aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States

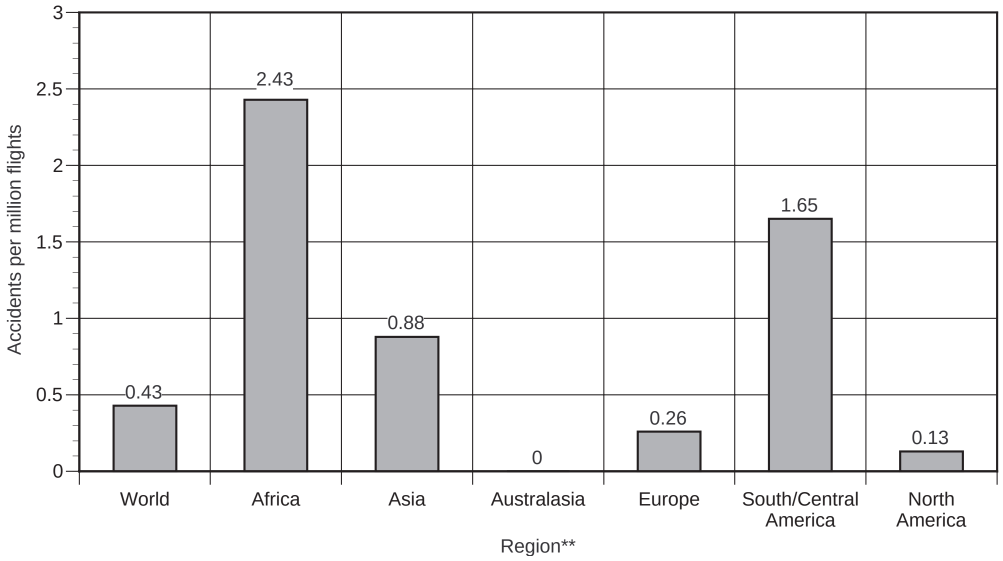
Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

**Regions defined by Airclaims and shown in Appendix A.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3–5

92 Fatal ALAs in Western-built Jets,* Rates by Region of Operator 1980–1996



*Excludes business jets. ALAs = Approach-and-landing accidents involving jet aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States

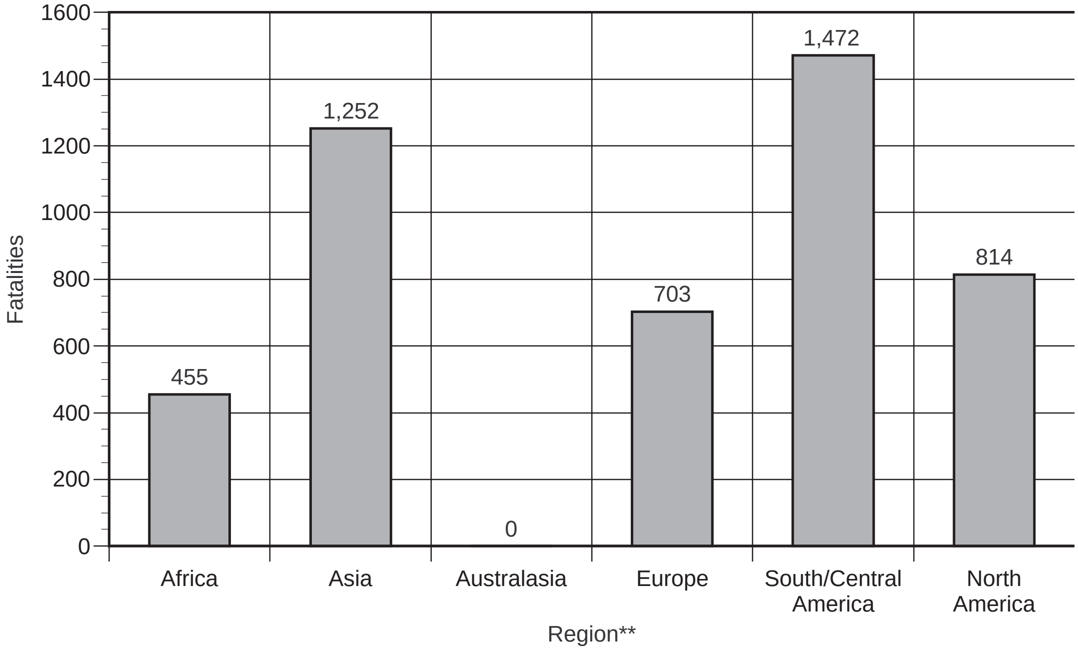
Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

**Regions defined by Airclaims and shown in Appendix A.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3–6

Fatalities in 92 ALAs in Western-built Jets,* by Region of Operator 1980–1996



*Excludes business jets. ALAs = Approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds/5,700 kilograms. U.S.S.R. = Union of Soviet Socialist Republics C.I.S. = Commonwealth of Independent States

Note: Accidents involving Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

**Regions defined by Airclaims and shown in Appendix A.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3–7

- Develop recommendations (prevention strategies) based on the study findings.

4.3 Data Sources

The following data sources were used by the DAAWG to compile the necessary data for each occurrence:

- AAIB;
- Airbus Industrie;
- Airclaims;
- AlliedSignal CFIT database;[13]
- BASI;
- The Boeing Co.;
- British Aerospace (BAe);
- U.K. CAA;
- TSBC;
- Cranfield University Safety Centre;
- FSF publications — *Accident Prevention* and *Flight Safety Digest* (various issues);
- FSF CFIT Task Force accident database;
- ICAO;
- IFALPA;
- NLR;
- NTSB; and,
- Netherlands Aviation Safety Board.

4.4 Occurrence-inclusion Criteria

An existing ALA data set was the starting point for developing the accident sample for the in-depth study.[5] The sample comprises 132 ALAs for the 10-year period 1984–1993 (inclusive). Considerable effort by NLR and the Foundation (using some 15 sources worldwide) was involved in developing that accident sample, and a virtually complete listing of all reported accidents at ICAO principal airports is included. Duplication of such an effort was not considered appropriate by the DAAWG. The inclusion of serious incidents and any occurrences after 1993 was deemed appropriate. The initial target sample selected for the study was representative of a cross-section of aircraft types, operators (major, regional, air taxi and corporate) and occurrence geographical locations. The DAAWG had great difficulties in accessing investigation reports from some geographical regions. Consequently, a number of occurrences were discarded and alternatives were selected so that the study could be completed within the agreed time frame. The data were included at the cost of biasing the sample by over-representing occurrences involving operators in specific areas of the world (because occurrence information from some parts of the world was scarce or not available at all). The final accident sample comprised 76 occurrences and is characterized by the following criteria:

- Events that occurred in flight phases after initiation of the descent (approach and landing, circling maneuvers, missed approach);
- Time period of 1984–1997;
- Public transport (majors, regional and air taxi);
- Corporate/executive operations;
- Passenger, freight and positioning flights;
- Fixed-wing aircraft with jet or turboprop powerplants;
- Fatal or nonfatal occurrences;
- Single-pilot and dual-pilot operations; and,
- Worldwide operations.

Two occurrences involving military transport aircraft have been included. Occurrences involving training flights, sabotage, terrorism and military action were beyond the scope of the study. The accident sample is presented in Appendix B.

The term “occurrence” is used to denote both accidents and serious incidents.

4.5 Occurrence Taxonomy

The record suggests that, in general, occurrences do not have a single cause, but result from a series of contributory factors. Such factors are generally related to one or more of the following categories: flight crew; environment; airport; air traffic control (ATC); aircraft; safety regulations and regulatory organizations; and operator organizations. This implies that a systemic approach to addressing safety issues is necessary. Although several models exist for analysis of occurrences, the DAAWG elected to adopt a combined approach that used:

- The U.K. CAA taxonomy (described in detail in section 3.5);
- Elements of the NLR-developed accident taxonomy;[4]
- Elements of the Reason model;[12] and,
- The University of Texas flight-crew behavioral markers.

Section 3 contains complete details of the U.K. CAA taxonomy, of which only brief details are presented below. The following steps in the analysis were adopted for reviewing each occurrence.

(a) **Occurrence-variable data.** Basic data were collected and categorized using an NLR taxonomy:[4]

  - Flight (e.g., aircraft type, geographical location, time of occurrence);
  - Flight crew (e.g., pilot flying, experience levels);
  - Environment (e.g., lighting conditions, weather); and,
  - Airport, ATC and approach (e.g., lighting available, type of approach flown, navigation aids, availability of radar).

The coding template is presented in Appendix C.

(b) **Sequential-event analysis.** Chronological listing of the sequence of errors/violations leading to the occurrence. This enabled the dynamic sequence of critical events to be formally captured.

(c) **Causal factors.** The U.K. CAA taxonomy was applied to identify occurrence causal factors. A causal factor is defined as an event or item that is judged to be directly instrumental in the causal chain of events leading to the occurrence.[6] Appendix C presents the causal-factors taxonomy. They are listed in generic groups and then divided into specific factors, e.g., one causal group is “aircraft systems” and one of the several specific factors in this group is “system failure affecting controllability.” The factors are identical to those employed in section 3, and an occurrence could be attributed to any number of causal factors from any one group and any combination of groups.

(d) **Circumstantial factors.** Circumstantial factors were also identified using the U.K. CAA taxonomy

— defined as an event or item judged not to be directly in the causal chain of events, but which could have contributed to the occurrence.[6] Just as with the causal factors, generic groups contain specific factors, and an occurrence could be attributed to any number of circumstantial factors from any one group and any combination of groups. Appendix C presents the circumstantial-factors taxonomy.

(e) **Consequences.** A list of consequences (e.g., collision, structural failure, fire and fuel exhaustion) was adopted to record the outcome of an occurrence (Appendix C). More than one consequence may be appropriate in some occurrences.

(f) **Behavioral markers.** Rating of key behavioral markers was identified in the occurrences. These are CRM-related behaviors that have been implicated as causal or mitigating factors in accidents and incidents. They are also used in evaluation of crew performance in line and simulator settings. Full details are given in section 5. These markers are specific behaviors that reflect effective and ineffective practice of CRM. The specific markers include, among others, effective briefings, vigilance, planning for contingencies and appropriate use of automation.

(g) **Occurrence-prevention strategies.** Identification of means that may have prevented the occurrence was based on the concept of "system defenses" as defined by the Reason model (Appendix C).[12] One or more of the following defenses identified were used to develop recommendations:

- Equipment;
- Policies and standards;
- Procedures; and,
- Training.

4.6 Occurrence-data Coding Protocol and Analytical Procedure

Individual DAAWG members were assigned specific occurrences to analyze. The analysts were provided with electronic templates for coding each occurrence. The appropriate report was reviewed for each occurrence in detail prior to coding the data in accordance with the process defined in section 4.5 and Appendix C. Only variables with clear information cited in the source were coded. The protocol precluded interpretation of the report by the reviewer to code any particular occurrence. Where insufficient information was provided, the parameter simply was coded as "unknown." This process may have resulted in some information being lost, but the risk of coding bias has been greatly reduced. The data for each occurrence were fed to a central location where an electronic occurrence database was established. The data were then subject to statistical analyses.

Because of the sample size, single-variable and bivariate analytical methods primarily were employed to study the data set.

4.7 Results

Unless stated otherwise, all percentages quoted are based on the total sample (76 occurrences) presented in Appendix C. Seventy-one of these were accidents and five were serious incidents. Because the set of data encompassed only a (small) selected set of occurrences, occurrence rates were not estimated. The lack of detailed information on aircraft movements worldwide does not allow the computation of occurrence rates for the various types of operation (e.g., air carrier, business or cargo) included in the sample.

4.7.1 Data Quality

Overall, there was a high level of confidence in the information obtained from the occurrence reports, as shown in Figure 4–1 (page 27). A stratification of data quality showed that Australasia, Europe and North America accounted for 84 percent of the high-quality data sample (see section 4.7.2 for further details about geographical distributions). The high levels of confidence in data correlate well with the percentage of aircraft equipped with an operating CVR (59 percent) and/or FDR (52 percent; Figure 4–2, page 27).

4.7.2 Flight Variables

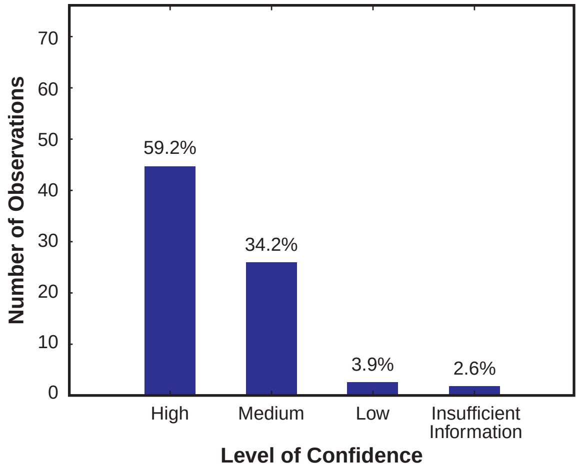
Year of occurrence. The distribution for the 76 occurrences by year (from 1984 to 1997) is shown in Figure 4–3 (page 27).

Occurrence type. To obtain some insight into broad occurrence types, each occurrence was coded as one of the primary categories shown in Table 4–1 (page 28). Categories were considered mutually exclusive and in some cases this proved to be difficult; e.g., a landing overrun also may have involved unstabilized conditions prior to touchdown. The five most frequent categories in Table 4–1 account for 76 percent of all occurrence types in the sample. This finding correlates with another recent study where a much larger sample (132 accidents) was employed.[3] The general trends in Table 4–1 relating to the most-frequent-occurrence categories are supported by data in Table 3–16.

The "other" category included a number of tail-strike incidents and landings on the wrong runway/airport.

Type of operator and aircraft category. The study sample included various types of operations, from public transport (major, regional and air-taxi operators), business and military transport to cargo operation. Figure 4–4 (page 29) presents the distribution for the operator types and aircraft types involved.

Level of Confidence, Study of 76 Approach-and-landing Occurrences

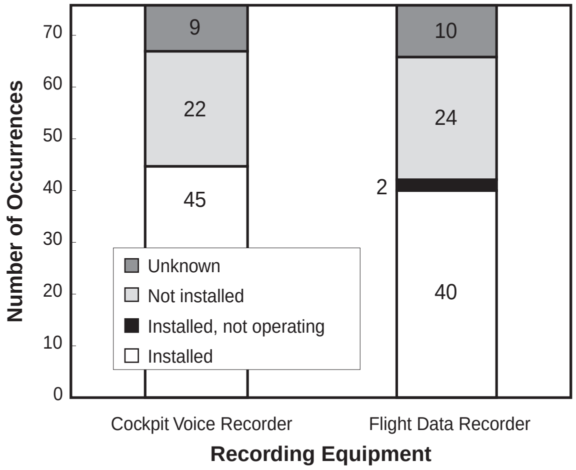


Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–1

Generally, the air-taxi and regional-operator occurrences involved turboprops, whereas the major-carrier occurrences involved jet aircraft. Two piston-engine aircraft were included.

Installed Recording Equipment, 76 Approach-and-landing Occurrences

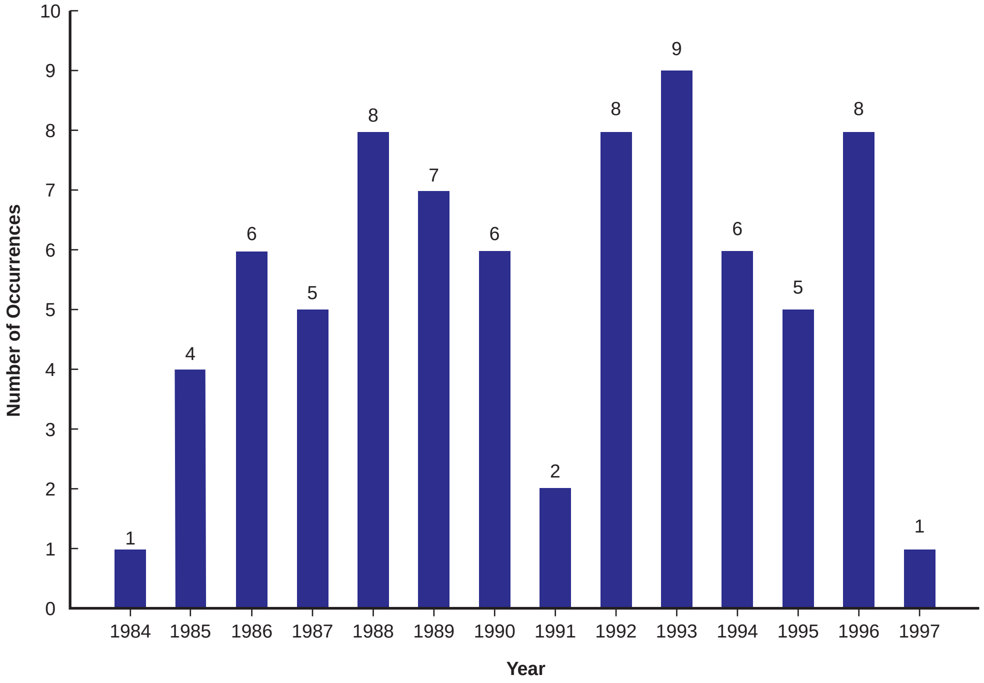


Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–2

The aircraft sample also was categorized as a function of engine type and primary market area. This produced the categories shown in Table 4–2 (page 29).

Annual Distribution of 76 Approach-and-landing Occurrences, 1984–1997



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–3

Table 4–1
Primary Categories in 76 Approach-and-landing Occurrences

Occurrence Category	Number of Occurrences	Percent
Controlled flight into terrain	28	36.8
Landing overrun	9	11.8
Loss of control	9	11.8
Runway excursion	6	7.9
Unstabilized approach	6	7.9
Other	6	7.9
Engine problem	2	2.6
Fuel exhaustion	2	2.6
Collision with terrain/water/ obstacle — non-CFIT	3	3.9
Aircraft structural problem	1	1.3
Airframe icing	1	1.3
Landing-gear problem	1	1.3
Wheels-up landing	1	1.3
Midair collision	1	1.3

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Almost 85 percent of the sample comprised transport and commuter airplanes.

Service type. The data generated the following distributions for service type:

- 83 percent passenger operations; and,
- 17 percent freight operations.

Although occurrence rates have not been estimated, the freight-operations contribution is not necessarily insignificant, especially when the movement data presented in section 3 are taken into consideration, i.e., to a first-order approximation, freight/ferry/repositioning flights account for 5 percent of all operations. Earlier NLR work showed that 26 percent of 156 CFIT accidents analyzed involved freight operations.[4] Another NLR/FSF analysis of 132 ALAs also shows a similar trend, i.e., freighter operations accounted for 24 percent of the total accident sample.[3] Thus, four recent studies draw attention to the proportion of accidents that involved freighters.

Geographical location of occurrence. The distribution of occurrences over world regions is presented in Table 4–3 (page 29).

These figures do not imply that a higher degree of risk is associated with regions demonstrating higher percentages of occurrence (occurrences per million movements have not been estimated for this small sample and are presented in section 3.7.6 for the larger accident sample). The significance of Table 4–3 is that it implies that the sample is biased because of the disproportionate number of occurrences associated with North America and Europe (71 percent). The DAAWG had considerable difficulties in obtaining reports and data from many of the other areas (a notable exception being Australasia). Many of the occurrences selected in the original sample were discarded because of these problems. As mentioned in section 4.7.1, the majority of high-quality occurrence data were generally associated with Australasia, North America and Europe. (Access to safety data is an ongoing industry problem that is hampering the effective resolution of global safety concerns. Similar problems continue to be reported by other safety analysts.)

Operator region of registration. The geographical region of registration per operator shows a strong correlation with the occurrence region, as indicated in Table 4–4 (page 30). Almost half of the occurrences involved domestic operations, which would account partly for this observation. Similar trends were reported in other studies (such as reference 4) involving larger samples and in section 3 (see Tables 3–2 and 3–3).

4.7.3 Airport and Approach Variables

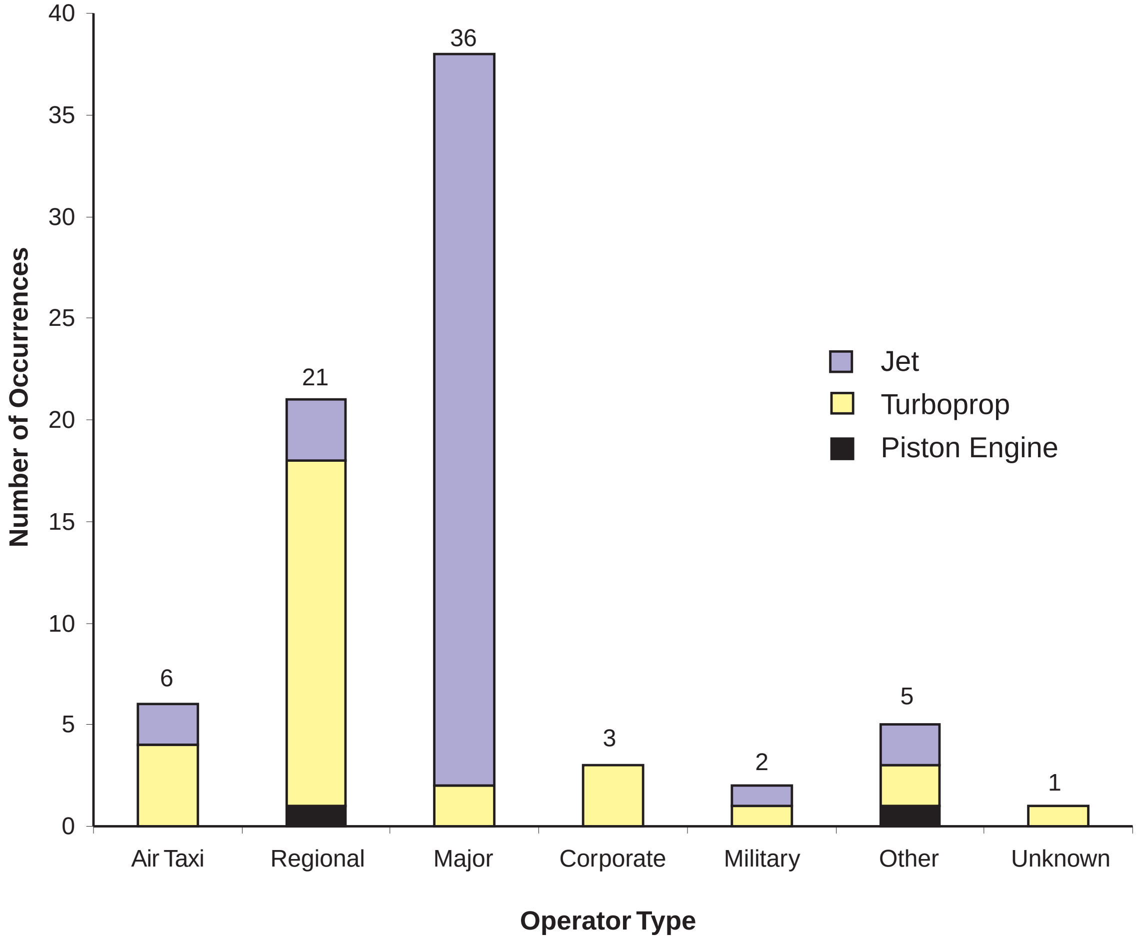
Type of approach. The distribution for the type of approach flown is shown in Table 4–5 (page 30).

An instrument landing system (ILS) was available in 42 percent of occurrences where a visual approach was made. These raw data alone do not necessarily provide insight into the risk associated with any approach type, and the following points need to be taken into account in the interpretation of the data:

- Movement data for nonoccurrence flights using the various approach types are required to estimate risk; and,
- The study sample is biased because 72 percent of the occurrences were in North America and Europe and the availability of ILS facilities is greater in these areas.[3] When the study data above are stratified by geographical region, it becomes evident that all the known ILS approaches among the occurrences are associated with Australasia, Europe, North America and the Middle East. See Figure 4–5 (page 30).

A recent study jointly conducted by NLR and the Foundation said that, on a worldwide basis, there appears to be a fivefold increase in accident risk among commercial aircraft flying nonprecision approaches compared with those flying precision approaches. When stratified by ICAO region, the risk increase associated with flying nonprecision approaches compared with flying precision approaches ranges from threefold to almost eightfold, depending on the region. That study used both accident data and movement data to reach those conclusions.[5] The study in section 3 reports that 75 percent of accidents

Distribution of Operator Type as a Function of Aircraft Category in 76 Approach-and-landing Occurrences



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–4

Table 4–2
Distribution by Aircraft Category in 76 Approach-and-landing Occurrences

Aircraft Category	Number of Occurrences	Percent
Transport jet	42	55.3
Transport turboprop	2	2.6
Business jet	6	7.9
Business turboprop	4	5.3
Commuter turboprop	20	26.3
Other: piston engine	2	2.6

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 4–3
Geographical Locations of 76 Approach-and-landing Occurrences

Geographical Location	Number of Occurrences	Percent
Africa	3	4
Asia	6	8
Australasia	4	5
Europe	25	33
Latin America and Caribbean	7	9
Middle East	2	3
North America	29	38

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 4–4
Operator Regions of 76 Approach-and-landing Occurrences

Region of Registration	Number of Occurrences
Africa	4
Asia	5
Australasia	4
Europe	20
Latin America and Caribbean	6
Middle East	2
North America	35

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

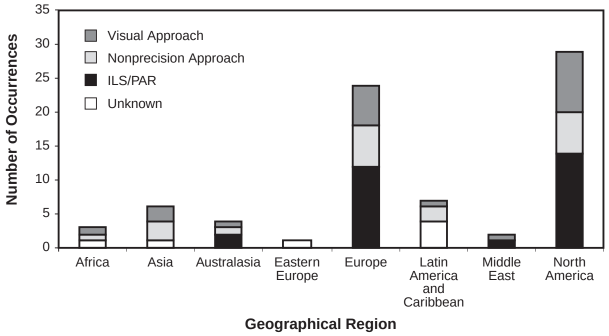
Table 4–5
Type of Approach Flown in 76 Approach-and-landing Occurrences

Approach Type	Number of Occurrences	Percent
Precision approach (typically ILS)	29	38
Nonprecision approach	19	25
Visual approach	21	28
Unknown	7	9

ILS = Instrument landing system

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Approach Type Flown as a Function of Geographical Region in 76 Approach-and-landing Occurrences



ILS = Instrument landing system
PAR = Precision-approach radar

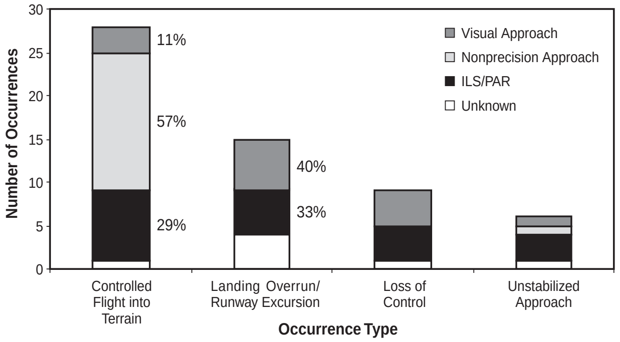
Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–5

reviewed occurred when a precision-approach aid was not available or was not used.

Figure 4–6 shows the approach type flown for the most frequent occurrence categories. Nonprecision approaches primarily were associated with CFIT. In addition, 57 percent of all CFIT occurrences involved nonprecision approaches.

Occurrence Type Stratified by Approach Flown in 76 Approach-and-landing Occurrences



ILS = Instrument landing system

PAR = Precision-approach radar

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

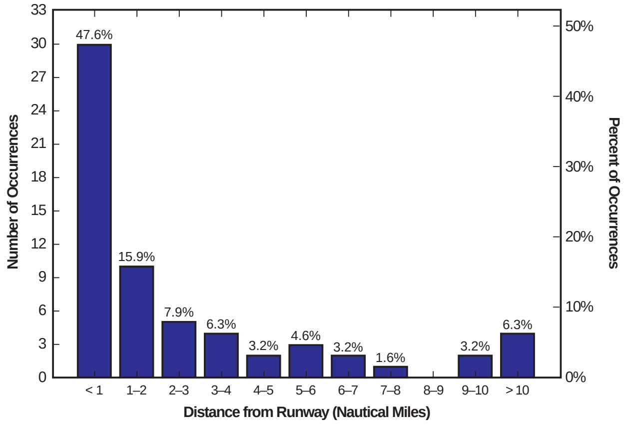
Figure 4–6

Location relative to the runway. For each occurrence, the location was determined relative to the runway and the (extended) runway centerline. Where this could be determined from the occurrence details, approximately 50 percent were found to be located on the extended centerline. Figure 4–7 (page 31) shows the distribution of occurrence locations relative to the runway. Almost half of the occurrences were within one nautical mile (NM; 1.85 kilometers) from the runway threshold, but these include runway overruns and excursions. Occurrences more than one NM from the runway were primarily CFIT occurrences.

Terminal-area facilities. Availability of terminal-area facilities is shown in Table 4–6 (page 31). In approximately 50 percent of the occurrences, radar surveillance was recorded as present at the occurrence location.

The generally high availability of terminal-area facilities reflects the sample bias — a high proportion of occurrences were in North America and Europe. Actual risk associated with the absence of these facilities was not estimated because of sample size and nonavailability of movement data. But a recent study conducted by NLR and the Foundation said (based on both accident and movement data) that the lack of terminal-approach radar (TAR) increases risk threefold compared to approaches with TAR present.[5] To some extent, this threefold

Distance from Runway of 76 Approach-and-landing Occurrences



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–7

Table 4–6
Terminal-area Facilities in 76 Approach-and-landing Occurrences

Facility	Yes Percent	No Percent	Unknown Percent
Approach lighting	79	5	16
Runway lighting	88	12	0
Visual approach-slope indicator (VASI)/Precision approach-path indicator (PAPI)	66	12	22
Terminal approach radar	51	23	26

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

increase in risk may be attributed to the risk associated with nonprecision approaches, because in certain regions a correlation exists between the presence of radar and the presence of precision-approach aids.

4.7.4 Environment Variables

Type of Terrain. Table 4–7 shows the type of terrain present at the occurrence location.

As Table 4–7 suggests, about 50 percent of the occurrences were in a flat-terrain environment. When the data are stratified by occurrence type (Table 4–1 shows categories), data show that CFIT accounted for the majority of occurrences in hilly and mountainous environments. To further examine the type of terrain present for the CFIT occurrences within the sample, stratification is given in Table 4–8.

Table 4–7
Terrain Characteristics for 76 Approach-and-landing Occurrences

Terrain Type	Number of Occurrences	Percent
Flat terrain/over water	41	54
Hilly	19	25
Mountainous	10	13
Unknown	6	8

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 4–8
Terrain Characteristics for CFIT Occurrences among 76 Approach-and-landing Occurrences

Terrain type	Percent
Flat terrain or water	29
Hilly	43
Mountainous	25
Unknown	4

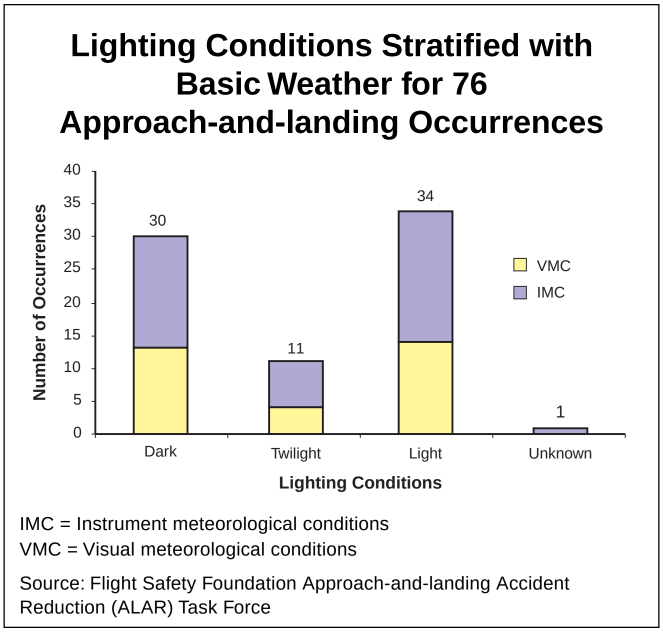
Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Approximately 67 percent of the CFIT occurrences were in hilly or mountainous environments. But a significant proportion of CFIT occurrences were in areas of flat terrain — primarily landing-short occurrences. Although significant terrain features are an important operational consideration, they are not necessarily a prerequisite for CFIT. This finding is fully supported by two other recent studies.[4,5]

Lighting conditions. Figure 4–8 (page 32) gives an overview of the lighting conditions for the occurrence. Figure 4–8 is also stratified by basic meteorological condition, i.e., whether the flight was conducted in instrument meteorological conditions (IMC) or visual meteorological conditions (VMC). Fifty-nine percent of all occurrences occurred in IMC and 53 percent occurred in lighting conditions of darkness and twilight.

Figure 4–9 (page 32) presents the lighting conditions for the primary occurrence categories.

Almost 60 percent of the CFIT occurrences were during dark or twilight conditions. When stratified by basic meteorological condition, the data show that 68 percent of all CFIT occurrences were associated with IMC. A more comprehensive study of CFIT accidents found that 87 percent of 107 CFIT accidents involved IMC and about half of these occurred in darkness.[4]

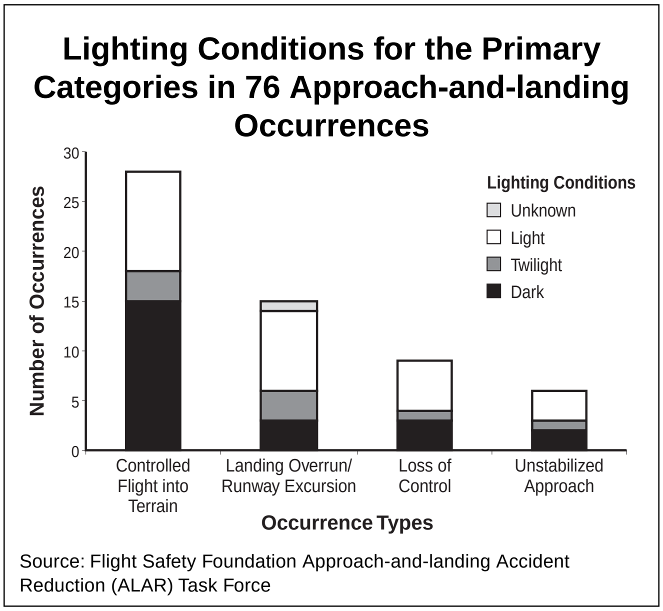


Lighting Conditions Stratified with Basic Weather for 76 Approach-and-landing Occurrences

IMC = Instrument meteorological conditions
VMC = Visual meteorological conditions

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–8

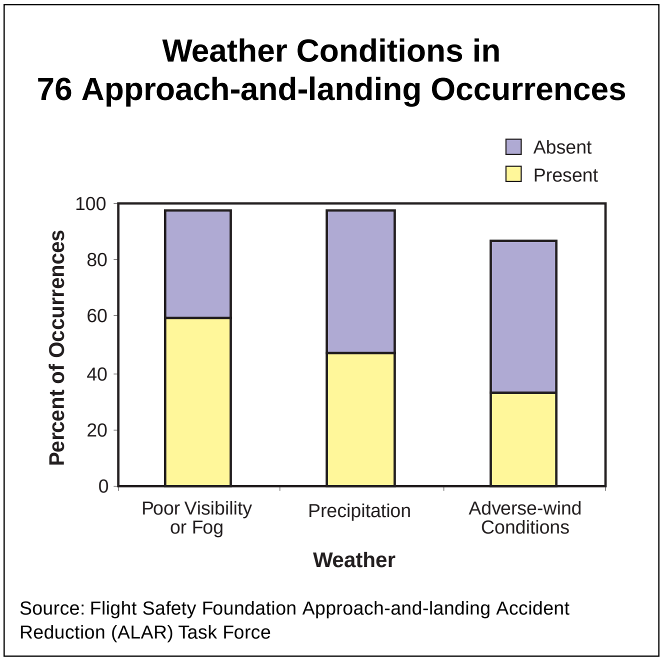


Lighting Conditions for the Primary Categories in 76 Approach-and-landing Occurrences

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–9

Generalized weather conditions. Figure 4–10 gives an overview of the weather conditions at the time of the occurrence. The data presented are categorized with respect to visibility, precipitation and wind. Precipitation includes rain, snow and icing. Adverse wind conditions indicate the presence of (strong) crosswinds, tailwind or wind shear. The data sets (bars) in Figure 4–10 do not extend to 100 percent because of problems associated with “unknown” data. Although rates of occurrence were not estimated, almost 60 percent of the occurrences were in poor-visibility conditions, about half in precipitation and almost one-third in the presence of adverse winds.



Weather Conditions in 76 Approach-and-landing Occurrences

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–10

In 38 percent of the occurrences, at least two of the weather conditions were present. Poor visibility was the fourth most frequent circumstantial factor in the study presented in section 3.

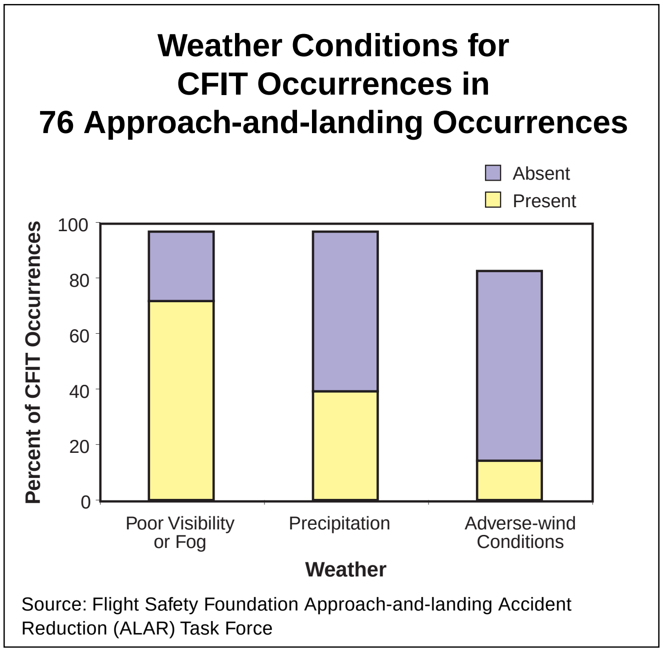
A more detailed analysis of the weather conditions for the primary occurrence categories was conducted. As expected, the majority of the CFIT occurrences were during poor-visibility conditions, as indicated in Figure 4–11 (page 33). These results correlate with lighting conditions shown in Figures 4–8 and 4–9. Precipitation was present in almost 40 percent of the occurrences. Adverse-wind conditions were not strongly associated with CFIT occurrences.

Figure 4–12 (page 33) gives an overview of weather during the combined landing-overrun and runway-excursion subset of the sample. The data indicate that the majority of these occurrences were during adverse weather. Wet-runway data also are shown in Figure 4–12, and 73 percent of landing overruns/runway excursions occurred on wet runways. Two-thirds of the overruns or excursions occurred with at least two of the weather factors in Figure 4–12 — i.e., rain, fog and/or crosswind — present.

Although the data are not presented in this report, the analysts found that a significant association between loss of control and weather could not be demonstrated for that small subset of the sample.

4.7.5 Flight-crew Variables

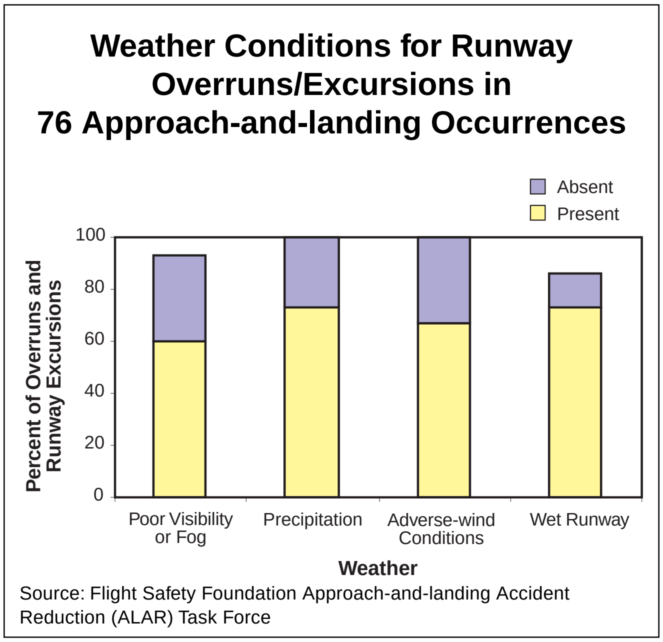
Pilot flying. Figure 4–13 (page 33) shows the distribution of data for pilot flying (PF) at the time of the occurrence. Although the data show the greatest percentage of



Weather Conditions for CFIT Occurrences in 76 Approach-and-landing Occurrences

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–11

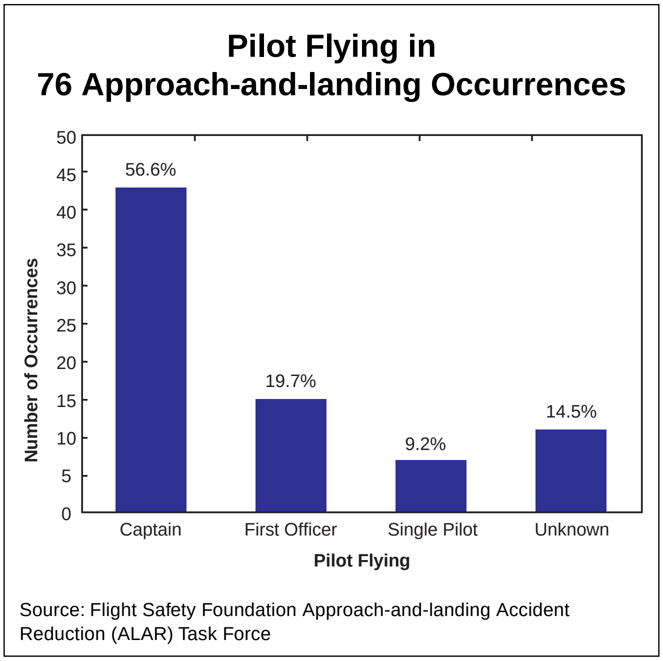


Weather Conditions for Runway Overruns/Excursions in 76 Approach-and-landing Occurrences

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–12

occurrences with the captain as PF, this does not imply an increase in risk, because movement data (i.e., exposure of captain as PF in normal line operations) are required to ascertain any measure of risk. Those data for worldwide operations were unavailable to the study group. When data for dual-pilot operations alone were analyzed, the captain was PF in 74 percent of occurrences in that sample. There were multiple examples demonstrating poor CRM. Several crews had received little, if any, CRM training.



Pilot Flying in 76 Approach-and-landing Occurrences

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–13

Figure 4–14 (page 34) presents the primary occurrence categories stratified by pilot flying. All single-pilot operation occurrences involved CFIT.

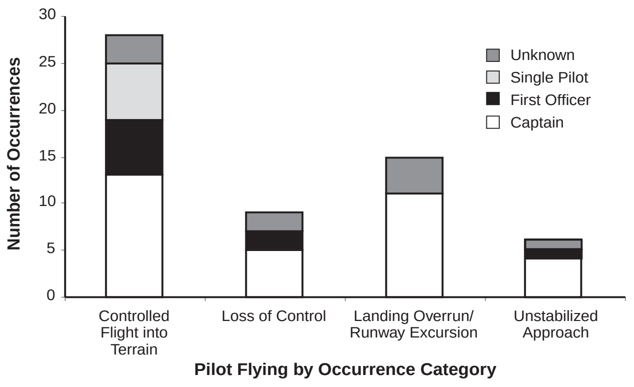
4.7.6 Causal Factors

The U.K. CAA taxonomy enabled the identification of causal factors for each occurrence. In contrast to the study reported in section 3, a single primary causal factor was not identified. One or more of the factors in the taxonomy could be attributed to any occurrence. The factors are not mutually exclusive, e.g., “press-on-itis” also may have involved being “high/fast on the approach.” The most frequent causal factors are presented in Table 4–9 (page 34). Supporting evidence is provided in the following sections, and several other relevant causal factors (not appearing in Table 4–9) are also referred to in the following sections. The relatively low magnitudes in the “unknown” category reflect the quality of data employed.

Poor professional judgment/airmanship. This was the most frequent causal factor (73.7 percent), and refers to poor decision making other than “press-on-itis” or actions not covered by another more specific factor. Specific examples of errors include:

- Not executing a missed approach (aircraft not stabilized, excessive glideslope/localizer deviations, absence of adequate visual cues at DH/MDA, confusion regarding aircraft position, problems interacting with automation);
- Ignoring multiple GPWS alerts (eight in one example);
- Poor/inappropriate division of cockpit duties;

Pilot Flying for the Most Frequent Categories in 76 Approach-and-landing Occurrences



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4–14

- Decision to execute a nonprecision approach, instead of an ILS approach, in demanding conditions to expedite arrival; and,
- Incorrect/inappropriate use of aircraft equipment.

Table 4–10 (page 35) shows that in 17.1 percent of occurrences, a go-around was initiated. Given the evidence provided in this whole section (see Table 4–9), analysts expected the initiation of a higher number of go-arounds in practice.

Omission of action/inappropriate actions. This was the second most frequent causal factor (72.4 percent) and represents inadvertent deviation from SOPs (i.e., an error). Deliberate “nonadherence to procedures” accounted for 39.5 percent and represents a violation of SOPs. Examples of procedural deviations include:

- Omission/inadequate approach briefing;
- Omission of standard speed and altitude callouts;
- Failing to check radio altimeter (RA);
- Failing to call out “runway in sight/no contact” at DH;
- Not requesting updated weather information;
- Omission of checklist items;
- Failing to verbalize/confirm inputs to systems such as the flight management system (FMS), autopilot (AP), navigation radios; and,

Table 4–9
Most Frequently Identified Causal Factors in 76 Approach-and-landing Occurrences

Causal Factor	Yes Percent	No Percent	Unknown Percent
Poor professional judgment/airmanship	73.7	19.7	6.6
Omission of action/inappropriate action	72.4	22.4	5.3
Failure in CRM (cross-check/coordinate)	63.2	25.0	11.8
Lack of positional awareness in air	51.3	42.1	6.6
Lack of awareness of circumstances in flight	47.4	40.8	11.8
Flight-handling difficulties	44.7	34.2	21.1
Slow/delayed crew action	44.7	43.4	11.8
“Press-on-itis”	42.1	42.1	15.8
Deliberate nonadherence to procedures	39.5	48.7	11.8
Slow and/or low on approach	35.5	55.3	9.2
Incorrect or inadequate ATC instruction/advice/service	32.9	60.5	6.6
Fast and/or high on approach	30.3	60.5	9.2
Postimpact fire (as a causal factor of the fatalities)	26.3	71.1	2.6
Aircraft becomes uncontrollable	25.0	69.7	5.3
Lack of qualification/training/experience	22.4	60.5	17.1
Disorientation or visual illusion	21.1	64.5	14.5
Interaction with automation	19.7	65.8	14.5

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 4–10
Go-around Initiation in 76 Approach-and-landing Occurrences

Go-around Initiated	Percent
Yes	17.1
No	82.9

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

- Deliberate deviation from a published IFR approach procedure.

Procedural deviations virtually always are associated with precursors (i.e., error-producing conditions).[12] Examples from this study include:

- Fatigue (causal factor in 6.5 percent of all occurrences);
- Management pressure;
- Inadequate training;
- High workload levels;
- Overconfidence and confirmation bias; and,
- Complacency, overfamiliarity and inadequate or inappropriate SOPs leading to nonstandard procedures.

Evidence from many of the occurrences analyzed suggests that the error types observed were representative of longstanding operating cultures.

Failure in CRM (cross-check/coordinate). This was the third most frequent causal factor (63.2 percent) and essentially refers to monitoring/challenging errors. It generally reflects a breakdown in crew coordination. Failures in monitoring/challenging occurred in situations including the following:

- Continuation of an approach in adverse conditions;
- Excessive airspeed and sink rate, glideslope deviation;
- Descent below MDA/DH prior to acquiring adequate visual cues;
- Failure to initiate a go-around or escape maneuver;
- Absence of standard callouts from another crewmember;
- Absence of standard briefings; and,
- Failure to recognize deviations from standard/approved procedures.

Associated factors included:

- Lack of experience or training/inappropriate training;
- Complacency or overconfidence;
- High-workload situations;
- National culture; and,
- Lack of risk assessment.

Evidence from some occurrences suggests that these problems were not isolated and represented line practice for a significant period prior to the occurrence.

Lack of positional awareness in the air. This accounted for 51.3 percent of all occurrences. This generally involved vertical-position awareness, resulting in CFIT. Supporting data are presented in section 4.7.3. The site was often on the extended runway centerline for CFIT occurrences. Other studies reinforce this finding.[4,14] "Failure in look-out" (to avoid other aircraft/obstacles) was a causal factor in 14.5 percent of all occurrences.

Flight-handling difficulties. The DAAWG defined this factor as the inability of the crew to control the aircraft to the desired parameters (e.g., speed, altitude, rate of descent). Inadequate aircraft handling was a causal factor in 44.7 percent of all occurrences analyzed. This factor resulted in loss of control, unstabilized approaches, landing overruns and runway excursions. Poor energy management was an associated factor in many occurrences. Aircraft-handling difficulties occurred in situations such as:

- Asymmetric-thrust conditions;
- Rushed approaches and "press-on-itis" occurrences;
- Attempts to execute demanding ATC clearances;
- Conditions involving strong tailwinds;
- Wind shear/loss of control/turbulence/gusts (a causal factor in 18.4 percent of the sample occurrences);
- Stall during an escape maneuver/go-around; and,
- Inappropriate/improper use of automation.

The factor "aircraft becomes uncontrollable" in Table 4–9 also includes situations such as engine detachment from the airframe and failure of powered flight controls.

Table 4–11 (page 36) presents data for engine anomalies and loss-of-control occurrences from the sample of 287 fatal ALAs reported in section 3. The comparison with nonloss-of-control situations is important. These data seem to suggest that the likelihood of encountering a loss-of-control situation is

Table 4–11
Engine Anomalies and Loss-of-control Accidents in 287 Fatal ALAs

	Engine Failure	Simulated Engine Failure	Engine Fire	Total
Loss of control	10	1	3	14
Nonloss of control	2	0	1	3

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

probably higher with the engine anomalies identified in Table 4–11.

Slow/delayed crew action. "Slow/delayed crew action" was a causal factor in 44.7 percent of the study-sample occurrences. In numerous occurrences, crew recognition of the seriousness of the situation was not timely, and hesitation in order to reassess resulted in time loss prior to the development of a more critical situation. Examples include:

- Delayed response to GPWS alerts;
- Delayed go-around decision;
- Delayed braking action during roll-out;
- Delayed configuration changes (e.g., flaps, landing gear); and,
- Delayed action to manage aircraft energy (e.g., in high/fast situations).

Evidence suggests that some occurrences were a direct result of poor or inappropriate training and/or company procedures.

"Press-on-itis." "Press-on-itis" refers to the flight crew's determination to get to a destination, or persistence in a situation when that action is unwise. This essentially represents poor decision making. In the current study, numerous examples of "press-on-itis" were identified (42.1 percent) and examples include:

- Continuation to the destination (as opposed to diverting) despite deteriorating weather conditions or conditions below minimums for a given approach;
- Acceptance of demanding ATC clearances;
- Continuation with the approach because of (excessive) management-induced commercial pressures;
- Pressure to complete a flight within the prescribed flying duty period;
- Repositioning of aircraft to meet operational needs;
- Operational penalty incurred by diversion; and,
- Continuing the approach when a missed approach or a go-around normally would be executed.

The consequence of "press-on-itis" was often increased cockpit workload, and reduced levels of both crew coordination and situational awareness. In many occurrences, there was a breakdown in CRM between the flight crew and ATC. Approach stability also was compromised frequently. Overall, it was evident that "press-on-itis" did not enable crews to prepare and execute safe approaches.

Slow and/or low on approach. Although low-energy approaches (35.5 percent, essentially "slow and/or low on approach") resulted in some loss-of-control occurrences, they primarily involved CFIT because of poor vertical-position awareness. Factors associated with being slow/low on approach include:

- Inadequate awareness of automation/systems status;
- Lack of vigilance and crew coordination, including omission of standard speed-and-altitude callouts; and,
- High workload and confusion during execution of nonprecision approaches.

Too fast and/or high on approach. Almost one-third (30.3 percent) of the occurrences involved high-energy approach conditions. Such conditions led to loss of control and landing overruns/excursions, and contributed to loss of situational awareness in some CFIT occurrences. Such occurrences were observed to be the consequences of factors such as:

- Overconfidence, lack of vigilance and "press-on-itis" (e.g., at familiar airfields);
- Lack of crew coordination; and,
- Accepting demanding ATC clearances leading to high-workload conditions.

Incorrect or inadequate ATC instruction/advice/service. This was a factor in 32.9 percent of the occurrences. This factor is primarily related to weather, local aircraft activity and approach instructions. Specific examples identified include incorrect radar vectoring, incorrect (or absence of) essential traffic information and inadequate controller technique in dealing with aircraft facing minor and serious difficulties. Associated factors included the ambiguous responsibility of air traffic services (ATS).

Evidence suggests that some instances of high workload on the flight deck were a function of the type of clearance issued by the controller, e.g., last-minute runway change or late notification of landing runway. Such situations resulted in less time for the flight crews to execute safe approaches. The consequences of some rushed approaches were unstabilized conditions, overruns, CFIT and loss-of-control occurrences. The high workload levels resulted in occurrences of poor crew coordination and reduced situational awareness. In aircraft with advanced flight-deck systems, demanding clearances can necessitate reprogramming systems such as the FMS, which can involve increased head-down time during a critical period. Controllers' inadequate knowledge of the capabilities and limitations of advanced-technology flight decks may have played a role in such occurrences. Recent studies conducted by BASI and the U.S. Federal Aviation Administration (FAA) Human Factors Team, and interviews with controllers support these observations.[15]

Other ATS-related causal factors (not shown in Table 4–9) included:

- Misunderstood/missed communication such as missed readback, call-sign confusion, simultaneous transmissions (11.8 percent);

- Ground-aid malfunction or unavailability (e.g., runway lights) (13.2 percent); and,

- Inadequate airport support such as emergency services, runway condition and lighting and wind-shear detection (14.5 percent).

There are documented occurrences of controllers and flight crews using nonstandard phraseology. In several occurrences involving non-native English speakers, the language issues exacerbated the poor communications between the flight crews and ATC.

Several occurrences involved ambiguous communication of an onboard emergency by flight crews, without an ATC request for clarification/verification of the ambiguous transmissions. In other occurrences, aspects of ATC handling of the aircraft during emergency situations may have confused or distracted flight crews, e.g., unnecessary requests for information. In contrast, there were also occurrences where crews ignored repeated urgent ATC warnings in critical situations. Such examples demonstrate poor CRM between flight crews and controllers.

Postimpact fire. Fatality resulting from "postimpact fire" was a causal factor in 26.3 percent of all occurrences (also see Table 3–12 where it was a factor in 11.8 percent of 287 occurrences). Associated factors included:

- Confusion during the rescue arising from poorly defined procedures and communication among ARFF services, airport authorities, ATC and operators;

- Ambiguous division of responsibilities during rescue; and,

- Lack of information about the number of people aboard the aircraft.

Lack of qualification/training/experience. "Lack of qualification/training/experience" on the aircraft type or type of operation being conducted was a causal factor in 22.4 percent of all occurrences. Occurrences involving inadequate training in type and for night operations, IFR operations and nonprecision approaches were among those identified. The range for total experience in type is shown in Table 4–12.

Disorientation or visual illusions. Visual and physiological illusions were involved in 21.1 percent of all occurrences. The result of these illusions is generally a false perception of altitude and/or attitude, resulting in landing short or loss of control. Visual illusions in the study sample resulted from runway slope effects, "black-hole"-type approach environments and whiteout conditions. Illusions of attitude occur almost exclusively when there are no visual references to provide a true horizon — both pitch-related and bank-related illusions were uncovered in the study sample (somatogravic and somatogyral illusions, respectively). Lack of vigilance, assigning a lower priority to monitoring primary instruments, and lack of training for and awareness of such illusions were associated factors.

Interaction with automation. As noted in Table 4–9, difficulties in "interaction with automation" were involved in almost one-fifth of all occurrences. The evidence suggests that this was caused primarily by unawareness of or unfamiliarity with the systems. On numerous occurrences,

Table 4–12
Experience in Type for Flight Crew in 76 Approach-and-landing Occurrences

Crewmember	Number of Occurrences	Range of Hours	Mean Hours
Captain	38	123–9,500	2,399
First officer	51	27–5,500	1,209
Single pilot	6	37–1,251	337

* Where data were known.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

this factor was associated with the quality and quantity of crew training. Occurrences were identified where basic crew training and/or reference material relating to systems such as the AP, flight director (FD) and RA were absent. The AP, autothrottle (AT), FD and FMS were the most frequent subsystems cited. There were occurrences where flight crews continued using the automation (fixation) despite confusion and/or high workload levels that arose as a result of doing so. A specific example is reprogramming the FMS because of a last-minute change of runway/approach. Operator policy/guidelines regarding use of the automation (when and when not to employ automation, and the appropriate levels to use) probably would have been beneficial in such occurrences. It is important to realize that the automation issues were not restricted to a specific aircraft type or to advanced-technology flight decks — aircraft equipped with electromechanical instruments also were involved. The following frequency of other pertinent causal factors, not presented in Table 4–9, was found:

- Design shortcomings that may encourage failure, error or misoperation (18.4 percent);
- Flight-deck-system failures such as warning lights or navigation systems (10.5 percent);
- Incorrect selection on instrument/navaid (11.8 percent); and,
- Action on wrong control/instrument (13.2 percent).

Noncontributory factors. The following factors (included in the CAA taxonomy) were not identified as causal, to any degree of certainty, in any occurrence analyzed:

- Wake turbulence;
- Fuel contaminated/incorrect;
- Engine failure simulated;
- Engine fire or overheat;
- Ground staff/passenger struck by aircraft;
- Bogus parts;
- Flutter; and,
- Unapproved modification.

This does not imply that such factors are unimportant, but shows their frequency of occurrence relative to other factors for the current study sample.

Causal factors and human error — a closer look. In the early 1980s when CRM was initiated, one important U.S. National Aeronautics and Space Administration (NASA) research finding was that pilot (human) error involving team interaction was implicated in 70 percent or more of air transport accidents.[16] The modal finding in accident investigations was that pilot error was the cause. With increasing sophistication and a deeper knowledge of the aviation system came the realization that most accidents involve multiple failures in a complex system. The term “system accident” began to be applied, and investigations focused on corporate culture and other factors outside the cockpit. Because few accidents and incidents have a single cause, it also was recognized that attempting to isolate a primary cause that outweighs other contributing factors could be difficult.

What then happened to pilot error? Error remains an inherent part of human function. James Reason has developed a model of error and causality that is used increasingly in accident investigation.[12] Error, in Reason’s view, is facilitated or mitigated by organizational and environmental factors. In this view, an accident represents the convergence of multiple factors to breach organizational and personal defenses. Each accident is unique in that the particular combination of contributing factors is unlikely to be replicated. Although the same factors are likely to be involved in many accidents (bringing some order to the process of analysis), one cannot expect the entire array of contributing circumstances to be repeated.

To illustrate this point, the full set of causal factors was examined for the occurrences analyzed for the ALAR study. First, ratings of the set of 64 factors identified were aggregated for each occurrence and these were contrasted by type of operation. Second, the 22 crew factors were similarly aggregated for each occurrence. The results of these analyses are shown in Table 4–13. An average of 10 (out of 64) factors was deemed to be causally involved, with a maximum of 24. For the 22 crew factors, the average was 6.9 with a maximum of 17. Most important, crew causal factors were implicated in 93 percent of the occurrences. The implication is that these occurrences are strongly multicausal, and that interventions

Table 4–13
Mean Number of Causal Factors By Type of Operation in 76 Approach-and-landing Occurrences

	All Factors	Crew Factors
Air Taxi	9.0	7.3
Regional	10.1	6.7
Major	10.8	7.2
Corporate	7.3	5.3
Military	12.0	6.0
Other	6.6	5.6
Total	10.1	6.9

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

in the interest of safety must address a variety of issues that include the infrastructure and culture as well as the crew.

Crew behavior and error. Of the 64 causal factors defined for the analysts, 22 (34 percent) dealt with crew actions or characteristics. But in the analyses, crew factors constituted 68 percent of the total causal ratings. The data again support the contribution of flight crews in the accident and incident sequence. Nevertheless, the roles of the environment, the infrastructure, the professional culture of the crew, and the organizational culture surrounding them are clearly implicated and cannot be disentangled. This is particularly critical for prevention-strategy development.

4.7.8 Causal Factors and CRM

Correlations among the crew causal factors were examined to determine patterns of relationships. In the lists used in the U.K. CAA and the ALAR analyses, the factors include items of different levels of specificity. The items "lack of positional awareness in air" and "lack of awareness of circumstances in flight" are one example. Not surprisingly, the two items are significantly and positively correlated, but are not correlated perfectly. Many raters checked both, but other raters used one or the other, depending on the circumstances of the occurrence. (With a larger database, it would be useful to perform factor analyses of the dataset to produce clusters of ratings, some of which could be subsets of broader categories.)

There are causal factors of equal and critical importance for the outcome but that influence the flight through different mechanisms and at different points during the flight. For example, CRM practices in the preflight, team-formation period that include establishing the team concept and briefing critical aspects of the flight may play a vital role during the approach phase, as shown in line-audit data in section 5. Although CRM was rather tightly defined as "failure in CRM (cross-check/coordinate)," the pattern of ratings shows the CRM linkage with other rated causes. The CRM rating was significantly correlated with nine (of the 22) causal factors. Thus, 10 of the 22 crew factors were linked as being associated with CRM. These are shown in Table 4–14.

4.7.9 Circumstantial Factors

Table 4–15 (page 40) presents all circumstantial factors identified.

Environmental factors. The most frequent circumstantial factor was "poor visibility" (59.2 percent), and this is wholly consistent with data presented in Figures 4–8 and 4–10. "Other weather" (36.8 percent) in Table 4–15 refers to conditions such as rain, snow and thunderstorms. Contaminated "runway condition" was a factor in 18.4 percent of all occurrences. As Figure 4–12 shows, almost three-fourths of all landing overruns and runway excursions occurred on wet runways.

Table 4–14
Causal Factors Correlated Significantly with CRM Rating in 76 Approach-and-landing Occurrences

Causal Factor	Statistical Probability (*p*)*
Lack of positional awareness in air	<.001
Lack of awareness of circumstances in flight	.004
Action on wrong control/instrument	.040
Omission of action/inappropriate action	.009
"Press-on-itis"	.032
Poor professional judgment/airmanship	<.001
Interaction with automation	.002
Fast and/or high on approach	<.001
Fatigue	.044

CRM = Crew resource management

*A measure of whether each causal factor's correlation with the CRM rating is statistically significant. For example, the causal factor "lack of positional awareness in air" was statistically significant at the .001 level, that is, the probability that this correlation resulted from sampling error is less than one in 1,000.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Monitoring/challenging (cross-check/coordinate). "Failure in CRM (cross-check/coordinate)" was the second most frequent circumstantial factor (58 percent), whereas it was the third most frequent causal factor.

Procedures. "Incorrect or inadequate crew procedures" accounted for 47.4 percent of all occurrences. Examples of these inadequacies include:

- Absence of specific procedures defining crew response to GPWS alerts;
- Absence of procedures defining conditions dictating a go-around (including stabilized-approach policy);
- Use of RA not included in normal procedures/checklists;
- Procedures for two-pilot operations not addressed;
- Weak SOPs for use of automation; and,
- Insufficient procedures for executing nonprecision approaches.

The evidence suggests that lack of procedures, together with incomplete guidance, can hamper the ability of pilots to make sound and consistent decisions.

Organizational failures. "Company management failure" was identified as a circumstantial factor in 46.1 percent of all occurrences. Examples of these deficiencies include:

Table 4–15
Circumstantial Factors in 76 Approach-and-landing Occurrences

Circumstantial Factor	Yes Percent	No Percent	Unknown Percent
Poor visibility	59.2	39.5	1.3
Failure in CRM (cross-check/coordinate)	57.9	31.6	10.5
Incorrect/inadequate procedures	47.4	42.1	10.5
Company management failure	46.1	40.8	13.2
Other weather	36.8	60.5	2.6
Training inadequate	36.8	40.8	22.4
Inadequate regulation	30.3	59.2	10.5
Nonfitment of presently available safety equipment	28.9	64.5	6.6
Inadequate regulatory oversight	25.0	60.5	14.5
Lack of ground aids	21.1	73.7	5.3
Runway condition	18.4	77.6	3.9
Failure/inadequacy of safety equipment	13.2	81.6	5.3
Lack of ATC	11.8	82.9	5.3

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

- Management attitudes supporting deviations from safe operational practices to achieve overall commercial objectives;

- Inadequate resources allocated to safety, including the provision of updated equipment;

- Ineffective communications inhibiting expression of concerns about safety by personnel;

- Failure to provide adequate crew training;

- Failure to implement provisions to adequately oversee the training of flight crews;

- Poor control of safety of flight operations; and,

- Inadequate planning and procedures.

Training. “Inadequate/inappropriate training” was a circumstantial factor in 36.8 percent of all occurrences. The types of training inadequacies identified in this study included:

- Inappropriate/lack of training for nonprecision approaches;

- Absence of the required night training in the aircraft type;

- Lack of training concerning visual illusions;

- No provisions for training in aviation human factors;

- Lack of CRM, error-management or pilot decision-making training;

- Inadequate training for two-pilot flight operations;

- Lack of GPWS recovery training;

- Inappropriate/inadequate unstabilized approach and go-around maneuver training; and,

- Basic training for AP, FD and RA not provided.

Regulation. “Inadequate regulation” accounted for 30.3 percent of the sample, whereas “inadequate regulatory oversight” was involved in 25 percent of the occurrences. In the occurrences involving inadequate regulation, examples identified include:

- No requirement to specify routine SOPs;

- Waivers granted for operation, resulting in lower operating standards;

- No requirement to equip aircraft with GPWS;

- Absence of adequate requirements for type-endorsement training;

- No requirement to provide CRM or pilot decision-making training; and,

- No regulatory minimum-approach-weather criteria for each approach type.

Issues related to regulatory oversight include:

- Deficiencies in the flight operations and maintenance activities of operator not detected;
- Inadequate audit and surveillance procedures;
- Poor planning of surveillance activities;
- Poor follow-up of corrective action required by operator in breach of requirements; and,
- Inadequate training of regulatory personnel.

In addition, some occurrence investigations suggested that inadequate resources restricted the ability of the authority to conduct audit and surveillance activities.

Provision of safety equipment. The factor "nonfitment of presently available safety equipment" (28.9 percent) generally referred to the absence of a GPWS. In the study reported in section 3, this was the most frequent circumstantial factor (47 percent). A recent NLR study concluded that in a sample of 108 CFIT accidents, 75 percent of the aircraft were not equipped with a GPWS.[4]

In the study sample, numerous aircraft were not equipped with an RA. One finding is that in many occurrences where an RA was present, it was not used (effectively) by the crew, because adequate training and/or procedures were not furnished.

It is likely that installation of a minimum safe altitude warning system (MSAWS) could have prevented numerous terrain collisions in the study sample.

Air traffic services and airport. "Lack of/inadequate ATC" (11.8 percent) and "lack of/inadequate ground aids" (21.1 percent) are the two circumstantial factors related to ground infrastructure. Lack of ground aids generally refers to inadequate provision of facilities such as basic navigation aids and lighting systems, e.g., DME, PAPI, VASI and runway markings.

4.7.10 Consequences

The five most frequent consequences are presented in Table 4–16. The same consequences were the most frequent consequences in the study presented in section 3. The U.K. CAA data are presented in the fourth column of Table 4–16. A high proportion of occurrences involved postimpact fire. This is particularly important because in some occurrences there was confusion during the rescue arising from poorly defined procedures and communication (see section 4.7.6). In addition, 16 percent of all occurrences involved emergency-evacuation difficulties.

Because any number of consequences could be attributed to a single occurrence, the data differ from those presented in Table 4–1 where a single factor was considered for any occurrence. The loss-of-control data include both crew-induced occurrences and airplane-induced occurrences, whereas Table 4–1 data refer to occurrences that were crew-induced. In addition, data for undershoots in Table 4–1 were included in the CFIT category.

4.8 Prevention Strategies

For each occurrence, a judgment was made to identify specific prevention strategies that may have prevented the occurrence. These strategies were classified as:

- Equipment;
- Policies and standards;
- Procedures; and,
- Training.[12]

The data from each occurrence were electronically stored, and then analyzed for commonality and frequency of occurrence for the sample as a whole. Prevention strategies that occurred with the greatest frequencies then were subjected to further analysis by the entire WG. An iterative process was employed that enabled the prioritization and refinement of the prevention strategies. Two workshops also were held that enabled the DAAWG members to interact during the development process. The meetings also were attended by representatives from other ALAR working groups. The DAAWG process also included identification of the specific industry sector that the prevention strategies applied to (e.g., operators, regulators, flight crew,

Table 4–16
Most Frequent Consequences in 76 Approach-and-landing Occurrences

Consequences	Number	Percent	Percent U.K. CAA Study
Collision with terrain/water/obstacle	37	48.7	44.6
Postimpact fire	32	42.1	22.6
Controlled flight into terrain (CFIT)	26	34.2	41.8
Undershoot	21	27.6	17.4
Loss of control in flight	20	26.3	25.8

U.K. CAA = United Kingdom Civil Aviation Authority

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

controllers, ATS, airports). The prevention strategies, presented in the form of industry recommendations, are detailed in section 7. Many of the DAAWG's recommendations also have been adopted by the Aircraft Equipment Working Group and the Operations and Training Working Group.

5. Proactive Safety Data from Normal Flight Operations: The Line Audit

5.1 The Need for Data

Efforts directed toward accident prevention historically have centered on findings from the investigation of accidents and, more recently, incidents. Effective safety efforts, including regulatory change, require valid data on factors deemed contributory in accidents and incidents. Efforts in accident reduction necessarily involve judgments of cost and benefit. Without data, efforts to reduce the accident rate represent only guesses as to how best to allocate resources. Accidents and incidents, however, provide only partial answers to the question of what efforts should be initiated or supported to enhance safety. An accident rarely involves a single cause but instead is a rare combination of multiple events.[17] As combinations of events, they are not the sole input available for organizations seeking to prioritize their safety efforts. Similarly, data on performance in training or during formal evaluations are not fully representative, because they yield a picture of crews showing optimal performance rather than behaving in a nonevaluated situation such as normal flight. In this instance, the data show whether or not crews and individuals can demonstrate the skills required for flight management; they do not show the way these skills are practiced in normal operations when there is no oversight.

5.2 Alternative Sources of Data: FOQA and Line Audits

The use of digital flight-data-recorder information to monitor normal operations is growing rapidly. In the United States, the FAA supports flight operational quality assurance (FOQA) programs for this purpose. Data from flight-recorder analysis objectively document exceedances in flight parameters, such as unstable approaches, and can trigger further investigations — for example, into clearances delivered at particular airports by ATC. Despite the demonstrated high value, FOQA information alone does not provide insights into the reasons why crews fly outside expected parameters.

Another source of information, the line audit, has proved to be a useful source of data on crew practices in normal flight operations.[18–21] In practice, the line audit is similar to the traditional line check. It differs by a primary focus on human factors and, most important, in the absence of jeopardy for flight crews observed. The conduct of line audits involves a team of specially trained observers assessing observable behaviors under an agreement that provides anonymity of data and full protection from organizational sanctions or regulatory enforcement for those observed. By using a common methodology and recording system, comparisons can be made over time of trends within organizations and of behavior in different organizations. Perhaps the greatest theoretical benefit of the line audit is the fact that the data are collected proactively and can show areas of risk prior to the occurrence of adverse events. A second benefit is the identification of areas of exemplary performance, enabling training programs to reinforce positive behaviors.

5.2.1 Line-audit Methodology

In the method developed by The University of Texas Aerospace Crew Research Project, a team of observers is given training in the use of the Line/LOS (line-oriented simulation) Checklist (LLC), a research instrument that defines a series of behavioral "markers," acts identified as causal in NASA research into aviation accidents.[18,20] LOS refers to the fact that the instrument is equally applicable for data collection in line operations and in simulations, including line-oriented flight training (LOFT). Organizations reach agreements of confidentiality and data protection with management and unions, and crews observed are given guarantees that observations do not place them under jeopardy. (The quality of the data and the success of line audits depend on the level of trust achieved between crews and the organization, and also assurances that the regulatory agency will not use audit information punitively.) The observer team usually is composed of pilots from training and human factors departments, check airmen, the union's safety and/or human factors committee, and members of the research group. Data usually are gathered for a month, with the number of observations depending on the size of the team, the size of the organization and the diversity of flight operations. Data are recorded by phase of flight on the LLC, which elicits ratings of the behavioral markers on a four-point scale.[22] The scale includes "poor," "below standard," "standard" and "outstanding."

5.2.2 Validation of the LLC Markers

The utility of line-audit data depends on the validity of the measures as causal factors in accidents and incidents. The LLC was developed initially to assess behaviors that had been implicated in U.S. accidents and incidents. Additional validation was conducted by coding the markers in U.S. accidents and incidents investigated by the NTSB and documented incidents at U.S. airlines.[20] The coding system also shares a common approach with the NTSB's 1994 Safety Study. The results of this preliminary investigation showed a negative rating on one or more markers in events where crew error was implicated. Conversely, a positive rating on one or more of the markers was found in events where crew performance was singled out as mitigating the severity of the event.

In the ALAR project, validation efforts consisted of relating a selected set of markers to a broader, international accident database — essentially, the 76 occurrences described in section 4.4. To achieve this goal, members of DAAWG were asked to indicate whether or not the marker could be identified in the accident or incident report. If found to be relevant, the evaluator marked whether or not the influence exacerbated or mitigated the outcome.

Finding evidence that the same markers play a causal role in the international database can enable consideration of audit findings from a normative database of about 3,300 flights in the effort to develop strategies to reduce the incidence of ALAs. The normative line-audit database was collected in six major U.S. airlines as part of collaborative studies between The University of Texas Aerospace Crew Research Project and participating carriers. The results have been de-identified and form the basis for analysis of system human factors issues.

5.3 Results of Marker Analyses

5.3.1 Markers and Characteristics of the Data Sample Used

Seven of the general markers from the LLC were included for rating the ALAR database, along with two markers specifically about flight-deck automation management. (The ALAR database consisted of the 76 occurrences studied as described in section 4, and six additional accidents about which information arrived too late to be included in that analysis, but which were coded in the line-audit phase of the analysis.) The markers are shown in Table 5–1 (page 44). Evaluators used notation similar to the following:

\+ The marker contributed to a successful outcome or reduced the severity of the occurrence. (This will be referred to as a “positive marker.”)

0 The marker had no effect on the occurrence.

– The marker had a negative effect on the outcome or contributed to the occurrence. (This will be referred to as a “negative marker.”)

“Unknown” was attributed when insufficient data were available to make a judgment.

Members of the working group who evaluated accidents for the database identified one or more of the seven general markers as relevant in 57 of the 82 occurrences in the database. Similarly, they identified as relevant the automation-management markers in 45 occurrences. The locations of the occurrences evaluated are shown in Table 5–2 (page 45), and the types of operators are shown in Table 5–3 (page 45). More than 50 percent of the occurrences with general markers implicated were in North America, as were more than 40 percent of those involving the automation markers. When interpreting the latter result, it is important to note that the sample is biased because of the disproportionate number of occurrences associated with North America and Europe, as reported in Section 4.7.2.

The data show that the markers significant in line audits are also operative in accidents. But positive markers that were present in the audit were missing in the behavior of accident crews as shown in Figure 5–1 (page 45). The most prevalent negative marker in the accident data was failure to be proactive in flight management (to “stay ahead of the curve”), which was noted in nearly 80 percent of the occurrences (see Figure 5–1, page 45). In decreasing order of frequency in the occurrences, other negative markers were noted in vigilance (70 percent), leadership (49 percent), inquiry (49 percent), assertion (38 percent), briefings (37 percent) and teamwork (26 percent). In the line-audit database, negative markers were found in between 15 percent and 25 percent of flights observed. Although these numbers are significantly lower than in the study-sample occurrences, they indicate that there are many instances of inadequate performance in flights that do not result in accidents or serious incidents. It is also noteworthy that about the same percentage of crews in the line-audit database were rated as outstanding in these markers.

The two automation markers yielded similar results. (Automation refers to equipment ranging in complexity from a mode-control panel to an FMS.) In verbalizing entries into the flight management computer (in those occurrences where this applied), more than 30 percent of the accident crews were rated negatively and more than 40 percent were deemed to be using the automation at an inappropriate level. Although these percentages were much higher than those found in the audit data, these variables indicated areas of risk in normal operations. The incidence of negative automation markers in accidents and of positive and negative markers in line audits is shown in Figure 5–2 (page 45).

5.4 Observable Error in Normal Flight Operations

Recent work by the University of Texas Aerospace Research Group extends the collection of data on normal flight operations during line audits to address directly the nature and extent of human error in normal line operations.[23] A study in progress has observed 102 flight segments from the United States to demanding non-U.S. destinations and back. (Ninety-one percent of destinations were designated as “demanding” because of terrain; all involved destinations where the primary language of air traffic controllers was other than English.) A total of 195 errors were recorded, an average of 1.9 per flight segment. The distribution of errors, however, is not symmetrical across flight segments. There were no observed errors on 26 percent of the flights observed, while 18 percent of the flights had four or more errors. The distribution of errors by flight is summarized in Figure 5–3 (page 46).

The locus of observed errors is consistent with the FSF ALAR Task Force focus on ALAs as shown in Table 5–4 (page 46).

Table 5–1
Behavioral Markers Included in the Study of 82 Approach-and-landing Occurrences

		+	0	–	Unknown
	Team Management and Crew Communications				
1.	**Teamwork** *Team concept and environment for open communications established and/or maintained, e.g., crewmembers listen with patience, do not interrupt or “talk over,” do not rush through the briefing, make eye contact as appropriate.*				
2.	**Briefing** *Briefings are operationally thorough and interesting, and address crew coordination and planning for potential problems. Expectations are set for how possible deviations from normal operations are to be handled, e.g., rejected takeoff, engine failure after lift-off, go-around at destination.*				
3.	**Inquiry** *Crewmembers ask questions regarding crew actions and decisions, e.g., effective inquiry about uncertainty of clearance limits, clarification of confusing/unclear ATC instructions.*				
4.	**Assertion** *Crewmembers speak up, and state their information with appropriate persistence, until there is some clear resolution and decision, e.g., effective advocacy and assertion: “I’m uncomfortable with ... , Let’s ... ”*				
5.	**Leadership** *Captain coordinates flight-deck activities to establish proper balance between command authority and crewmember participation, and acts decisively when the situation requires.*				
	Situational Awareness and Decision Making				
6.	**Vigilance** *Crewmembers demonstrate high levels of vigilance in both high-workload and low-workload conditions, e.g., active monitoring, scanning, cross-checking, attending to radio calls, switch settings, altitude callouts, crossing restrictions.*				
7.	**“Staying Ahead of the Curve”** *Crew prepares for expected or contingency situations including approaches, weather, etc., i.e., stays “ahead of the curve.”*				
	Automation Management				
8.	**Verbalization** *Crewmembers verbalize and acknowledge entries and changes to automated-systems parameters.*				
9.	**Automation Level** *Automated systems are used at appropriate levels, i.e., when programming demands could reduce situational awareness and create work overloads, the level of automation is reduced or disengaged, or automation is effectively used to reduce workload.*				

+ = Positive marker 0 = No effect – = Negative marker

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Almost half of all errors (49.4 percent) occurred during this phase of flight.

The best outcome for a flight is to avoid errors through the effective use of countermeasures. Initially, this study defined two outcomes for errors observed: (1) they can be trapped or mitigated to avoid or reduce the consequences (the best outcome) or (2) actions can exacerbate the consequences of the error (the worst outcome). In a pilot investigation and the present study, the researchers found that another prominent category emerged — errors undetected by the crew. The great majority of these had no consequences (for example, when a crew mis-sets an altitude or heading received from ATC, but the clearance is changed before the error takes effect). Instances where the crew commits an error by noncompliance with SOPs or regulations also are observed in line operations (but probably are not seen with the same frequency in the training and checking environment).

A preliminary listing of types of errors observed is shown in Table 5–5 (page 46). One of the most frequent error categories involved crew interaction with ATC (defined as “crew ATC

Table 5–2
Location of Operator in ALAs With LLC Markers Identified

	General Markers Percent	Automation Markers Percent
Africa	3.6	4.4
Asia/Pacific	10.5	13.4
Eastern bloc	0.0	0.0
Europe	31.6	35.6
North America	52.3	44.4
South America	3.6	4.4

ALAs = Approach-and-landing accidents LLC = Line/line-oriented simulation (LOS) checklist

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 5–3
Type of Operator Involved in ALAs With LLC Markers Identified

Type of operator	General Percent	Automation Percent
Air taxi	10.5	4.4
Regional	28.1	27.3
Major	49.1	56.8
Corporate	1.8	2.3
Military	1.8	2.3
Other	8.8	9.0

ALAs = Approach-and-landing accidents LLC = Line/line-oriented simulation (LOS) checklist

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

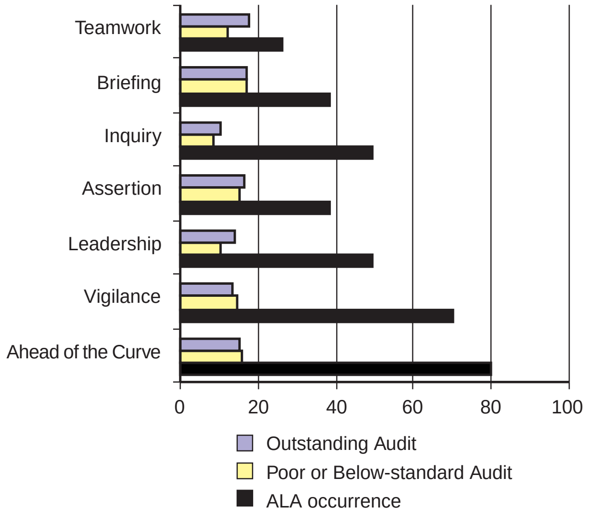
error — readback or callback errors/missed calls”). Other errors included navigation, checklist mistakes and sterile-cockpit violations. Several instances of unstabilized approaches were noted, as were failures to respond to GPWS or traffic-alert and collision avoidance system (TCAS) warnings. The underlying reasons for these deviations also are important when assessing such data.

5.5 Example Comparisons of Audit, NTSB and Accident Data

5.5.1 Pilot Flying and Performance

One of the striking findings in the NTSB’s 1994 study of U.S. air carrier accidents in which crew performance was deemed causal was that the captain was flying in more than 80 percent of these accidents.[24] A similar pattern was found in the ALAR accident data. In the accident flights with multiperson crews, 74 percent involved the captain flying at the time of the accident

Percent of Negative and Positive LLC Markers Found in Line-audit Database And Negative LLC Markers Found in ALA Database

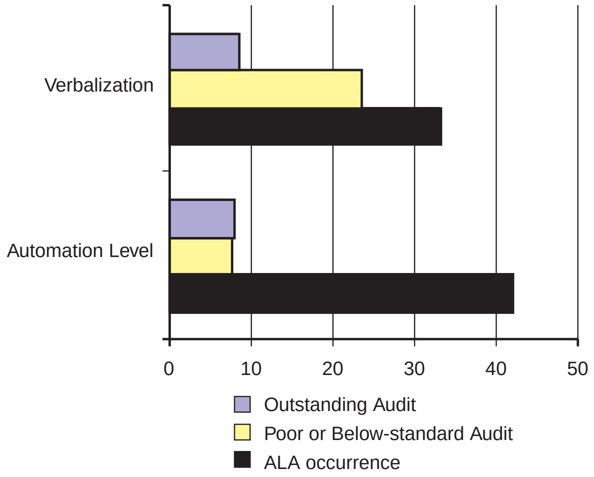


ALA = Approach-and-landing accident LLC = Line/line-oriented simulation (LOS) checklist

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 5–1

Percent of Negative and Positive LLC Markers Found in Line-audit Database And Negative LLC Markers Found in ALA Database

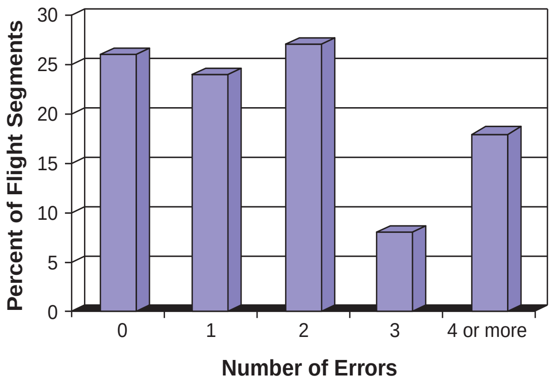


ALA = Approach-and-landing accident LLC = Line/line-oriented simulation (LOS) checklist

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 5–2

Distribution of Observed Errors across 102 Flight Segments



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 5–3

Table 5–4
Distribution of Observed Errors, By Phase of Flight in 102 Flight Segments

Phase of Flight of Error	Percent of Errors
Preflight	23.6
Takeoff/climb	16.3
Cruise	10.7
Approach and landing	49.4

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Table 5–5
Types of Errors Observed in 102 Flight Segments

- Checklists (omissions, memory, etc.);
- Crew-based ATC errors (response, readback, etc.);
- Sterile-cockpit violations;
- Navigation errors (lateral, vertical, speed);
- Tactical decision making;
- Unstable approaches; and,
- Various other SOP/U.S. Federal Aviation Regulations (FARs) deviations.

ATC = Air traffic control SOP = Standard operating procedures

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

(Figure 4–13). The line-audit data may provide some insights into this finding. Overall, in the audit data, rated overall effectiveness and leadership were comparable whether the captain or the first officer was flying. But when the data were subdivided into operationally simple and operationally complex conditions based on weather, traffic and mechanical abnormalities, a significant difference was found. When the conditions were not challenging, performance was unaffected by who was flying. In complex environments, performance was superior when the first officer was pilot flying.[21] It was suggested that under complex operating conditions, the captain may become overloaded if he or she is simultaneously trying to control the aircraft and manage the complex situation.

5.5.2 The Influence of Briefings

Briefings appeared as a factor in nearly 40 percent of the accidents. In the case of CVR records in ALAs, the briefings implicated were inevitably for the approach-and-landing phase of flight. Earlier research, however, has shown that the preflight briefing serves multiple purposes — establishing the team concept and providing an overall template for the conduct of the flight.[25–26] Line-audit data show a similar pattern.[21] For example, briefings rated as below standard were associated with substandard ratings of vigilance in as many as one-third of flights observed, as shown in Figure 5–4 (page 47). The effect was moderated by the complexity of the operating environment. In high-complexity operating environments, briefings rated as standard or outstanding (according to the four-point scale in section 5.2.1) were associated with not only a low percentage of below-standard vigilance markers but, significantly, with nearly 25 percent of crews receiving outstanding evaluations on vigilance.

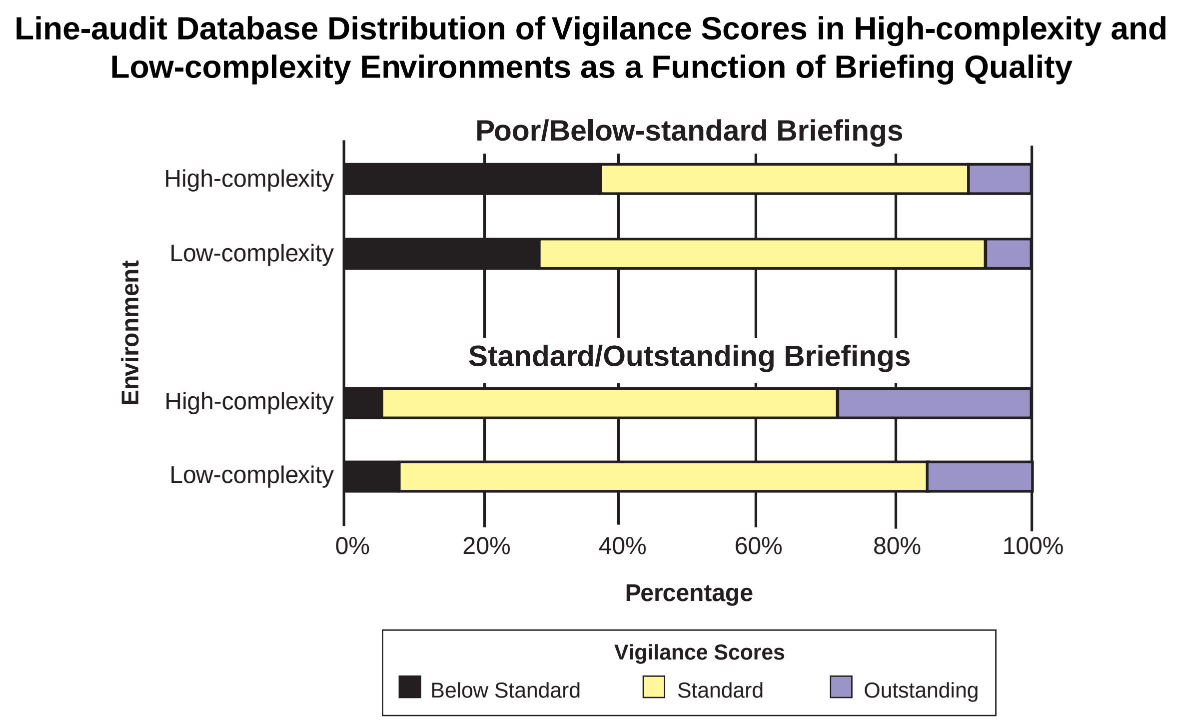
5.6 Implications of Line-audit Data

The current data provide additional support for the validity of the line-audit approach to assessment of organizational performance and for the validity of the behavioral markers defined as factors in accidents. The data support the position that audits can provide organizations with critical information that can be used in an error-management strategy and to define human factors training needs.

The markers reflect behaviors that represent the core concepts of CRM and, as such, strongly support the importance of effective, behaviorally oriented CRM training. The converging evidence from accident analysis and line audits also indicates the importance of CRM concepts in training programs. Multiple sources of data are needed to understand fully the aviation system and the strengths and weaknesses of any single organization. Line-audit data, like accident investigations, are only one source of information.

5.6.1 Limitations of Safety Methods Limited to Crew Behavior

Despite strong evidence for the validity and importance of crew behavior in accidents and incidents (and in prevention), it must be remembered that the crew is the last line of defense


Line-audit Database Distribution of Vigilance Scores in High-complexity and Low-complexity Environments as a Function of Briefing Quality

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 5–4

in a complex system. Crews are, in James Reason's terms, those at the "sharp end" of the airplanes.[12] Because accidents are almost without exception complex system events with multiple causes, methods limited to changing or enhancing crew behavior address only a piece of the puzzle. Indeed, some of the misunderstandings regarding the influence of CRM and its purported failings stem from unrealistic expectations about its ability to eliminate human error, and hence accidents.

It is vital that valid measures of crew behavior be analyzed and interpreted in the appropriate context, which includes information regarding system function and the organizational culture that surrounds and influences the actions of every crew. Interventions necessarily will address the larger context, including the organization itself, as well as the crew.

6. Conclusions

6.1 Analysis of Fatal Approach-and-landing Accidents

The following conclusions were reported for the analyses of 287 fatal ALAs, involving jet and turboprop aircraft (MTOW greater than 12,500 pounds/5,700 kilograms) and occurring between 1980 and 1996 (inclusive):

1. There were 287 ALAs resulting in 7,185 fatalities to passengers and crew.

2. The average ALA rate is 14.8 fatal accidents per year for non-C.I.S. aircraft. If the trend observed continues, 23 fatal accidents per year can be expected by the year 2010. Fatal ALAs involving Western-built jets averaged five per year to six per year.

3. The world average accident rate for Western-built jets is 0.43 accidents per million flights. The fatal accident rate for Western-built jets was highest for Africa (2.43 accidents per million flights) and South America and Central America (1.65 accidents per million flights). Australasia did not have any fatal accidents involving Western-built jets.

4. The fatal accident rate involving Western-built jets for Europe's 19 full-member JAA states is 0.16 accidents per million flights, 10 times lower than that for the other 26 European states.

5. Sixty-two percent of the accidents involved passenger operations, whereas 25 percent involved freight, ferry and positioning flights (no passengers carried). When movement data are applied to estimate rates of occurrence, the ALA rate for freight, ferry and positioning flights is possibly eight times higher than for passenger flights.

6. In those occurrences where data were available, three-fourths of the accidents occurred in instances where a precision-approach aid was not available or was not used.

7. Fifty percent of the accidents occurred during daylight, 39 percent during night and 2 percent in twilight. Although exact movement data for night approaches and day approaches were not available, the accident rate at night was estimated to be close to three times that for day.

8. "Omission of action/inappropriate action" by a flight crewmember was identified as the most common primary causal factor. This usually referred to the crew's continuing descent below the DH or MDA without adequate visual reference.

9. The second most common primary causal factor was "lack of positional awareness in the air," generally resulting in CFIT.

10. When all causal factors (primary and contributory) are considered, the most frequent are those referred to as primary causes, plus "slow and/or low on approach," "flight handling" and "poor professional judgment/airmanship."

11. Crews of aircraft built and operated in the C.I.S. had "press-on-itis" as the most frequent causal factor, even though this was sixth in the overall ranking. (Press-on-itis refers to continuing an approach when conditions suggest otherwise.)

12. The most frequent circumstantial factors were "nonfitment of presently available safety equipment" (generally GPWS) and "failure in CRM." Inadequate CRM practices were seen as circumstantial factors in nearly half of the accidents. "Lack of ground aids" was cited in at least 25 percent of all accidents.

13. The most frequent consequences were "collision with terrain etc.," and "CFIT." These were followed by "loss of control in flight," "postimpact fire" and "undershoot." For Eastern-built (C.I.S.) jets, fatal overruns were the most frequent consequence, though this ranked sixth overall.

6.2 Analysis of ALAs and Serious Incidents

The following conclusions emerged from the analyses of 76 ALAs and serious incidents that occurred during the period 1984–1997 (inclusive):

1. Fifty-nine percent of the aircraft were equipped with an operating CVR and 52 percent with an FDR. Much of the high-quality occurrence data available to the DAAWG were associated with those occurrences.

2. The study sample is biased because of the disproportionate number of occurrences associated with North America and Europe (71 percent). This was a result of the DAAWG's difficulties obtaining data from many other geographical areas.

3. CFIT, landing overruns, loss of control, runway excursion and nonstabilized approaches accounted for 76 percent of all occurrences.

4. Freight operations accounted for 17 percent of the sample, whereas 83 percent involved passenger operations. There is possibly a higher accident rate for freight operations if movement data are considered.

5. Approximately 50 percent of occurrences were located on the extended runway centerline. Almost half occurred within one nautical mile of the runway threshold, but these occurrences include runway overruns and excursions.

6. All ILS approaches in the sample were associated with Australasia, Europe, North America and the Middle East. Nonprecision approaches primarily were associated with CFIT occurrences.

7. Sixty-seven percent of CFIT occurrences were in hilly or mountainous-terrain environments, and 29 percent in areas of flat terrain — primarily landing-short accidents. Although significant terrain features are clearly an important operational consideration, they are not necessarily a prerequisite for the occurrence of CFIT.

8. Almost 60 percent of the occurrences were in poor-visibility conditions. About half of the occurrences were in precipitation and almost one-third in the presence of adverse winds. In 38 percent of the occurrences at least two of the environmental conditions (i.e., poor visibility, precipitation and adverse winds) were present.

9. Seventy-one percent of the CFIT occurrences were in poor-visibility conditions. Seventy-three percent of overruns/excursions occurred on wet runways and involved precipitation, and 67 percent involved adverse-wind conditions.

10. When data for dual-pilot operations alone were analyzed, the captain was PF in 74 percent of occurrences. (This is not a measure of risk, because data for exposure of captain as PF in normal line operations also are required.)

11. The most frequent causal factor (74 percent) was poor "professional judgment/airmanship" (i.e., decision making). Another form of poor decision making, "press-on-itis," accounted for 42 percent of all occurrences.

12. "Omission of action/inappropriate action" (inadvertent SOP deviation) was the second most frequent causal factor (72 percent). "Deliberate nonadherence to procedures" accounted for 40 percent of the sample occurrences.

13 "Failure in CRM" (cross-check/coordinate) (63 percent) was the third most frequent causal factor.

14. The fourth most frequent causal factor (51 percent) was "lack of positional awareness." This generally implied lack of vertical-position awareness, resulting in CFIT.

15. Poor "aircraft handling" was a causal factor in 45 percent of all occurrences. This typically resulted in loss of control, unstabilized approaches, landing overruns and runway excursions. Poor energy management was an associated factor in many occurrences. Although low-energy approaches (36 percent "slow and/or low") resulted in some loss-of-control occurrences, CFIT was the primary consequence. Thirty percent of all occurrences involved high-energy approach conditions.

16. "Slowed/delayed crew action" was a causal factor in 45 percent of the study sample.

17. "Incorrect or inadequate ATC instruction/advice/service" was a causal factor in 33 percent of all occurrences. Consequences included increased cockpit workload, reduced levels of both crew coordination and situational awareness, and a breakdown in CRM between the flight crew and ATC.

18. Documented occurrences exist of controllers and flight crews using nonstandard phraseology. In some occurrences involving non-native English speakers, the language issues exacerbated the poor communications between the flight crews and ATC.

19. Occurrences involving ambiguous communication of an onboard emergency by flight crews, without an ATC request for clarification/verification, were identified. In other occurrences, aspects of ATC handling of the aircraft during emergency situations may have confused or distracted the flight crews.

20. Fatality resulting from postimpact fire was a factor in 26 percent of all occurrences. Associated factors included confusion during the rescue arising from poorly defined procedures and communication among ARFF services, airport authorities, ATC and operators.

21. "Lack of qualification/training/experience" in aircraft type or type of operation being conducted was a causal factor in 22 percent of all occurrences.

22. "Disorientation and visual illusions" was a causal factor in 21 percent of the study-sample occurrences.

23. "Automation interaction" was a causal factor in 20 percent of all occurrences. Evidence suggests that crew unawareness or unfamiliarity with the systems was a factor. The AP, AT, FD, FMS and RA were the typical subsystems cited.

24. On average, 10 (out of 64) causal factors were involved, with a maximum of 24. For the 22 crew causal factors, the average was 6.9, with a maximum of 17. Crew causal factors were implicated in 93 percent of the accidents and serious incidents. Crew factors constituted 68 percent of the total causal ratings.

25. The causal factor "failure in CRM (cross-check/coordinate)" was significantly correlated with nine of the other 22 causal factors. Thus, 10 of the 22 crew factors were associated with CRM.

26. The most frequent circumstantial factor was "poor visibility" (59 percent). Contaminated "runway condition" was a factor in 18 percent of all occurrences.

27. "Failure in CRM (cross-check/coordinate)" appears as the second most frequent circumstantial factor (58 percent), whereas it was the third most frequent causal factor.

28. "Incorrect or inadequate crew procedures" was attributed to 47.4 percent of all occurrences, the third most frequent circumstantial factor.

29. "Company management failure" was identified as a circumstantial factor in 46 percent of all occurrences.

30. "Inadequate/inappropriate training" was a circumstantial factor in 37 percent of all occurrences.

31. "Inadequate regulation" accounted for 30 percent of the sample, whereas "inadequate regulatory oversight" was involved in 25 percent of the occurrences.

32. The "nonfitment of presently available safety equipment" (generally GPWS) was a circumstantial factor in 29 percent of all occurrences.

33. "Lack of/inadequate ATC" (12 percent) and "lack of/inadequate ground aids" (21 percent) were the two circumstantial factors related to ground infrastructure.

34. A high proportion of occurrences involved postimpact fire (42 percent) and 16 percent of all occurrences also involved emergency-evacuation difficulties.

6.3 Analysis of Crew Behavioral Markers in Line Audits

1. The analysis of crew errors during line audits showed that the highest percentage of errors (49.4 percent) was committed during the approach-and-landing phase of flight. This confirms the greater risk associated with this phase.

2. In order of importance, the most frequently cited negative behavioral markers were: failure to stay "ahead of the curve" (80 percent), poor vigilance (70 percent), poor

leadership (49 percent), failures of inquiry (49 percent), inadequate assertion (38 percent), poor briefings (37 percent) and inadequate teamwork (26 percent).

3. The two automation-management markers were failure to use the technology at the appropriate level (42 percent), followed by failure to verbalize inputs to the flight-management computer (33 percent).

4. Line-audit data give organizations information needed to take proactive steps for safety and to design training that addresses critical issues.

7. Recommendations

7.1 Regulatory Authorities

7.1.1 Audit and Surveillance

Regulatory authorities must ensure that robust audit and surveillance methods are employed, and should:

1. Establish procedures, together with an effective planning strategy, to implement the monitoring and surveillance programs;

2. Adopt an effective process to track follow-up actions required of operators that are noncompliant with regulatory requirements;

3. Ensure the proper level of enforcement action in occurrences of noncompliance with regulations;

4. Increase oversight of operators demonstrating adverse safety-trend indicators;

5. Establish oversight methods to deal with the particular characteristics of freight, air-taxi and corporate operators. Add resources within regulators to perform this function; and,

6. Provide training for all regulatory inspectors to enable the above recommendations to be realized.

7.1.2 Flight Data Recorders/Cockpit Voice Recorders

Regulatory authorities should:

1. Encourage the installation of FDRs and CVRs on aircraft for which they are currently not required. Encourage replacement of older-generation FDRs with modern systems that offer superior recording capabilities;

2. Introduce new requirements for installation of FDRs and CVRs on all new aircraft with maximum certified takeoff mass (MCTM) in excess of 12,500 pounds/5,700 kilograms, engaged in public transport, freight and corporate operations (Reference ICAO Annex 6 parts I and II); and,

3. Establish procedures to ensure confidentiality of both FDR and CVR data.

7.1.3 Flight-data-monitoring and Safety-reporting Programs

Regulatory authorities should:

1. Promote nonpunitive flight-monitoring programs such as FOQA, FAA Aviation Safety Action Programs and British Airways Safety Information System (BASIS) that identify factors to enhance safety; and,

2. Establish a means to share FOQA data and other safety information with operators, airport authorities and air traffic services on a confidential basis, respecting commercial sensitivity.

7.1.4 Terrain Awareness

Regulatory authorities should:

1. Set requirements for aircraft with MCTM in excess of 12,500 pounds/5,700 kilograms, in use for public transport, freight and corporate operations, and engaged in domestic and/or international operations, to be equipped with TAWS. Note: Basic GPWS capability is included. Reference ICAO State Letter AN 11/1.1.25-98/59 (dated July 17, 1998) and FAA notice of proposed rule making (NPRM) (dated Aug. 26, 1998, TAWS on all aircraft with six passenger seats or more), ICAO Annex 6 Parts I and II;

2. Require operators to furnish crew procedures and initial and recurrent training for the use of TAWS and GPWS;

3. Support the development and use of instrument-approach and area charts that depict colored contours to present either terrain or minimum flight altitudes. Reference ICAO Annex 4, ICAO State Letter AN 9/1-98/64 (July 17, 1998);

4. Support the development of charts that depict terrain profile below the initial and final approaches, including the missed approach, within the vertical-profile box of the approach chart; and,

5. Require implementation of radar coverage MSAWS where such coverage is not provided currently. Reference ICAO PANS-RAC DOC 4444, ICAO State Letter AN 11/1.1.24-97/91 (Dec. 12, 1997).

7.1.5 Approach Procedures

Regulatory authorities should:

1. Design and/or redesign instrument-approach procedures to ensure that where possible they are in accordance with continuous-descent stabilized-approach criteria and with a three-degree approach gradient as the norm. Reference ICAO PANS-OPS, Aircraft Operations, DOC 8168, Vol. II Amendment 10 for Design, Vol. I for Crew Information;

2. Implement a voluntary educational program advising the industry to be aware of the safety and workload benefits in flying:

   - Precision approaches rather than nonprecision approaches; and,

   - Nonprecision approaches using continuous-descent stabilized-approach criteria, rather than a series of stepped descents.

3. Promote the role of GNSS for providing precision approach-and-landing guidance to runways at all airports used for civil operations; and,

4. Encourage the development and implementation of required navigation performance (RNP) approaches or barometric VNAV procedures, particularly for runways not currently equipped with precision approach aids.

7.1.6 Training

Regulatory authorities should:

1. Require operators involved in civil operations to provide all operational personnel (e.g., flight crew, cabin crew, air traffic controllers) effective training in CRM principles, i.e., error management, risk assessment and decision making;

2. Require operators involved in civil operations to develop adequate initial and recurrent CRM programs; and,

3. Furnish oversight personnel with adequate initial and recurrent CRM programs that provide familiarization with all aspects of the type of training given to other operational personnel.

7.1.7 Standard Operating Procedures

Regulatory authorities should:

1. Require all operators to publish basic SOPs for the conduct of their in-flight operations. Reference ICAO Annex 6 Part I.

7.1.8 Operating Standards

Regulatory authorities should:

1. Establish standards for corporate and freight operators equivalent to those for major carriers. Reference FAA Initiative for Single Safety Standard; and,

2. Ensure that an accurate weather observation is available at all civil airfields. Accurate weather reports are required by ICAO Manual of All Weather Operations, DOC 9365.

7.2 Operators

Company management must institute and support a risk-averse culture. The policy must be formally documented, stating the safety goals, and must be conveyed clearly to all company personnel.

7.2.1 Training

The training curricula of all operators should:

1. Emphasize the challenges associated with approaches in conditions involving night, poor visibility/light, illusions, adverse wind conditions, precipitation and wet or contaminated runways;

2. Deal specifically with nonprecision approaches, especially those that involve abnormally shallow approach paths and those that are designed with a series of stepped descents;

3. Train flight crews to manage automation to optimize overall situational awareness and to reduce overall flight-deck workload;

4. Train flight crews to achieve a proper understanding of aircraft minimum-control criteria for approach and landing in degraded aircraft conditions, such as

   - Standard and nonstandard engine (and/or propeller) failures; and,

   - Engine(s) separation from airframe.

5. Emphasize adherence to SOPs and the increase in operational risk associated with conditions such as:

   - Continuing descent below DH/MDA in the absence of adequate visual cues;

   - Omission of standard callouts, the approach and missed-approach briefing;

   - Ignoring GPWS alerts; and,

   - Failure to go around in an unstabilized approach condition.

Flight-crew training should include scenarios that demonstrate the need to execute timely go-arounds during the above conditions;

6. Provide improved error-management and risk-assessment training on avoiding, trapping and mitigating the consequences of errors and system faults;

7. Include training scenarios that allow crews to experience overload, task saturation, loss of situational awareness, out-of-control and too-far-behind-the-aircraft situations, and communications in stressful circumstances;

8. Provide simulator training that includes scenarios that explore the operating flight envelope beyond the range of normal operation;

9. Introduce joint training sessions between pilots and air traffic controllers dealing with in-flight emergencies. The scenarios should promote mutual understanding of issues on both the flight deck and in the ATC environment, and foster improved communications during emergency situations;

10. Develop guidance material to ensure that pilots and controllers are aware of the importance of unambiguous information exchange during in-flight emergencies;

11. Develop jointly with airport authorities, air traffic services and local emergency services, emergency-training programs that are conducted regularly; and,

12. Emphasize the use of standard ICAO phraseology.

7.2.2 Standard Operating Procedures

All operators should establish:

1. Basic SOPs for their in-flight operations, which are developed and reviewed with input from line crew;

2. A no-fault go-around policy;

3. Explicit definitions of conditions requiring a timely go-around. Acceptable stabilized-approach criteria, visual cues necessary to continue descent below MDA/DH and flight-deck alerts (e.g., GPWS) requiring timely action should be clearly defined. Company operating manuals should detail these definitions;

4. Unless otherwise required by state regulation, an approach-ban policy that prohibits the continuation of an approach beyond a point not less than 1,000 feet above the threshold of the landing runway, unless minimum visibility or runway visual range requirements as appropriate for that particular approach type and as established in SOPs are met or exceeded. Reference FAA approach ban FARs Part 121.651;

5. Guidelines that identify the crewmember responsible for assuming pilot-flying duties in the event of abnormal airworthiness or complex environmental conditions requiring demanding analysis and decision making;

6. A policy for the use of automation and appropriate guidelines to flight crew; and,

7. The implementation, jointly with airport authorities, air traffic services and emergency services, of unambiguous emergency procedures and common phraseology to eliminate confusion.

7.2.3 Flight-safety-monitoring Programs

All operators should:

1. Implement nonpunitive safety-monitoring programs to collect data within their organizations to identify system deficiencies. Examples include incident and hazard reporting, line audits and FOQA programs;

2. Establish a process to identify and correct observed deficiencies; and,

3. Establish a process to share relevant safety information with other parties, including air traffic services and airport authorities.

7.2.4 Flight-safety-enhancement Equipment

All operators should:

1. Equip all aircraft with an MCTM in excess of 12,500 pounds/5,700 kilograms in use for public transport, freight and corporate operations, engaged in domestic and/or international operations, with TAWS. Associated SOPs should be established and flight crews should be trained accordingly. Operators are encouraged to adopt the Industry CFIT Training Aid. Note: Basic GPWS capability is included. Reference ICAO State Letter AN 11/1.1.25-98/59 (dated July 17, 1998) and the FAA NPRM (dated Aug. 26, 1998, TAWS on all aircraft with six passenger seats or more), ICAO Annex 6 Parts I and II;

2. Adopt additional means of increasing flight-crew terrain awareness, including the use of RAs and navigation charts that display colored terrain or area minimum-altitude contours;

3. Support the development of RNP/GNSS/barometric VNAV procedures, particularly for runways not currently equipped with precision-approach aids; and,

4. Investigate the use of head-up display for improving safety in their specific operations.

7.3 Flight Crews

All flight crews should:

1. Be fully aware of situations demanding a timely go-around;
2. Ensure adequate planning to prevent the development of a rushed approach;
3. Conduct the necessary briefing, which includes risk assessment, prior to each approach;
4. Exercise particular care in international operations to verify ATC understanding of communications;
5. Accurately report the status of abnormal situations and the need for emergency assistance using standard ICAO phraseology;
6. Notify air traffic controllers of clearances that are likely to impose such unreasonable demands on flight-crew workload that safety may be compromised; and,
7. Review minimum standards with industry to ensure that adequate safety margins are provided. Flight crews should take a strategic role with the regulator in establishing effective visibility criteria for continuation beyond DH or MDA.

7.4 Air Traffic Services and Airport Authorities

7.4.1 Training

Air traffic services should:

1. Introduce joint training programs that involve both ATC personnel and flight crews to:
   - Promote mutual understanding of issues such as procedures and instructions on the flight deck and in the ATC environment;
   - Improve controllers' knowledge of the capabilities and limitations of advanced-technology flight decks; and,
   - Foster improved communications and task management by pilots and controllers during abnormal/emergency situations.

   The programs should demonstrate resource-management skills to ATC personnel; and,
2. Ensure that controllers are aware of the importance of unambiguous information exchange during in-flight emergencies. The need to use ICAO standard phraseology should be emphasized.

Air traffic services and airport authorities should:

3. Develop, jointly with operators and local emergency services, emergency training programs that are conducted on a regular basis.

7.4.2 Procedures

Air traffic services should:

1. Apply the ICAO standard glossary of definitions and terms for use between pilots and ATC in emergency conditions to ensure common understanding. Reference the ICAO Trainair Program;
2. Implement procedures that require immediate clarification/verification from flight crews of unclear transmissions that indicate a possible emergency situation or need for assistance;
3. Implement procedures for ATC handling of aircraft in emergency situations to minimize flight-crew distraction; and,
4. Avoid issuing clearances that are likely to impose unreasonable demands on flight-crew workload.

Air traffic services and airport authorities should:

5. Implement, jointly with operators and emergency services, unambiguous emergency procedures and common phraseology to eliminate confusion.

7.4.3 Equipment

Air traffic services should:

1. Implement radar coverage including MSAWS where such coverage is not provided currently. Reference PANS-RAC DOC 4444;
2. Recognize the increased risk associated with flying nonprecision approaches relative to precision approaches. Commit more funding and priority for the provision of precision-approach aids, together with adequate approach and runway lighting; and,
3. Implement new technologies to equip airfields with precision (visual and/or electronic) guidance capability where present ground-based equipment is incapable of providing this service.

7.4.4 Flight-safety-monitoring Programs

Air traffic services and airport authorities should:

1. Implement nonpunitive safety-monitoring programs to collect data within their organizations to identify system deficiencies. Examples include incident and hazard reporting, and audits;

2. Establish a process to identify and correct observed deficiencies; and,

3. Establish a process to share relevant safety information with other parties, including operators.

7.5 Accident-investigation Bodies

1. All states should comply with the ICAO Standards and Recommended Practices (SARPs) for the investigation of accidents and serious incidents (Annex 13); and,

2. All investigation bodies should publish and circulate as widely as possible, including by electronic means, all reports on accidents and incidents. Reference Annex 13 — Investigation of Accidents and Serious Incidents.

7.6 Manufacturers

Airplane and equipment (aircraft and ground) manufacturers should:

1. Promote the installation of FDRs, CVRs and TAWS on all new aircraft of MCTM in excess of 12,500 pounds/ 5,700 kilograms, engaged in public transport, freight and corporate operations;

2. Promote the installation of RAs on all new aircraft engaged in public transport, freight and corporate operations;

3. Promote the installation of HUD as a potent safety-enhancement tool;

4. Develop technologies to equip airfields with precision-guidance capability where present ground-based equipment is incapable of providing this service;

5. Support the development of RNP/GNSS/barometric VNAV procedures to all runways not currently equipped with precision approach aids; and,

6. Develop and implement flight-deck technologies that provide better terrain, aircraft-position, energy and systems awareness than is currently available.

7.7 Industry

1. Flight Safety Foundation should bring the industry together to develop and coordinate programs for the worldwide sharing and distribution of safety information. Existing initiatives include the Global Analysis and Information Network (GAIN) and the European Union's European Coordination Center for Aircraft Incident Reporting Systems (ECCAIRS) program;

2. The ICAO evaluation program of states' safety-oversight arrangements should be enhanced and given greater support by industry;

3. Where a state is currently experiencing difficulties complying with ICAO Standards and Recommended Practices for the investigation of accidents and serious incidents (Annex 13) and Facilitation (Annex 9), measures should be taken, under the auspices of ICAO, but with industry assistance and support, to remedy the situation. Remedies could take various forms, including investigator assistance, investigator training, delegation to other investigation bodies and infrastructure. Note: The subject "Assistance in Accident Investigations" is to be an agenda item at the ICAO Accident Investigation and Prevention (AIG) Divisional meeting scheduled for September 1999. ICAO States Letter SD 33/1-98/12 dated Feb. 20, 1998, convening the meeting, said, "The meeting would consider the means for facilitating assistance to States in major accident investigations, improvements to the ICAO Accident/Incident Data Reporting (ADREP) System, the adequacy of AIG documentation and the need for, and content of, training seminars and workshops";

4. ICAO should take action to ensure that item 19 of an ICAO Flight Plan is available by ATCs and airport authorities for the purpose of expediting rescue efforts;

5. Industry links with government and news media should emphasize the safety of the system, using objective data and positive attitudes; and,

6. The insurance industry should assist the aviation industry by examining its criteria and standards for making insurance available to risk-prone operators; this could result in improved standards within the industry.

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Disclaimer

The information presented herein represents the collective opinions of the FSF ALAR Task Force DAAWG and is not necessarily endorsed by any organization represented within the FSF ALAR Task Force.♦

Appendix A
Definitions

Causal factor

An event or item that was directly instrumental in the causal chain of events leading to the accident.

Circumstantial factor

An event or item that was not directly in the causal chain of events but could have contributed to the accident.

C.I.S. (Commonwealth of Independent States) countries

Armenia
Azerbaijan
Belarus
Georgia
Kazakstan
Kyrgyzstan
Moldova
Russia
Tajikistan
Turkmenistan
Ukraine
Uzbekistan

Consequence

Outcome of the accident.

Joint Aviation Authorities (JAA) full-member countries

Austria
Belgium
Denmark
Finland
France
Germany
Greece
Iceland
Ireland
Italy
Luxembourg
Monaco
Netherlands
Norway
Portugal
Spain
Sweden
Switzerland
United Kingdom

Level of confidence

The level of confidence in the accident summary and the consequent factors allocated by the group.

Operator region

The world region from which the operator originates.

Primary causal factor

The dominant causal factor of the accident as judged by the group.

Regions* and Countries

Africa

Algeria
Angola
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Cape Verde
Central African Republic
Chad
Ciskei
Comoros
Congo
Democratic Republic of Congo
Djibouti
Egypt
Ethiopia
Gabon
Gambia
Ghana
Guinea
Guinea-Bissau
Ivory Coast
Kenya
Lesotho
Liberia
Libya
Madagascar
Malawi
Mali
Mauritania
Mauritius
Morocco
Mozambique
Namibia
Niger
Nigeria
Republic of Bophuthatswana
Rwanda
Sao Tome and Principe
Senegal

Regions* and Countries (continued)

Seychelles
Sierra Leone
Somalia
South Africa
Sudan
Swaziland
Tanzania
Togo
Tunisia
Uganda
Zambia
Zimbabwe

Asia

Afghanistan
Bahrain
Bangladesh
Bhutan
Brunei
Cambodia
China
Hong Kong
India
Indonesia
Iran
Iraq
Israel
Japan
Jordan
Korea
Kuwait
Laos
Lebanon
Macau
Malaysia
Maldives
Mongolia
Myanmar
Nepal
Oman
Pakistan
Palestine
Philippines
Qatar
Saudi Arabia
Singapore
Sri Lanka
Syria
Taiwan
Thailand
Vietnam
Yemen

Australasia

American Samoa
Australia
Cook Islands
Fiji
French Polynesia
Guam
Kiribati
Marshall Islands
Nauru
New Caledonia
New Zealand
Northern Marianas Islands
Pacific Islands
Palau
Papua New Guinea
Solomon Islands
Tonga
Vanuatu
Western Samoa

Europe

JAA full-member countries in **bold** and C.I.S. countries in *italic*:

Albania
Armenia
Austria
Azerbaijan
Belarus
Belgium
Bosnia-Herzegovina
Bulgaria
Croatia
Cyprus
Czechoslovakia
Czech Republic
Denmark
Estonia
Faroe Islands
Finland
France
Georgia
Germany
Gibraltar
Greece
Greenland
Hungary
Iceland
Ireland
Italy
Kazakhstan
Kyrgyzstan
Latvia
Lichtenstein
Lithuania
Luxembourg
Macedonia
Malta
Moldova
Monaco
Montenegro
Netherlands
Norway
Portugal
Romania
Russia
Serbia
Slovakia
Slovenia
Spain
Sweden
Switzerland
Tajikistan
Turkey
Turkmenistan
Ukraine
United Kingdom
U.S.S.R.
Uzbekistan
Yugoslavia

North America

Anguilla
Antigua and Barbuda
Aruba
Bahamas
Barbados
Bermuda
Canada
Cayman Islands
Cuba
Dominica
Dominican Republic
Grenada
Guadeloupe
Haiti
Jamaica
Martinique
Montserrat
Puerto Rico
St. Kitts and Nevis
St. Lucia
St. Pierre and Miquelon
Trinidad and Tobago
St. Vincent and the Grenadines
Turks and Caicos Islands
United States
Virgin Islands (U.S. and British)

South/Central America

Argentina
Belize
Bolivia
Brazil
Chile
Colombia
Costa Rica
Ecuador
El Salvador
Falkland Islands
French Guyana
Guatemala
Guyana
Honduras
Mexico
Nicaragua
Panama
Paraguay
Peru
Suriname
Uruguay
Venezuela

*Regions defined by Airclaims

Rest of Europe

All European countries other than the JAA full members, but including all C.I.S. countries.

Western-built jets

The following aircraft are included:

Airbus A300, A310, A319, A320, A321, A330, A340

Avro RJ

BAC-111

BAe146

BAe (DH) Comet

BAe (HS) Trident

BAe (Vickers) VC-10

BAe/Aérospatiale Concorde

Boeing B-707, B-720, B-727, B-737, B-747, B-757, B-767, B-777

Canadair RJ

Caravelle

CV880, CV990

Fokker F28, FK70, FK100

Lockheed L-1011 Tristar

McDonnell Douglas DC-8, DC-9, DC-10, MD-11, MD-80, MD-90 (some, such as the MD-80, are the Boeing MD-80 if manufactured on or after Aug. 1, 1997)♦

Appendix B
Accident Sample

U.K. Civil Aviation Authority (CAA) Database of Fatal Approach-and-landing Accidents (Section 3)

Date	Location: City/Airport, Region*	Aircraft Type
Jan. 21, 1980	(near) Lashgarak, Asia	Boeing 727
Feb. 6, 1980	(near) N'Gaoundere, Africa	Gulfstream II
Feb. 27, 1980	Manila, Asia	Boeing 707
March 3, 1980	(near) Port-au-Prince, North America	Learjet 25
April 12, 1980	(near) Florianopolis, Latin America	Boeing 727
April 27, 1980	Bangkok, Asia	HS 748
May 6, 1980	Richmond, North America	Learjet 23
June 2, 1980	(near) Yacuiba, Latin America	Fokker F27
Aug. 1, 1980	(near) Mexico City, Latin America	Douglas DC-8
Aug. 13, 1980	(near) Tetuan, Europe	Learjet 35
Aug. 26, 1980	(near) Jakarta, Asia	Vickers Viscount
Sept. 11, 1980	(near) Iquitos, Latin America	Douglas DC-8
Nov. 18, 1980	Seoul, Asia	Boeing 747
Dec. 19, 1980	(near) Many, North America	Rockwell Jet Commander
Jan. 21, 1981	Bluefield, North America	Cessna Citation 500
Feb. 11, 1981	White Plains, North America	Lockheed Jetstar
Feb. 24, 1981	(near) Belem, Latin America	EMB-110 Bandeirante
May 2, 1981	(near) Monterrey, Latin America	HS 125
May 7, 1981	(near) Buenos Aires, Latin America	BAC 111
June 26, 1981	Nailstone, Europe	HS 748
July 27, 1981	Chihuahua, Latin America	Douglas DC-9
Nov. 16, 1981	(near) Lagos, Africa	Aérospatiale Corvette
Dec. 1, 1981	(near) Ajaccio, Europe	MD-80
Dec. 18, 1981	(near) Sanantero, Latin America	DHC-6 Twin Otter
Jan. 24, 1982	Boston, North America	Douglas DC-10
Feb. 8, 1982	Tokyo, Asia	Douglas DC-8
March 20, 1982	Telukbetung, Asia	Fokker F28
May 9, 1982	Aden, Asia	DHC-7 Dash 7
May 19,1982	Kassel, Europe	Cessna Citation II
May 24, 1982	Brasilia, Latin America	Boeing 737
June 8, 1982	(near) Fortaleza, Latin America	Boeing 727
June 12, 1982	Tabatinga, Latin America	Fairchild FH-227
June 21, 1982	Bombay, Asia	Boeing 707
Sept. 3, 1982	Rio Branco, Latin America	Learjet 25
Dec. 9, 1982	(near) La Serena, Latin America	Fokker F27
Jan. 9, 1983	Brainerd, North America	Convair 580
Jan. 11, 1983	Toronto, North America	Rockwell Sabreliner
Jan. 16, 1983	Ankara, Europe	Boeing 727
March 11, 1983	Barquisimeto, Latin America	Douglas DC-9
March 30, 1983	Newark, North America	Learjet 25
April 1, 1983	(near) Eagle Pass, North America	Cessna Citation 500
April 29, 1983	Guayaquil, Latin America	Sud-Aviation Caravelle
July 11, 1983	(near) Cuenca, Latin America	Boeing 737
Sept. 23, 1983	(near) Mina Jebel Ali, Asia	Boeing 737
Oct. 8, 1983	(near) Myitkyina, Asia	DHC-6 Twin Otter

* (Defined by Airclaims in Appendix A, page 57.)

U.K. Civil Aviation Authority (CAA) Database of Fatal Approach-and-landing Accidents (Section 3) *(Continued)*

Date	Location: City/Airport, Region*	Aircraft Type
Oct. 11, 1983	(near) Pinckneyville, North America	HS 748
Nov. 23, 1983	Lansdowne House, North America	DHC-6 Twin Otter
Nov. 27, 1983	(near) Madrid, Europe	Boeing 747
Nov. 28, 1983	Enugu, Africa	Fokker F28
Dec. 8, 1983	(near) Stornoway, Europe	Cessna Citation 500
Dec. 17, 1983	Paulatuk, North America	DHC-6 Twin Otter
Dec. 20, 1983	Sioux Falls, North America	Douglas DC-9
Jan. 30, 1984	Santa Catalina Island, North America	Learjet 24
Feb. 20, 1984	(near) Proserpine, Australasia	Cessna Citation 500
March 28, 1984	(near) Florianopolis, Latin America	Learjet 24
April 18, 1984	(near) Imperatriz, Latin America	EMB-110 Bandeirante
May 15, 1984	(near) Ushuaia, Latin America	Learjet 35
June 5, 1984	Windsor Locks, North America	Learjet 23
June 28, 1984	(near) San Pedro da Aldeia, Latin America	EMB-110 Bandeirante
July 21, 1984	Tau, Australasia	DHC-6 Twin Otter
Aug. 5, 1984	Dhaka, Asia	Fokker F27
Oct. 9, 1984	(near) Fort Franklin, North America	DHC-6 Twin Otter
Nov. 10, 1984	St. Thomas, North America	Learjet 24
Feb. 19, 1985	(near) Bilbao, Europe	Boeing 727
March 28, 1985	(near) Florencia, Latin America	Fokker F28
April 15, 1985	(near) Phang-Nga, Asia	Boeing 737
May 21, 1985	Harrison, North America	Cessna Citation 500
June 23, 1985	(near) Diamantino, Latin America	EMB-110 Bandeirante
Aug. 2, 1985	Dallas, North America	Lockheed L-1011 Tristar
Aug. 20, 1985	(near) Gulkana, North America	Learjet 24
Sept. 22, 1985	Auburn, North America	Learjet 35
Oct. 12, 1985	Putao, Asia	Fokker F27
Nov. 10, 1985	Cliffside Park, North America	Dassault Falcon 50
Dec. 31, 1985	(near) Kaduna, Africa	HS 125
Jan. 15, 1986	(near) Chalon-Vatry, Europe	Dassault Falcon 20
Jan. 18, 1986	Flores, Latin America	Sud-Aviation Caravelle
June 10, 1986	Cairo, Africa	Fokker F27
June 12, 1986	(near) Port Ellen, Europe	DHC-6 Twin Otter
Aug. 2, 1986	Bedford, North America	HS 125
Aug. 3, 1986	North America	DHC-6 Twin Otter
Oct. 23, 1986	(near) Peshawar, Asia	Fokker F27
Dec. 15, 1986	Casablanca, Africa	HS 125
Jan. 3, 1987	Abidjan, Africa	Boeing 707
March 4, 1987	Detroit, North America	CASA 212
March 27, 1987	Eagle, North America	Learjet 24
April 4, 1987	Medan, Asia	Douglas DC-9
April 13, 1987	Kansas City, North America	Boeing 707
May 8, 1987	Mayaguez, North America	CASA 212
May 19, 1987	(near) Santa Cruz, Latin America	DHC-6 Twin Otter
May 31, 1987	Luebeck, Europe	Cessna Citation 500
July 31, 1987	(near) Guatemala City, Latin America	Learjet 23
Aug. 4, 1987	Calama, Latin America	Boeing 737
Aug. 31, 1987	Phuket, Asia	Boeing 737
Sept. 21, 1987	Luxor, Africa	Airbus A300
Nov. 24, 1987	Homer, North America	Beech 1900
Dec. 5, 1987	Lexington, North America	HS 125

* (Defined by Airclaims in Appendix A, page 57.)

U.K. Civil Aviation Authority (CAA) Database of Fatal Approach-and-landing Accidents (Section 3) *(Continued)*

Date	Location: City/Airport, Region*	Aircraft Type
Dec. 21, 1987	(near) Bordeaux, Europe	EMB-120 Brasilia
Jan. 2, 1988	(near) Izmir, Europe	Boeing 737
Jan. 8, 1988	(near) Monroe, North America	Learjet 36
Jan. 18, 1988	Houston, North America	HS 125
Jan. 19, 1988	Bayfield, North America	Fairchild Metro III
Feb. 8, 1988	(near) Mulheim, Europe	Fairchild Metro III
Feb. 9, 1988	Springfield, North America	BAe Jetstream 31
Feb. 24, 1988	(near) Macre, Latin America	Learjet 24
Feb. 27, 1988	Ercar, Europe	Boeing 727
March 4, 1988	(near) Fontainebleau, Europe	Fairchild FH-227
May 6, 1988	Broennoeysund, Europe	DHC-7 Dash 7
May 26, 1988	Hannover, Europe	Fokker F27
June 12, 1988	(near) Posadas, Latin America	MD-80
July 6, 1988	Barranquilla, Latin America	Canadair CL-44
July 21, 1988	Lagos, Africa	Boeing 707
July 26, 1988	Morristown, North America	Learjet 35
July 30, 1988	Riverside, North America	Learjet 23
Aug. 31, 1988	Hong Kong, Asia	HS Trident
Oct. 17, 1988	Rome, Europe	Boeing 707
Oct. 19, 1988	Ahmedabad, Asia	Boeing 737
Oct. 19, 1988	Gauhati, Asia	Fokker F27
Nov. 14, 1988	Seinajoki, Europe	EMB-110 Bandeirante
Dec. 14, 1988	(near) Luxor, Africa	Boeing 707
Jan. 8, 1989	East Midlands, Europe	Boeing 737
Feb. 19, 1989	(near) Kuala Lumpur, Asia	Boeing 747
March 15, 1989	Lafayette, North America	NAMC YS-11
March 18, 1989	(near) Saginaw, North America	Douglas DC-9
March 21, 1989	Sao Paulo, Latin America	Boeing 707
April 10, 1989	Valence, Europe	Fairchild FH-227B
June 7, 1989	Paramaribo, Latin America	Douglas DC-8
June 28, 1989	Yaounde, Africa	HS 748
June, 29, 1989	Cartersville, North America	Dassault Falcon 20
July 19, 1989	Sioux City, North America	Douglas DC-10
July 21, 1989	Manila, Asia	BAC 111
July 27, 1989	Tripoli, Africa	Douglas DC-10
Sept. 23, 1989	(near) Posadas, Latin America	Learjet 25
Sept. 27, 1989	Grand Canyon, North America	DHC-6 Twin Otter
Oct. 2, 1989	Roxboro, North America	Cessna Citation II
Oct. 21, 1989	(near) Tegucigalpa, Latin America	Boeing 727
Oct. 28, 1989	Molokai, North America	DHC-6 Twin Otter
Nov. 14, 1989	(near) Bardufoss, Europe	Cessna Citation II
Nov. 27, 1989	(near) Jamba, Africa	Lockheed C-130 Hercules
Dec. 26, 1989	Pasco, North America	BAe Jetstream 31
Jan. 19, 1990	Little Rock, North America	Gulfstream II
Jan. 25, 1990	New York, North America	Boeing 707
Jan. 31, 1990	(near) Columbia, North America	HS 125
Feb. 12, 1990	Bauru, Latin America	Fokker F27
Feb. 14, 1990	Bangalore, Asia	Airbus A320
March 21, 1990	(near) Tegucigalpa, Latin America	Lockheed L-188 Electra
April 6, 1990	Juiz de Fora, Latin America	Learjet 25
May 10, 1990	Tuxtla Gutierrez, Latin America	Fokker F27

* (Defined by Airclaims in Appendix A, page 57.)

U.K. Civil Aviation Authority (CAA) Database of Fatal Approach-and-landing Accidents (Section 3) *(Continued)*

Date	**Location: City/Airport, Region***	**Aircraft Type**
May 11,1990	(near) Cairns, Australasia	Cessna Citation 500
June 6, 1990	Altamira, Latin America	Fairchild FH-227
Aug. 13, 1990	Cozumel, Latin America	Rockwell Jet Commander
Sept. 13, 1990	Sverdlovsk, Europe	Yakovlev Yak-42
Sept. 24, 1990	San Luis, North America	Cessna Citation 500
Oct. 10, 1990	(near) Novosibirsk, Europe	Antonov An-8
Oct. 24, 1990	(near) Santiago de Cuba, North America	Yakovlev Yak-40
Nov. 14, 1990	Zurich, Europe	Douglas DC-9-32
Nov. 21, 1990	Koh Samui Island, Asia	DHC-8 Dash 8
Dec. 4, 1990	Nairobi, Africa	Boeing 707
Jan. 11, 1991	(near) Belo Horizonte, Latin America	Learjet 25
Feb. 1, 1991	Los Angeles, North America	Boeing 737
Feb. 10, 1991	(near) Chihuahua, Latin America	Rockwell Sabreliner
Feb. 13, 1991	Aspen, North America	Learjet 35
Feb. 20, 1991	Puerto Williams, Latin America	BAe 146
March 3, 1991	Colorado Springs, North America	Boeing 737
March 18, 1991	Brasilia, Latin America	Learjet 25
March 23, 1991	Navoi, Europe	Antonov An-24
April 5, 1991	Brunswick, North America	EMB-120 Brasilia
April 19, 1991	Marquess Islands, Australasia	Dornier 228
May 23, 1991	Leningrad (St. Petersburg), Europe	Tupolev Tu-154
June 26, 1991	(near) Sokoto, Africa	BAC 111
July 11, 1991	Jeddah, Asia	Douglas DC-8-61
Aug. 16, 1991	Imphal, Asia	Boeing 737-200
Sept. 16, 1991	(near) Barranquilla, Latin America	Handley Page Herald
Sept. 23, 1991	Khatanga, Europe	Antonov An-12
Nov. 7, 1991	(near) Makhachkala, Europe	Yakovlev Yak-40
Nov. 26, 1991	Bugulma, Europe	Antonov An-24
Dec. 29, 1991	(near) Taipei, Asia	Boeing 747
Jan. 3, 1992	(near) Saranac Lake, North America	Beech 1900
Jan. 20, 1992	(near) Strasbourg, Europe	Airbus A320
Feb. 15, 1992	Toledo, North America	Douglas DC-8
March 12, 1992	Knoxville, North America	BAe Jetstream 31
March 24, 1992	Athens, Europe	Boeing 707-320C
April 4, 1992	(near) Baykovo, Europe	Let L-410 Turbolet
April 7, 1992	(near) Sarrah, Africa	Antonov An-24
May 2, 1992	Venustiano Carranza, Latin America	Learjet 35
June 7, 1992	Mayaguez, North America	CASA 212
June 22, 1992	Norilsk, Europe	Antonov An-12
June 22, 1992	Cruzeiro do Sul, Latin America	Boeing 737-200
July 23, 1992	(near) Jaboiciste, Europe	Antonov An-12
July 24, 1992	Ambon Island, Asia	Vickers Viscount
Aug. 27, 1992	Ivanovo, Europe	Tupolev Tu-134
Sept. 10, 1992	Bellavista, Latin America	Fokker F27
Sept. 28, 1992	Kathmandu, Asia	Airbus A300
Oct. 4, 1992	Amsterdam, Europe	Boeing 747
Oct. 9, 1992	(near) Mogadishu, Africa	Antonov An-32
Oct. 18, 1992	(near) Garut, Asia	CASA CN-235
Oct. 29, 1992	(near) Chita, Europe	Antonov An-8
Nov. 14, 1992	(near) Nha Trang, Asia	Yakovlev Yak-40
Nov. 15, 1992	(near) Puerto Plata, North America	Ilyushin Il-18

* (Defined by Airclaims in Appendix A, page 57.)

U.K. Civil Aviation Authority (CAA) Database of Fatal Approach-and-landing Accidents (Section 3) *(Continued)*

Date	Location: City/Airport, Region*	Aircraft Type
Nov. 24, 1992	(near) Guilin, Asia	Boeing 737
Dec. 13, 1992	Goma, Africa	Fokker F27
Dec. 18, 1992	Billings, North America	Cessna Citation II
Dec. 21, 1992	Faro, Europe	Douglas DC-10
Dec. 22, 1992	(near) Tripoli, Africa	Boeing 727
Jan. 6, 1993	Paris, Europe	DHC-8 Dash 8
Jan. 8, 1993	(near) Hermosillo, Latin America	Learjet 35
June 6, 1993	El Yopal, Latin America	DHC-6 Twin Otter
July 1, 1993	Sorong, Asia	Fokker F28
July 26, 1993	Mokpo, Asia	Boeing 737-500
July 31, 1993	Bharatpur, Asia	Dornier 228
Aug. 26, 1993	Aldan, Europe	Let L-410 Turbolet
Sept. 14, 1993	Warsaw, Europe	Airbus A320
Oct. 26, 1993	Fuzhou, Asia	MD-80
Oct. 27, 1993	Namsos, Europe	DHC-6 Twin Otter
Nov. 13, 1993	Urumqi, Asia	MD-82
Nov. 15, 1993	(near) Kerman, Asia	Antonov An-124
Nov. 20, 1993	Ohrid, Europe	Yakovlev Yak-42
Dec. 1, 1993	Hibbing, North America	BAe Jetstream 31
Dec. 15, 1993	Goodland, North America	Mitsubishi MU-300 Diamond
Dec. 15, 1993	Orange County, North America	IAI Westwind
Dec. 26, 1993	Gyumri (Leninakan), Europe	Antonov An-26
Jan. 3, 1994	(near) Irkutsk, Europe	Tupolev Tu-154
Jan. 7, 1994	(near) Columbus, North America	BAe Jetstream 41
Jan. 18, 1994	(near) Kinshasa, Africa	Learjet 24
Jan. 27, 1994	Meadow Lake, North America	IAI Westwind
Feb. 24, 1994	Nalchik, Europe	Antonov An-12
March 23, 1994	(near) Bogota, Latin America	Cessna Citation VI
March 25, 1994	Ciudad Miguel Aleman, Latin America	Cessna Citation 500
April 4, 1994	Amsterdam, Europe	Saab 340
April 27, 1994	M’banza Congo, Africa	Boeing 727
May 7, 1994	Sao Gabriel, Latin America	EMB-110 Bandeirante
June 18, 1994	(near) Palu, Asia	Fokker F27
June 18, 1994	Washington, D.C., North America	Learjet 25
June 26, 1994	Abidjan, Africa	Fokker F27
July 1, 1994	Tidjikja, Africa	Fokker F28
July 17, 1994	Boma, Africa	Yakovlev Yak-40
Sept. 8, 1994	(near) Pittsburgh, North America	Boeing 737
Sept. 13, 1994	(near) Abuja, Africa	DHC-6 Twin Otter
Sept. 18, 1994	Tamanrasset, Africa	BAC 111
Oct. 29, 1994	Ust-Ilimsk, Europe	Antonov An-12
Nov. 5, 1994	San Martin Province, Latin America	Yakovlev Yak-40
Dec. 13, 1994	Raleigh-Durham, North America	BAe Jetstream 32
Dec. 19, 1994	(near) Kano, Africa	Boeing 707
Dec. 21, 1994	Willenhall, Europe	Boeing 737-200
Dec. 29, 1994	Van, Europe	Boeing 737-400
Jan. 11, 1995	(near) Masset, North America	Learjet 35
Jan. 20, 1995	Paris, Europe	Dassault Falcon 20
Jan. 30, 1995	(near) Linkou, Asia	ATR 72
March 16, 1995	Ossora, Europe	Antonov An-26
April 23, 1995	Lagos, Africa	DHC-6 Twin Otter

* (Defined by Airclaims in Appendix A, page 57.)

U.K. Civil Aviation Authority (CAA) Database of Fatal Approach-and-landing Accidents (Section 3) *(Continued)*

Date	Location: City/Airport, Region*	Aircraft Type
April 27, 1995	(near) Alice Springs, Australasia	IAI Westwind
April 28, 1995	Guatemala City, Latin America	Douglas DC-8
May 3, 1995	(near) Quito, Latin America	Gulfstream II
June 9, 1995	(near) Palmerston North, Australasia	DHC-8 Dash 8
June 22, 1995	(near) Tepic, Latin America	Learjet 35
June 24, 1995	Lagos, Africa	Tupolev Tu-134
July 12, 1995	Alotau, Australasia	DHC-6 Twin Otter
Aug. 9, 1995	(near) San Salvador, Latin America	Boeing 737
Sept. 15, 1995	Tawau, Asia	Fokker F50
Oct. 25, 1995	Ufa, Europe	Antonov An-32
Nov. 13, 1995	Kaduna, Africa	Boeing 737
Nov. 30, 1995	(near) Baku, Europe	Boeing 707
Dec. 3, 1995	(near) Douala, Africa	Boeing 737
Dec. 19, 1995	(near) Guatemala City, Latin America	Rockwell Jet Commander
Dec. 30, 1995	Eagle River, North America	Cessna Citation V
Dec. 31, 1995	(near) East Naples, North America	Cessna Citation II
Jan. 17, 1996	(near) Kano, Africa	HS 125
Feb. 16, 1996	(near) El Quiche, Latin America	DHC-6 Twin Otter
Feb. 19, 1996	(near) Salzburg, Europe	Cessna Citation II
Feb. 29, 1996	Arequipa, Latin America	Boeing 737
March 2, 1996	(near) Sao Paulo, Latin America	Learjet 25
April 5, 1996	(near) Petropavlovsk-Kamchatsky, Europe	Ilyushin Il-76
April 5, 1996	(near) Matsu Island, Asia	Dornier 228
May 3, 1996	Haj Yousif, Africa	Antonov An-24
May 10, 1996	(near) Otaez, Latin America	DHC-6 Twin Otter
May 11, 1996	(near) Opa Locka, North America	Douglas DC-9
June 20, 1996	(near) Jos, Africa	Gulfstream II
July 24, 1996	Myeik, Asia	Fokker F27
Aug. 8, 1996	Offenburg, Europe	Dassault Falcon 10
Aug. 19, 1996	Belgrade, Europe	Ilyushin Il-76
Aug. 29, 1996	(near) Longyearbyen, Europe	Tupolev Tu-154
Oct. 2, 1996	(near) Ancon, Latin America	Boeing 757
Oct. 23, 1996	Buenos Aires, Latin America	Boeing 707
Oct. 26, 1996	Hanti-Mansiysk, Europe	Yakovlev Yak-40
Nov. 1, 1996	(near) Flores, Latin America	EMB-110 Bandeirante
Nov. 19, 1996	Quincy, North America	Beech 1900
Dec. 6, 1996	Stephenville, North America	Learjet 36
Dec. 21, 1996	(near) Medellin, Latin America	Antonov An-32

* (Defined by Airclaims in Appendix A, page 57.)

DAAWG Database of Approach-and-landing Accidents and Serious Incidents (Section 4)

Date	Location	Aircraft Type
April 26, 1984	Bremen, Germany	Boeing 727
Jan. 9, 1985	Kansas City, Missouri, U.S.	Lockheed L-188 Electra
May 27, 1985	Leeds Bradford, U.K.	Lockheed L-1011 Tristar
Aug. 2, 1985	Dallas–Fort Worth, Texas, U.S.	Lockheed L-1011 Tristar
Nov. 18, 1985	Jeddah, Saudi Arabia	Boeing 737-200
Jan. 27, 1986	Ezeiza International, Argentina	Boeing 707
Jan. 31, 1986	East Midlands, U.K.	Shorts 360
Feb. 21, 1986	Erie, Pennsylvania, U.S.	Douglas DC-9-31
March 20, 1986	Naha, Indonesia	CASA 212
Sept. 14, 1986	Amsterdam, Netherlands	Britten Norman Trislander
Oct. 25, 1986	Charlotte, North Carolina, U.S.	Boeing 737-222
Jan. 15, 1987	Salt Lake City, Utah, U.S.	Fairchild Metro II
March 4, 1987	Detroit, Michigan, U.S.	CASA 212
April 13, 1987	Kansas City, Missouri, U.S.	Boeing 707
Oct. 8, 1987	Memphis, Tennessee, U.S.	Hamilton HA-1
Oct. 19, 1987	Leeds Bradford, U.K.	Beech King Air 200
Jan. 18, 1988	Houston, Texas, U.S.	HS 125
Jan. 19, 1988	Bayfield, Colorado, U.S.	Fairchild Metro III
April 1, 1988	Kansas City, Missouri, U.S.	Beech H18
April 12, 1988	London Gatwick, U.K.	BAC 111
May 26, 1988	Hannover, Germany	Fokker F27
Aug. 2, 1988	Reykjavik, Iceland	CASA 212
Aug. 31, 1988	Hong Kong International, Hong Kong	HS Trident
Sept. 12, 1988	Eindhoven, Netherlands	Mitsubishi MU2B-60
Nov. 29, 1988	Chapleau, Canada	Beech King Air A100
Jan. 8, 1989	East Midlands, U.K.	Boeing 737-400
Feb. 19, 1989	Kuala Lumpur, Malaysia	Boeing 747
April 2, 1989	Iquitos, Peru	Boeing 737-248
Sept. 8, 1989	Kansas City, Missouri, U.S.	Boeing 737-200
Sept. 26, 1989	Terrace, Canada	Fairchild Metro III
Dec. 26, 1989	Pasco, Washington, U.S.	BAe Jetstream 31
Jan. 25, 1990	J.F. Kennedy International, New York, U.S.	Boeing 707
Feb. 5, 1990	Ibhue, Colombia	Gulfstream I
April 30, 1990	Moosonee, Canada	Beech King Air C90
May 4, 1990	Wilmington, North Carolina, U.S.	GAF Nomad
July 14, 1990	Khartoum, Sudan	Boeing 707
Nov. 14, 1990	Zürich, Switzerland	Douglas DC-9-32
July 11, 1991	Jeddah, Saudi Arabia	Douglas DC-8-61
Dec. 17, 1991	Okecie, Poland	Douglas DC-9-30
Jan. 7, 1992	Devonport, Tasmania, Australia	Saab 340
Jan. 20, 1992	(near) Strasbourg, France	Airbus A320
March 30, 1992	Granada, Spain	Douglas DC-9-32
June 7, 1992	Mayaguez, Puerto Rico	CASA 212
July 31, 1992	Kathmandu, Nepal	Airbus A310-300
Sept. 28, 1992	Kathmandu, Nepal	Airbus A300
Oct. 4, 1992	Amsterdam, Netherlands	Boeing 747
Dec. 21, 1992	Faro, Portugal	Douglas DC-10
Jan. 6, 1993	Paris, France	DHC-8 Dash 8
Feb. 10, 1993	Toronto, Canada	Boeing 757

DAAWG Database of Approach-and-landing Accidents and Serious Incidents (Section 4) *(Continued)*

Date	Location	Aircraft Type
April 14, 1993	Dallas–Fort Worth, Texas, U.S.	Douglas DC-10
May 26, 1993	Southampton, U.K.	Cessna Citation II
July 18, 1993	Augusto Cesar Sandino, Nicaragua	Boeing 737
Oct. 20, 1993	London Gatwick, U.K.	Boeing 737
Nov. 4, 1993	Hong Kong International, Hong Kong	Boeing 747
Dec. 1, 1993	Hibbing, Minnesota, U.S.	BAe Jetstream 31
Dec. 27, 1993	Namos, Norway	DHC-6 Twin Otter
Jan. 14, 1994	Sydney, Australia	Commander 690
April 4, 1994	Amsterdam, Netherlands	Saab 340
Sept. 18, 1994	Tamanrasset, Algeria	BAC 111
Oct. 19, 1994	Sydney, Australia	Boeing 747
Dec. 13, 1994	Raleigh-Durham, North Carolina, U.S.	BAe Jetstream 32
Dec. 14, 1994	Acapulco, Mexico	Boeing 757
Dec. 21, 1994	Willenhall, U.K.	Boeing 737-200
April 27, 1995	(near) Alice Springs, Australia	IAI Westwind
Sept. 27, 1995	Campbell River, Canada	Cox DHC-3T Turbo Otter
Nov. 12, 1995	Bradley International, Connecticut, U.S.	MD-83
Dec. 20, 1995	Cali, Colombia	Boeing 757
Feb. 19, 1996	Houston, Texas, U.S.	Douglas DC-9-30
Feb. 20, 1996	Washington National, D.C., U.S.	Boeing 737-130
March 8, 1996	Halifax, Nova Scotia, Canada	Boeing 767
April 3, 1996	Dubrovnic, Croatia	Boeing 737-200
June 20, 1996	(near) Jos, Nigeria	Gulfstream II
July 15, 1996	Eindhoven, Netherlands	Lockheed C-130 Hercules
Aug. 13, 1996	Northolt, U.K.	Learjet 25B
Oct. 19, 1996	La Guardia, New York, U.S.	MD-88
Nov. 11, 1997	Corpus Christi, Texas, U.S.	Boeing 737-500

ATR = Avions de Transport Regional
BAC = British Aircraft Corp.
BAe = British Aerospace
CASA = Construcciones Aeronauticas SA
DHC = de Havilland Canada
EMB = Empresa Brasileira de Aeronautica SA (Embraer)
GAF = Government Aircraft Factory
HS = Hawker Siddeley
IAI = Israel Aircraft Industries
MD = McDonnell Douglas
NAMC = Nihon Airplane Manufacturing Co.

Appendix C
Approach-and-landing Accident Coding Form

National Aerospace Laboratory (NLR)–Netherlands Taxonomy for Occurrence Variables

Please fill out every item on this survey for each accident for which you are responsible.

Working Group member name:

Data sources — List resources used in analyzing this accident:

Flight Variables

Aircraft type and series:

FDR installed? (Check all that apply.)

_____ Installed and operational
_____ Installed but not operational
_____ Not installed
_____ Unknown

CVR installed? (Check all that apply.)

_____ Installed and operational
_____ Installed but not operational
_____ Not installed
_____ Unknown

Date: (yy/mm/dd)

Local time: (hh/mm/ss)

Crash site (city, state, country):

Distance from runway (nautical miles):

Centerline of runway? (Check one.)

_____ On
_____ Off
_____ Unknown

Operator name:

Country of origin of operator:

Type of operation (check one in each group):

_____ Passenger
_____ Freight
_____ Unknown

_____ Domestic
_____ International
_____ Unknown

_____ Air taxi
_____ Regional
_____ Major
_____ Corporate
_____ Military
_____ Government
_____ Other
_____ Unknown

Flight Crew Variables

Pilot flying at accident:

_____ Captain
_____ First officer (FO)
_____ Single pilot (SPO)
_____ Unknown

Experience Level:

Total Hours captain/SPO_______ or Unknown ______

Total Hours FO ________ or Unknown ______

Hours on Type Captain/SPO _________ or Unknown ______

Hours on Type FO _________ or Unknown ______

Hours on type last 28 days captain/SPO ________ or Unknown ______

Hours on type last 28 days FO _________ or Unknown ______

Number of flights into airfield last 28 days captain/SPO ________ or Unknown _____

Number of flights into airfield last 28 days FO ___________ or Unknown _______

Environmental Variables

Lighting conditions:

_____ Dark
_____ Twilight
_____ Light
_____ Unknown

Weather conditions:

_____ VMC
_____ IMC
_____ Unknown

Weather Factor (check each)	Yes	No	Unknown
Poor visibility			
Fog			
Wind shear			
Strong crosswinds			
Tailwinds			
Headwinds			
Snow			
Rain			
Ice			

Quality of weather update:

_____ Satisfactory
_____ Poor
_____ Unknown

Runway conditions?

_____ Dry
_____ Wet
_____ Ice
_____ Slush
_____ Snow
_____ Unknown

Airport, ATC and Approach Variables

Runway lights available at this airport?

_____ Yes

_____ No

_____ Unknown

Approach lights available at this airport?

_____ Yes

_____ No

_____ Unknown

VASI/PAPI equipped?

_____ Yes

_____ No

_____ Unknown

VFR approach/landing?

_____ Yes (includes traffic pattern/straight in/valley-terrain following/go-around)

_____ No

_____ Unknown

Navaids flown:

ADF/NDB	Yes	No	Unknown
LOC type aid			
VOR			
DME			
ILS Full/ILS Backcourse			
PAR/ASR			
None			

Go-around flown?

_____ Yes

_____ No

_____ Unknown

Number of approaches flown:

_____ One

_____ Two

_____ Three or more

Terminal-approach radar?

_____ Yes

_____ No

_____ Unknown

Terrain:

_____ Flat

_____ Over water

_____ Hilly

_____ Mountainous

_____ Unknown

Accident Type (Please check the one box that is most appropriate.)

	CFIT
	Collision with terrain/water/obstacles (non-CFIT)
	Collision with another aircraft on ground
	Midair collision
	Landing overrun
	Runway excursion
	Landing-gear problem (e.g., collapse)
	Wheels-up landing
	Unstabilized approach condition
	Loss of control
	Wake-vortex encounter
	Airframe icing
	Engine problem (e.g., loss of power)
	Aircraft structural problem
	Aircraft system malfunction
	Fuel exhaustion
	Fire
	Other

If other, specify accident type:

____

ALAR Factors Analysis (from U.K. CAA)

Please check each factor which applies. Each accident usually has more than one factor. To ensure consistency across all raters, please check “yes,” “no” or “unknown” for each factor listed.

Please estimate your level of confidence with these judgments. (Check one.)

_____ High

_____ Medium

_____ Low

_____ Insufficient information

Causal factors

Note: Unk = Unknown

GROUP	FACTOR ID	FACTOR	Yes	No	Unk
A-1 Aircraft Systems	1.1	System failure - affecting controllability			
	1.2	System failure - flight deck information			
	1.3	System failure - other			
A-2 ATC/Ground Aids	2.1	Incorrect or inadequate instruction/advice/service			
	2.2	Misunderstood/missed communication			
	2.3	Failure to provide separation in the air			
	2.4	Failure to provide separation on the ground			
	2.5	Ground aid malfunction or unavailable			
A-3 Environmental	3.1	Structural overload			
	3.2	Wind shear/upset/turbulence/gusts			
	3.3	Icing			
	3.4	Wake turbulence — aircraft spacing			
	3.5	Volcanic ash/sand/precipitation, etc.			
	3.6	Birds			
	3.7	Lightning			
	3.8	Runway condition unknown to crew			
A-4 Crew	4.1	Lack of positional awareness in the air			
	4.2	Lack of positional awareness on the ground			
	4.3	Lack of awareness of circumstances in flight			
	4.4	Incorrect selection on instrument/navaid			
	4.5	Action on wrong control/instrument			
	4.6	Slow/delayed action			
	4.7	Omission of action/inappropriate action			
	4.8	“Press-on-itis”			
	4.9	Failure in CRM (cross check/coordinate)			
	4.10	Poor professional judgment/airmanship			
	4.11	Disorientation or visual illusion			

Causal factors (continued)

GROUP	FACTOR ID	FACTOR	Yes	No	Unk
	4.12	Fatigue			
	4.13	State of mind			
	4.14	Interaction with automation			
	4.15	Fast and/or high on approach			
	4.16	Slow and/or low on approach			
	4.17	Loading incorrect			
	4.18	Flight handling			
	4.19	Lack of qualification/training/experience			
	4.20	Incapacitation/medical/crew performance			
	4.21	Failure in look-out			
	4.22	Deliberate nonadherence to procedures			
A-5 Engine	5.1	Engine failure or malfunction			
	5.2	Propeller failure			
	5.3	Damage because of noncontainment			
	5.4	Fuel contaminated/incorrect			
	5.5	Engine failure simulated			
A-6 Fire	6.1	Engine fire or overheat			
	6.2	Fire because of aircraft systems			
	6.3	Fire — other cause			
	6.4	Postimpact fire			
A-7 Maintenance/ Ground handling	7.1	Failure to complete due maintenance			
	7.2	Maintenance or repair error/oversight/inadequacy			
	7.3	Ground staff or passenger struck by aircraft			
	7.4	Loading error			
	7.5	Bogus parts			
A-8 Structure	8.1	Corrosion/fatigue			
	8.2	Overload failure			
	8.3	Flutter			
A-9 Infrastructure	9.1	Incorrect, inadequate or misleading info to crew			
	9.2	Inadequate airport support			
A-10 Design	10.1	Design shortcomings			
	10.2	Unapproved modification			
	10.3	Manufacturing defect			
A-11 Performance	11.1	Unable to maintain speed/height			
	11.2	Aircraft becomes uncontrollable			
A-12 Other	12.1	Caused by other aircraft			
	12.2	Nonadherence to cabin safety procedures			

Circumstantial Factors

GROUP	FACTOR ID	FACTOR	Yes	No	Unk
B-1 Aircraft Systems	1.1	Nonfitment of presently available safety equipment			
	1.2	Failure/inadequacy of safety equipment			
B-2 ATC/Ground aids	2.1	Lack of ATC			
	2.2	Lack of ground aids			
B-3 Environmental	3.1	Poor visibility			
	3.2	Other weather			
	3.3	Runway condition (ice, slippery, standing water, etc.)			
B-4 Crew	4.1	Training inadequate			
	4.2	Presented with situation beyond training			
	4.3	Failure in CRM (cross-check/coordinate)			
B-5 Infrastructure	5.1	Incorrect/inadequate procedures			
	5.2	Company management failure			
	5.3	Inadequate regulation			
	5.4	Inadequate regulatory oversight			
B-6 Other	6.1	Illegal/unauthorized/drug-smuggling flight			

Consequences (Note: For this item, more than one consequence may be appropriate.)

CONSEQUENCE ID	CONSEQUENCE	Yes	No	Unk
1	Controlled flight into terrain (CFIT)			
2	Collision with terrain/water/obstacle			
3	Midair collision			
4	Ground collision with other aircraft			
5	Ground collision with object/obstacle			
6	Loss of control in flight			
7	Fuel exhaustion			
8	Overrun			
9	Undershoot			
10	Structural failure			
11	Postimpact fire			
12	Fire/smoke during operation			
13	Emergency evacuation difficulties			
14	Forced landing - land or water			
15	Other cause of fatality			

ALAR Human Factors Checklist (from line audit)

- Please complete this checklist for each ALA or serious incident.
- **Check the + (plus) column** if the factor contributed to a successful outcome or reduced the severity of the event.
- **Check the "0" column** if the action had no effect on the event.
- **Check the – (minus) column** if the action had a negative effect on the outcome or contributed to the occurrence of the event.

Check the "Unknown" column if the factor cannot be evaluated from the data. **Please enter one of the four options for each item.**

		+	0	–	unknown
Team Management and Crew Communcations					
1.	*Team concept and environment for open communications established and/or maintained, e.g., crewmembers listen with patience, do not interrupt or "talk over," do not rush through the briefing, make eye contact as appropriate.*				
2.	*Briefings are operationally thorough, interesting, and address crew coordination and planning for potential problems. Expectations are set for how possible deviations from normal operations are to be handled, e.g., rejected T/O, engine failure after lift-off, go-around at destination.*				
3.	*Crewmembers ask questions regarding crew actions and decisions, e.g., effective inquiry about uncertainty of clearance limits, clarification of confusing/unclear ATC instructions.*				
4.	*Crewmembers speak up, and state their information with appropriate persistence, until there is some clear resolution and decision, e.g., effective advocacy & assertion: "I'm uncomfortable with ... , Let's ... "*				
5.	*Captain coordinates flight-deck activities to establish proper balance between command authority and crewmember participation, and acts decisively when the situation requires.*				
Situational Awareness and Decision Making					
6.	*Crewmembers demonstrate high levels of vigilance in both high and low workload conditions, e.g., active monitoring, scanning, cross-checking, attending to radio calls, switch settings, altitude callouts, crossing restrictions.*				
7.	*Crew prepares for expected or contingency situations including approaches, weather, etc., i.e., stays "ahead of the curve."*				
Automation Management					
8.	*Crewmembers verbalize and acknowledge entries and changes to automated-systems parameters.*				
9.	*Automated systems are used at appropriate levels, i.e., when programming demands could reduce situational awareness and create work overloads, the level of automation is reduced or disengaged, or automation is effectively used to reduce workload.*				

Accident Prevention Strategies Attachment (based on Reason's concept of system defenses[12])

Identify any means that may have prevented this accident, using the following topic areas as guidelines:

1. Equipment

2. Policies and Standards

3. Procedures

4. Training

5. Other

Appendix D
Flight Safety Foundation ALAR Task Force Data Acquisition and Analysis Working Group Members

Co-chairs

Ratan Khatwa, Ph.D.†	Rockwell Collins
Robert Helmreich, Ph.D.	The University of Texas at Austin

Core Group

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Kevin Comstock	Air Line Pilots Association, International (ALPA)
Jim Danaher	U.S. National Transportation Safety Board (NTSB)
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Dick van Eck	ATC the Netherlands
Capt. Andres Fabre	Aviacsa Aeroexo Airlines
Capt. Carl Kuwitzky	Southwest Airlines Pilots Association (SWAPA)
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Paul Mayes	International Society of Air Safety Investigators (ISASI)
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Capt. Lou van Munster	International Federation of Air Line Pilots' Associations (IFALPA)
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Jerry Nickelsburg	FlightSafety Boeing
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Paul Russell	Boeing Commercial Airplanes Group
Adrian Sayce	U.K. Civil Aviation Authority (U.K. CAA)
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Frank Taylor	Cranfield University Safety Centre
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Flight Safety Foundation
Approach-and-landing Accident Reduction Task Force

Operations and Training Working Group

Final Report (Version 2.0)

Capt. Dick McKinney
American Airlines (retired)
U.S. Air Force (retired)

Executive Summary

Approach-and-landing Safety Demands Improvement

Since the early 1990s, Flight Safety Foundation (FSF) has given its highest priority to improving safety in approach-and-landing flight operations. Early on, the Foundation created and led an international task force to reduce controlled flight into terrain (CFIT), which was shown statistically to be the greatest cause of aviation fatalities. In cooperation with the International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA), the task force identified specific causes of CFIT, developed solutions to those problems and disseminated safety information to prevent CFIT accidents. As the task force's work on CFIT came to a conclusion, the FSF CFIT Steering Committee began to focus on approach-and-landing accidents (ALAs); virtually all data on aviation accidents and incidents show significantly more risk to safety in these phases of flight than any others. In 1996, the steering committee was expanded to include the additional efforts of approach-and-landing accident reduction (ALAR).

Working Groups Created to Study Accidents

The FSF CFIT-ALAR Steering Committee commissioned the international FSF ALAR Task Force of several working groups (WGs) to study the reduction of ALAs. The Air Traffic Control (ATC) Training and Procedures/Airport Facilities WG, led by Robert Vandel (Flight Safety Foundation), examined ATC processes; the Aircraft/ Equipment WG, led by Jean-Pierre Daniel (Airbus Industrie), examined the equipment aspects; and the Operations and Training WG (OTWG), led jointly by Capt. Erik Reed Mohn (Scandinavian Airlines System [SAS] Flight Academy and Pat Andrews (Mobil Corp. Global Aircraft Services), was created to develop conclusions and recommendations for practices that would improve safety in approach-and-landing operations. Later, the demand for substantive ALA data led to the creation of the Data Acquisition and Analysis WG, led by Ratan Khatwa, Ph.D., (Rockwell Collins) and Robert Helmreich, Ph.D., (The University of Texas at Austin), which focused on researching accident causes and validating accident-prevention strategies.

The OTWG recognized the importance of ensuring broad industry participation in this problem-solving process. Since 1996, as many as 25 people from diverse aviation disciplines met on six occasions to discuss operations and training issues related to safety in approach-and-landing operations. The meeting attendees were not always the same individuals, but each WG meeting was conducted with balanced representation. The significant amount of work conducted between meetings involved additional participants. This high level of involvement contributed to the development of the robust set of conclusions and recommendations presented herein.

Hypotheses Built Framework

Because of the significance of ALAs, and the failure of current data to point definitively to specific solutions, the OTWG used an inductive process that began with definitions of objectives and the formation of “cause-and-effect” hypotheses (statements of belief). These hypotheses served as the study’s framework, allowing WG members to identify the information needed to test their beliefs. Through an extensive series of iterations, the more than 50 original hypotheses developed in 1996 evolved into the eight conclusions presented in this paper.

Data Support Findings

The OTWG members agreed that no conclusion or recommendation would be offered to the aviation community unless it was clearly supported by multiple data sets and confirmed through several analysis methodologies. At the OTWG’s request, a Data Acquisition and Analysis WG was created in 1997 by the steering committee to develop the resources that could serve as a screen for potential recommendations.

With each conclusion, recommendations are provided to support change in the areas addressed. Care was taken by the WG to make the recommendations universally applicable and low cost. Particular emphasis was given to ensuring that implementing the WGs’ recommendations would help improve safety in regions of the world where ALA rates are highest.

Conclusions and Recommendations

Eight conclusions and associated recommendations were developed and validated by the FSF ALAR Task Force. The following conclusions and recommendations include comments in italics for clarification and amplification. No priority is implied by the number or sequence of the conclusions.

Conclusion No. 1: Establishing and adhering to adequate standard operating procedures (SOPs) and flight-crew decision-making processes improve approach-and-landing safety.

Recommendations

States should mandate, and operators should develop and implement, SOPs for approach-and-landing operations. *Although all factors cannot be anticipated, the data clearly showed that the absence of good, practical SOPs (recommended techniques) resulted in higher exposure to approach-and-landing problems.*

Operators should develop SOPs that are practical and can be applied in a normal operating environment. The involvement of flight crews is essential in the development and evaluation of SOPs. *Crews will adhere to SOPs that they helped develop and know the reasons for. They will identify and help eliminate unworkable or unreasonable procedures, and will support adherence to SOPs they “own” through a development process.*

Operators should implement routine and critical evaluation of SOPs to determine the need for change. *Procedures that are obsolete, ineffective or outdated must be eliminated and new ones developed as operational changes require. Crew input should be a primary resource for this ongoing evaluation.*

Operators should provide education and training that enhance flight-crew decision making and risk (error) management. *Whether the training is a version of crew resource management (CRM) or other tools, the ultimate goal is good flight-crew decision making. Significant training resources must be allocated for this purpose.*

Operators should develop SOPs regarding the use of automation in approach-and-landing operations, and train accordingly.

There should be a clear policy in all operators’ manuals regarding the role of the pilot-in-command in complex and demanding flight situations. Training should address the practice of transferring pilot flying duties during operationally complex situations. *The data clearly show that task saturation and overload for the pilot flying are significant contributors to ALAs. Company policy on the sharing of cockpit duties needs to recognize that the effective distribution of tasks and decision making among crewmembers is critical to avoid overloading the pilot flying.*

Conclusion No. 2: Failure to recognize the need for and to execute a missed approach when appropriate is a major cause of ALAs.

Recommendations

Company policy should specify well-defined go-around gates (such as those suggested under Conclusion No. 3) for approach-and-landing operations. Parameters should include:

- Visibility minima required prior to proceeding past the final approach fix (FAF) or the outer marker (OM);
- Assessment at FAF or OM of crew and aircraft readiness for the approach; and,
- Minimum altitude at which the aircraft must be stabilized.

Companies should declare and support no-fault go-around and missed-approach policies. *Training and company performance-management systems should reinforce those policies.*

Conclusion No. 3: Unstabilized and rushed approaches contribute to ALAs.

Recommendations

Operators should define the parameters of a stabilized approach (Example in Table 1) in their flight operations manuals, including at least the following:

- Intended flight path;
- Speed;
- Power setting;
- Attitude;
- Sink rate;
- Configuration; and,
- Crew readiness

Company policy should state that a go-around is required if the aircraft becomes destabilized during the approach. *Training should reinforce this policy.*

Flight crews should "take time to make time" when the cockpit situation becomes confusing or ambiguous. *This means climbing, holding, requesting vectors for delaying purposes, or going missed-approach early when things do not look right or crew confusion or distraction exists. Rushed approaches and "press-on-itis" (continuing toward the destination in spite of a lack of readiness of the airplane or crew) are major contributing factors to ALAs.*

The implementation of certified constant-angle, stabilized-approach procedures for nonprecision approaches should be expedited globally.

Flight crews should be trained on the proper use of constant-angle, stabilized-approach procedures. Flight crews also should be educated on approach-design criteria and obstacle-clearance requirements.

Conclusion No. 4: Improving communication and mutual understanding between ATC specialists and flight crews of each other's operational environments will improve approach-and-landing safety

Recommendations

ATC services and operators should:

- Introduce joint training programs that involve both ATC personnel and flight crews to:
  - Promote mutual understanding of issues such as procedures, instructions, operational requirements and limitations between the flight deck and the ATC environment;
  - Improve controllers' knowledge of the capabilities and limitations of advanced-technology flight decks; and,
  - Foster improved communications and task management by pilots and controllers during emergency situations;
- Ensure that controllers are aware of the importance of unambiguous information exchange, particularly

Table 1
Elements of a Stabilized Approach

Note: A suggested definition or policy that might be considered by operators could be as follows: "All flights shall be stabilized by 1,000 feet height above touchdown (HAT) in instrument meteorological conditions (IMC) and by 500 feet HAT in visual meteorological conditions (VMC)." An approach is considered stabilized when all of the following criteria are met:

1. The aircraft is on the correct flight path;
2. Only small changes in heading and pitch are required to maintain that path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed (KIAS) and not less than V_{REF};
4. The aircraft is in the proper landing configuration (approach configuration for small twins);
5. Sink rate is maximum 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be performed;
6. Power setting appropriate for configuration and not below the minimum power for approach as defined by the aircraft operations manual;
7. All briefings and checklists have been performed;
8. Specific types of approaches are considered stabilized if they also fulfill the following: instrument landing system (ILS) approaches — must be flown within one dot of the glideslope or localizer; a Category II or III approach must be flown within the expanded localizer band. Visual approaches — wings must be level on final when the aircraft reaches 500 feet HAT. Circling approaches — wings must be level on final when aircraft reaches 300 feet HAT; and,
9. Unique approaches such as the "old" Hong Kong Airport, and the DCA (Washington, D.C.) river visual approach to Runway 18 require a special briefing.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

during in-flight emergencies. *The use of standard ICAO phraseology should be emphasized*;

- Implement procedures that require immediate clarification or verification of transmissions from flight crews that indicate a possible emergency situation;
- Implement procedures for ATC handling of aircraft in emergency situations to minimize flight-crew distraction;
- In cooperation with airport authorities and rescue services, implement unambiguous emergency procedures and common phraseology to eliminate confusion; and,
- Develop, jointly with airport authorities and local rescue services, emergency-training programs that are conducted on a regular basis.

Flight crews should:

- Verify understanding of each ATC communication and request clarification when necessary; and,
- Accurately report the status of abnormal situations and the need for emergency assistance *using standard ICAO phraseology.*

These recommendations mirror those developed by the Data Acquisition and Analysis WG. Both WGs agree that improving the ATC-flight crew understanding and interface could significantly improve safety in approach-and-landing operations. To be successful, however, the goals and reward mechanisms for ATC services must be reconciled with those of the operators. This means developing a shared mental model that universally prioritizes safety over capacity and on-time operations.

Conclusion No. 5: The risk of ALAs is higher in operations conducted in low light and poor visibility, on wet or otherwise contaminated runways, and with the presence of optical or physiological illusions.

Recommendations

Flight crews should be trained in operations involving these conditions before they are assigned line duties.

Flight crews should make operational use of a risk-assessment tool or checklist to identify approach-and-landing hazards. Appropriate procedures should be implemented to mitigate the risks.

Operators should develop and implement constant-angle, stabilized-approach procedures to assist crews during approach operations.

Operators should develop and implement a policy for the use of appropriate levels of automation/navigation aids for the approach being flown.

Conclusion No. 6: Using the radio altimeter (RA) as an effective tool will help prevent ALAs.

Recommendations

Education is needed to improve crew awareness of RA operation and benefits.

Operators should install RAs and activate “smart callouts” at 2,500 feet, 1,000 feet, 500 feet, the altitude set in the “DH” (decision height) window, 50 feet, 40 feet, 30 feet, 20 feet and 10 feet for better crew terrain awareness. *“Smart callouts” recognizes when an ILS approach is being conducted, and some callouts can be eliminated to prevent confusion.*

Operators should state that the RA is to be used during approach operations and specify procedures for its use.

The RA is a reliable and inexpensive tool that is widely misunderstood and misused by flight crews. The WG supports the recent development and installation of new, more advanced terrain-awareness and warning systems (TAWS) that could be highly effective in reducing CFIT accidents. This recommendation, however, is offered in recognition of the reality that it will take time to implement these new systems worldwide, to emphasize that all terrain-awareness tools must be well understood and correctly used, and to call attention to the need to partner training and education with new or current-technology installations.

Conclusion No. 7: Collection and analysis of in-flight parameters (e.g., flight operational quality assurance [FOQA] programs) identify performance trends that can be used to improve approach-and-landing safety.

Recommendations

FOQA should be implemented worldwide in conjunction with information-sharing partnerships such as Global Analysis and Information Network (GAIN), British Airways Safety Information System (BASIS) and FAA Aviation Safety Action Partnership (ASAP).

Examples of FOQA benefits (safety improvements and cost reductions) should be publicized widely.

A process should be developed to bring FOQA and information-sharing partnerships to regional airlines and business aviation.

Conclusion No. 8: Global sharing of aviation information decreases the risk of ALAs.

Recommendations

De-identification of aviation-information data sources should be a cardinal rule in FOQA and information-sharing processes.

Public awareness of the importance of information sharing must be increased through a coordinated, professional and responsible process.

Airlines and regions of the world that share information have the lowest accident rates.

Crews that are aware of an accident and its causes are not likely to repeat the events that led to that accident. Distribution of accident reports in the crews' native languages will enhance their understanding.

Move Forward on the Path to Implementation

With the study complete, the WG's conclusions and recommendations must now be translated into industry action that will further improve the safety of approach-and-landing operations. Guiding principles that the WGs recommend for this effort are:

- Cohesiveness — across all aviation sectors and regions to participate jointly in the implementation process. Competitive issues have no place in this arena; and,
- Commitment — to a significant awareness campaign that will ensure availability of this information to everyone who participates in approach-and-landing operations worldwide so that all can play a part in improving safety within their spheres of influence.

These principles are challenging — but with so much at stake, we cannot advocate doing any less.

Working Group's Scope Defined

The scope of the OTWG was defined as follows:

To identify operational or training measures that will improve safety from the point at which an aircraft commences an instrument or visual approach, while on the approach, circling, landing or during any missed-approach procedure.

This definition was validated by the steering committee on Sept. 9, 1996, with the proviso that effort should be made to avoid duplication of CFIT recommendations that already had been made and accepted by industry.

The WG agreed in principle to avoid duplication of effort, but was committed to adding emphasis to CFIT recommendations, where appropriate, to accelerate their implementation. The WG also decided not to exclude CFIT-accident data from review, because CFIT and ALAR lessons learned were not believed to be mutually exclusive.

The OTWG goals are:

- A 50 percent reduction in ALAs within five years of issuing recommendations; and,
- A reduction in regional ALA rates so that no regional rate is more than twice that of the lowest rate achieved by a region.

The second goal is particularly aggressive because current data show that the ALA rate in the African region is more than eight times higher than that of the regions with the lowest rates (Europe and the United States). Latin American and Asian accident rates are not much lower than that of the African region. The WG believed that the goal needed to be established to bring the greatest effort to the regions of the world where improvement is needed most.

Inductive Reasoning Led the Way

Early in its effort, the WG recognized that existing studies of approach-and-landing operations (both normal and abnormal) did not identify specific reasons for the high accident rates in those phases of flight. As one working-group member stated, there was no "silver bullet" available to solve this problem.

Therefore, the working-group members agreed to use an inductive process that began with development of project objectives and cause-and-effect hypotheses based solely on members' experience and knowledge. The WG's 50 initial hypotheses ultimately were refined during two and a half years, through iteration and data analysis, to a set of eight, presented here as the WG's conclusions. Each conclusion has been fully endorsed by the OTWG as well as the Data Acquisition and Analysis WG and is supportable by all data sets examined.

The WG's inductive process proceeded as follows:

- Define project objectives;
- Generate and refine hypotheses;
- Determine information needs (pose key questions);
- Develop work plan;

- Gather data;
- Analyze data to iterate and refine hypotheses; and,
- Develop conclusions and recommendations.

The WG's hypotheses effectively served as the project's framework. They allowed members to clearly identify information needs for testing the statements of belief about the problems of approach-and-landing safety. After hypotheses were developed and prioritized through an impact/changeability assessment, working-group members examined the issues or opportunities represented by each and posed key questions that would have to be answered satisfactorily before the hypotheses were deemed true or false.

After assigning members to subteams and developing work plans, the OTWG co-chairs formally requested the ALAR steering committee to commission the Data Acquisition and Analysis WG to gather and analyze the data needed to test the hypotheses. The Data Acquisition and Analysis WG began its work in mid-1997. A cooperative effort between the two working groups allowed rigorous testing of the hypotheses. Some were validated; some were eliminated because they were not supported by the data; and some were modified to reflect lessons learned in data analysis. The eight conclusions in this report evolved from hypotheses that survived this process and, as a result, have a high degree of confidence attached to them.

The Data Acquisition and Analysis WG examined both historical and predictive data sets in the hypothesis-testing process. Several taxonomies were pursued on accident data and line-audit data to ensure proper validation. A hypothesis did not become a conclusion unless all data tests supported it.

Table 2 shows the working-group process as it applied to one of the WG's hypotheses that ultimately evolved into a conclusion.♦

Table 2
Operations and Training Working Group's Hypothesis-testing Process

Hypothesis	Issues/Opportunities	Key Questions	Data Required
Failure to recognize the need for or to execute a missed approach when appropriate is a major cause of preventable landing accidents. NOTE: Two initial related hypotheses, "The lack of mandatory go-around gates causes approach-and-landing accidents" and "The lack of no-fault go-around policies contributes to a reluctance to miss, resulting in many landing accidents" were merged with the primary hypothesis above.	• Crew decision making • Policy on go-around • Go-around gates • Go-around cues • Company culture • On-time arrival mindset • Company procedures • Training for go-around • Stabilized-approach criteria • Recognition of the need to go around • Error detection • Approach-briefing quality • ATC services involvement in go-around decision making	1. Why do crews "fail to recognize" the need to go around? 2. Would SOPs that establish gates to be met (or go around) reduce landing accident rates? 3. What industry guidelines exist on go-around criteria? 4. What can be done to achieve more effective monitoring of approach-and-landing operations? 5. What differences exist among entities with the lowest approach-and-landing accident rates and those with higher rates? - etc. -	Worldwide safety board accident analyses, particularly with regard to situational awareness and crew behaviors Line audit data on crew behaviors in approach-and-landing operations Company policies, procedures and training practices on approach-and-landing operations (particularly go-around) ICAO guidelines on go-around operations Policies, processes and procedures by region and operator Assessment of carriers with confidential crew reporting processes - etc. -

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Appendix A
Examples of Good Standard Operating Procedures

Use of the Radio Altimeter as an Effective Terrain-awareness Tool

Description

The radio altimeter (RA) has been standard equipment on most air transports for over 40 years, but is effectively used only for Category II and III approaches by most operators. The RA has great utility as a crew-terrain-awareness tool if understood and employed correctly. Because it measures actual height above terrain, the RA is the heart of GPWS and autoland systems. Typical accuracy is ±5 feet or ±5 percent of the elevation above the terrain measured from the aircraft main gear in a normal approach attitude within ±5 degrees of pitch and ±20 degrees of bank. The accuracy of the system is unaffected by changes in pressure or temperature. Limitations of the system: decreased accuracy above 2,500 feet above ground level and the limitation against looking forward and warning of a cliff or obstructions such as trees.

Evidence

CFIT occurs because of a lack of crew awareness of terrain proximity. CFIT is currently the greatest threat to air safety and is the primary causal event in the ALAs studied by the FSF ALAR Task Force. The FSF ALAR Task Force, the FSF CFIT Task Force and the Joint Safety Action Team on CFIT recommend that the RA be used as an effective tool for crew terrain awareness. When using the procedures recommended below where 200 feet is always set in the DH window except for Category II or III approaches, "minimums" will be announced 15 seconds prior to impact on level terrain at normal approach descent rates, (800 feet per minute). "Minimums" will be announced 5 seconds before impact with closure rates of 2,400 feet (732 meters) per minute due to high sink rates or rising terrain. Five seconds warning is considered the absolute minimum to effect a pullup under such conditions. A review of CFIT accidents found that approximately 75 percent of the flight crews would have had 5 seconds to 15 seconds to recover after the DH light illuminated or "minimums" was announced if the equipment had been installed and used as recommended.

Recommendations

- **Set 200 feet in the RA DH window at all times except for Category II or III approaches.** Only Category II or III runways guarantee the approach to the runway end is graded to near threshold elevation. Why set 200 feet instead of 250 feet, which is the lowest minimum obstacle clearance altitude from the final approach fix (FAF) to the runway on a nonprecision approach? Because approach designers allowed for barometric altimeter tolerances in computing obstacle clearance limits. Some aircraft have allowable errors in excess of -50 feet at airport elevations above 5,000 feet mean sea level (MSL) so the effective obstacle clearance could be 200 feet for a normal approach. Why not set minimum descent altitude (MDA) in the DH window? Because the world is not flat. For example: A localizer distance-measuring-equipment (LOC DME) approach has an MDA of 400 feet height above touchdown (HAT), probably because of a 150-foot obstruction in the approach corridor from the FAF to the runway. If the obstruction were a ridgeline, the RA would announce "minimums" 150 feet above the obstacle clearance floor and 150 feet above the barometric MDA altitude. We have a message that will be ignored by the crew because we are within approach design criteria.

- **Activate "smart callouts" or require crews to call out RA altitudes of 2,500 feet, 1,000 feet, 500 feet and minimums at the setting in the DH window.** These calls alert the crew to the proximity of the terrain. Smart callouts can determine when a precision approach is being made, and callouts can be modified to prevent conflict with precision-approach procedures.

- **Train crews to initiate an aggressive go-around if the call "minimums" at 200 feet is made and the flight crew is not in visual contact with and in the slot for the landing runway.** This is a true minimums call. Instrument procedures require the pilot to avoid obstacles and terrain visually from DH/MDA to the runway.

- **Set 200 feet in the DH window for takeoff. Illumination of the DH light or the announcement of "minimums" after takeoff should trigger an aggressive climb.** The light or the callout indicates a descent or terrain rising faster than the aircraft. The light will not illuminate at 200 feet on the way up, but will illuminate going down if the aircraft has been above 200 feet.

Altitude Awareness and Clearance Awareness

Altitude Awareness

When setting the assigned altitude in the altitude display window, both pilots will verify that the altitude specified in the clearance has been correctly set, by stating the altitude and pointing at the altitude display window.

If the autopilot is being used, monitor the autopilot level-off at the assigned altitude.

The pilot not flying (PNF) will make all standard altitude callouts.

Because transition altitudes and transition levels vary by country and terminal area, pilots should exercise increased vigilance to ensure the proper altimeter reference (QNH [height above sea level], QNE [pressure altitude], or QFE [height above field elevation) is set.

Clearance Awareness

After the PNF reads back any ATC clearance, the pilot flying (PF) should acknowledge the clearance received.

The PF should repeat all of the following:

- Headings;
- Crossing restrictions;
- Airspeeds; and,
- Clearance limits, to include any runway crossing or hold short instructions.

The relief pilot or second officer, when at his or her duty station and not performing other duties, should monitor all ATC clearances and notify the pilots if there is any disagreement or misunderstanding of the clearance or readback.

Alternating Flight Legs

The captain and first officer usually fly alternate legs. However, after considering all factors, the captain may elect to alter the sequence. When making this determination, the captain should consider the following:

- Experience level and authorized minima of the first officer;
- Low time restrictions;
- Takeoff and landing recency, including relief pilot(s);
- Variety of departures and approaches during the rotation; and,
- Weather.

Automation Policy

General

Automation is provided to enhance safety, reduce pilot work load and improve operational capabilities. Automation should be used at the most appropriate level.

Pilots will maintain proficiency in the use of all levels of automation and the skills required to shift between levels of automation. The level used should permit both pilots to maintain a comfortable work load distribution and maintain situational awareness. The following guidelines apply to the use of automation:

- If any autoflight system is not operating as expected, disengage it;
- All pilots should be aware of all settings and changes to automation systems;
- Automation tasks should not interfere with outside vigilance;
- Briefings should include special automation duties and responsibilities; and,
- The PF must compare the performance of the autoflight systems with the flight path of the aircraft.

Area Navigation System Operations

The following applies to all area-navigation-system (flight management system [FMS], inertial navigation system [INS], etc.) operations:

- Whenever the aircraft is being flown in an FMS NAV (navigation) mode, at least one pilot will have the map displayed on the horizontal situation indicator/ navigation display (HSI/ND), if installed. If the distance is greater than 320 statute miles (515 kilometers), verify the active waypoint on the control display unit (CDU). For situational awareness during descent and approach, the map display, if installed, should have the active waypoint visible;
- All pilots shall maintain proficiency in programming and operating their aircraft's area navigation system;
- Avoid excessive heads-down time at low altitude for system operation. Raw-data very-high-frequency omnidirectional radio (VOR), instrument landing system (ILS), and automatic direction finder (ADF) displays should be used in the traditional manner when necessary;
- Both pilots should not simultaneously become involved with area-navigation-system tasks during high work load periods, such as departure and approach; and,
- For departures, arrivals, and approaches, supporting Jeppesen airway manual documents will be out of the flight kit, opened, and available. During the en route phase of flight, supporting Jeppesen documents should be readily available for use even though total autoflight/ FMS navigation may be in use. This practice promotes situational awareness, makes additional information readily available for route changes, and is a backup in the event of FMS failure.♦

Appendix B
Timeline and OTWG Members

Key events are shown in Table A-1.

In addition to the aforementioned activities, several members of the WG presented the status and progress of the project to various industry audiences during 1997 and 1998. The venues for these reports included Guangzhou and Hangzhou, China; Taipei, Taiwan; Cartagena, Colombia; Cromwell, Connecticut, U.S.; Dubai, United Arab Emirates; and Amsterdam, Netherlands.

Success Required Diverse and Dedicated Members

The WG's membership was seen as a critical matter that would heavily influence both the validity of the recommendations and their successful implementation. Because problems in approach-and-landing operations are widespread, leading to more than 50 percent of airplane accidents worldwide, a targeted effort was mounted to recruit members from as many world regions as possible and from all aviation-industry sectors. Major and regional air carriers, business aviation, airframe manufacturers, pilot unions, regulators, researchers and air traffic services participated. The diverse backgrounds and experience of group members added to the quality of the process and outcome.

A deliberate effort was made to include individuals who had been involved in CFIT WGs, to help avoid duplication of previous effort. Also, a number of OTWG members participated in the Data Acquisition and Analysis WG. (Ratan Khatwa and Dick McKinney were full-time members of three WGs.)

Table A-1
Timeline

Date	Event
March 26, 1996	FSF CFIT-ALAR Steering Committee appoints Pat Andrews and Capt. Erik Reed Mohn co-chairs of ALAR Operations and Training Working Group (OTWG). Charter for OTWG established.
May-June 1996	Working Group members recruited.
June 25-26, 1996	First OTWG meeting — Fairfax, Virginia, U.S.; original hypotheses established; OTWG process agreed; and work plan developed.
Aug. 28-29, 1996	Second OTWG meeting — Gatwick Airport, England; hypotheses refined through issues/opportunities discussion, posing of key questions; and subteams begin to look for data sources to assess validity of hypotheses.
Sept. 9, 1996	Report presented to steering committee by co-chairs on mission, scope, participants, process and goals.
Feb. 7-8, 1997	Third OTWG meeting — Cartagena, Colombia; continued to refine hypotheses; and identified critical issue of data deficiency
March 18, 1997	Progress report to steering committee included appeal for sponsorship of Data Acquisition and Analysis Working Group (WG) to provide needed resources to OTWG for further refinement of hypotheses.
April 1997	Data Acquisition and Analysis WG established by steering committee; chaired by Ratan Khatwa, Ph.D., and Robert Helmreich, Ph.D.
Sept. 10, 1997	Progress report to steering committee; noted early evidence that Data Acquisition and Analysis WG effort will be of significant help in advancing hypotheses to hard conclusions.
Nov. 3, 1997	Fourth OTWG meeting — Washington, D.C., U.S.; major progress on hypotheses from early work of Data Acquisition and Analysis WG; some OTWG members begin to participate on both teams; and set of emerging recommendations developed.
March 19, 1998	Steering committee outlines final report requirements for ALAR working groups due in late 1998.
April 8, 1998	Fifth OTWG meeting — Alexandria, Virginia, U.S.; hypotheses progressed to preliminary conclusions with support and participation of Data Acquisition and Analysis WG.
Aug. 10-11, 1998	Sixth and final OTWG meeting — Alexandria, Virginia; conclusions and recommendations finalized; and subteam established to write final report to steering committee.
Sept. 15-16, 1998	ALAR Final Report and Recommendations approved by steering committee, Alexandria, Virginia.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Working-group members were in three categories:

1. Core Team Members — involved full-time;
2. Participants — involved for at least 50 percent of the project; and,
3. Contributors — attended at least one session or provided tangible input to the process.

Some key information regarding participants follows:

Jim Anderson — Core Team
Director flight safety, Delta Air Lines

Previously involved in CFIT and Rejected Takeoff (RTO) Training WGs; Air Transport Association of America Safety and Training Committees; Air Traffic Procedures Advisory Committee; former program manager, Airbus A310 at Delta Air Lines; former system director-Flight Training at Pan American World Airways; and Airline Pilots Association, International (ALPA) central air safety chairman at National Airlines.

Capt. Pat Andrews — Core Team Co-chair
General manager, Global Aircraft Services, Mobil Corp.

Previously involved in FSF efforts including the FSF Fatigue Countermeasures Task Force for Business and Corporate Aviation; active in Free Flight Steering Team; FAA Research, Engineering and Development Advisory Committee; National Business Aviation Association Safety Committee; and more than 7,000 flight hours, type-rated in five business jets including the Gulfstream IV.

Capt. Dayo Awobokun — Contributor
Chief pilot, Mobil Producing, Nigeria

Capt. Jaime Bahamon — Contributor
Flight safety officer, Avianca

Don Bateman — Contributor
Engineer, AlliedSignal, CFIT-ALAR Steering Committee

Jim Bender — Contributor
Senior engineer, Airplane Safety Engineering,
Boeing Commercial Airplane Group

Previously lead training instructor/engineer, Boeing 737 Products. Currently responsible for Airplane Safety Engineering-Crew Interface. Member Boeing-sponsored Approach-and-landing WG. Member, Data Acquisition and Analysis WG.

Ben Berman — Contributor
U.S. National Transportation Safety Board (NTSB)

Phillippe Burcier — Core Team
Operational prevention and safety-assurance manager, Airbus Industrie

Participated in a CFIT WG. In charge of FCOM A320 Procedures 1989-96; three years as safety officer in the French Navy; and navy pilot from 1965-85.

Ron Coleman — Contributor; Member of Data WG
Air safety investigator, Transport Canada; and colonel, Canadian Air Force

Kevin Comstock — Participant
Engineering and Air Safety Department, ALPA

Suzanna Darcy — Core Team Member
Boeing 777 experimental test pilot

Test pilot/instructor/check airman on B-737, B-757, B-767, B-747-400 and B-777.

David Downey — Contributor
Assistant manager, Engine and Propeller Directorate, Air Certification Service, U.S. Federal Aviation Administration (FAA)

Team leader, FAA Safety Analysis Team, Commercial Aviation Safety Team (Industry- U.S. National Aeronautics and Space Administration [NASA]-FAA), CFIT Joint Safety Analysis Team member; and former FAA test pilot.

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Involved in Avianca's Accident Prevention Program, Emergency Action Plan and CFIT assessment and reduction program for Avianca and SAM Airlines; nine years in Colombian Air Force, two years as instructor pilot and four years in flight-safety activities; and completed accident/incident investigation courses while in the air force.

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Air traffic controller, senior expert, Air Traffic Management Development and Support, ATC, Netherlands

Former training manager; conductor Joint Crew/ATC Aircraft Emergency Training Plan; member of Human Factors WG, and Eurocontrol Aircraft Unusual Incident WG; tower manager, Schiphol Airport; and currently involved in development of capacity, safety and environmental aspects of air traffic management.

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CFIT-ALAR WG, ALPA

Holds a B.S. degree in aeronautics with a major in aircraft maintenance engineering from Parks College of Aeronautical Technology; served nine years with ALPA Safety Committee and seven years in accident investigation; participated in investigation of two major accidents; employed 20 years as line pilot; currently a US Airways captain on B-757/767; and prior to airline employment, flew charter and corporate operations, performed flight instruction, and served seven years with U.S. Air National Guard flying KC-135 and KC-97 aircraft.

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Previously involved in Air Transport Association Advanced Qualification Program (ATA/AQP) Line-oriented Simulation Training WG, and has special interest in crew resource management research and development.

Lance McDonald — Participant
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Capt. Dick McKinney — Core Team Member;
Member of Data Acquisition and Analysis WG, Aircraft Equipment WG and Air Traffic Control Training and Procedures/Airport Facilities WG
Captain (ret.), American Airlines; colonel (ret.), U.S. Air Force

Twenty-six years military experience (13 years active duty); flew as tactical fighter pilot in F-100, F-105, F-84 and F-4C for 4,130 hours, including 86 combat missions over North Vietnam; captain for American Airlines on numerous types from 1966 until retirement in 1997; check airman, FAA designee on McDonnell Douglas MD-80, Boeing B-757/767; various training roles and chair of Training Standards Committee; author of articles in numerous industry publications; and previously involved in other safety committees, including avionics-charting-database harmonization.

Capt. Erik Reed Mohn — Core Team Co-chair
Manager, Government Affairs, SAS Flight Academy

Former pilot in Royal Norwegian Air Force; has flown for SAS since 1978 and currently flies McDonnell Douglas MD-80; and previous positions with SAS Flight Academy include manager simulator operations standards, director standards and quality.

Henri Mudigdo — Contributor
Manager, Flight Safety, Garuda Airlines

Capt. Luis Garcia Perez — Core Team Member
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International Civil Aviation Organization (ICAO) AMC/Panel member; IFALPA Air Traffic Services (ATS) Committee member; Asociación International de Transporte Aéreo Latinamericano (AITAL) Safety Committee Chairman; Mexico Airlines Chamber Safety Committee Member; frequent speaker for ICAO communication and navigation surveillance/air traffic management (CNS/ATM) conferences; addressed pilot-controller communication errors in FAA Human Factors WG; and involved at Mexicana in human factors and training programs (integrated cabin and crew resource management), flight operations management and confidential reporting system.

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Capt. Keith Yim — Contributor; Member of Data Acquisition and Analysis WG
Chief pilot, Fokker 70; Operations Manager, KLM Cityhopper

Capt. Tom Young — Core Team Member
Chairman, Charting and Instrument Procedures Committee, ALPA

Former participant in CFIT WG; chair for Society of Automotive Engineers (SAE) G-10 Charting Subcommittee; ALPA Air Safety Committee (accident investigator); U.S. Air Force and U.S. Air Force Reserve pilot/instructor pilot 1968-82; and currently with US Airways.♦

Appendix C
ALAR Additional Reading Material

Blake, W.; Elliot, R. "The Last Two Minutes." *Boeing Airliner* (January–March 1991): 1–9.

This article deals with preventing landing-overrun accidents. It reviews some of the basic principles of airplane performance during landing roll-out and how approach, flare and touchdown influence the final stopping maneuver.

Boeing Commercial Airplane Division. "Landing Approach Factors: Lateral Offset Approach." *Boeing 727 Flight Crew Training Manual*. Seattle, Washington, U.S.: The Boeing Co., 1 October 1968. Pp 10-1.16–10-1.26.

This flight crew training excerpt recommends techniques for flying a lateral offset approach. It also highlights the problem of flying a correct glide path in relation to gear height over threshold and factors that may quickly reduce gear clearance to zero unless factors which vary during an approach are clearly understood. It also illustrates some common visual illusions.

Boeing Commercial Airplane Division. "Landing Approach and Flare: Approach Speed Control and Stopping under Adverse Conditions." *Boeing Airliner* (December 1965): 3–5, 7–12.

This article discusses various effects and elements present during an approach that affect landing distance and stopping capability. It details prudent techniques to alleviate difficult circumstances that may arise.

Boeing Commercial Airplane Division. "Night Visual Approaches." *Boeing Airliner* (March–April 1969): 2–4.

Night visual approaches, even at the best of times, require careful preparation. This article highlights the dangers and illusions that should be known and carefully considered by pilots when flying this kind of approach.

Boeing Commercial Airplane Group. "Landing Approach Factors: Landing Gear Clearance over Approach End of Runway." *Boeing 737 Flight Crew Training Manual*. Seattle, Washington, U.S.: The Boeing Co., 1 February 1982. Pp 05.30.01–05.30.09.

This training manual section provides a thorough overview of the factors and problems with landing-gear clearance over the approach end of a runway for the B-737. The principles are universally applicable, but unfortunately are poorly understood by many pilots. The excerpt also provides a good overview of wind corrections and approach-speed effects.

Boeing Commercial Airplane Group. "Landing Factor Considerations: Optical Illusion during Landing Approach." *Boeing 737 Flight Crew Training Manual*. Seattle, Washington, U.S.: The Boeing Co., 1 February 1982. Pp 05.60.01–05.60.02

This extract deals with optical illusions that may influence the way a pilot flies an approach with respect to glide-path angle and touchdown point.

Boeing Commercial Airplane Group. "Reverse Thrust and Crosswind, Rejected Landing, Overweight Landing, and Effect of Various Controls after Landing." *Boeing 737 Flight Crew Training Manual*. Seattle, Washington, U.S.: The Boeing Co., 28 February 1990. Pp. 2-71, 2-72, 2-75, 2-76.

This excerpt details problems and techniques for stopping during adverse conditions of crosswinds and slippery runways.

Douglas Aircraft Co. "Landing on a Wet Runway." *Twin Jet Flight Crew Newsletter* (May 1995): 1–12.

This document gives a comprehensive overview of information a pilot needs to know concerning aerodynamic, propulsive, inertial and external forces acting on an aircraft during landing. It goes into details about coefficients of friction and friction forces, reverse-thrust effects, hydroplaning phenomena and antiskid-system operation. This is a "must read" for anyone who wants a thorough understanding of what happens to an aircraft during landing roll.

Lorenz, F. "Visual Approaches." *Boeing Airliner* (April–June 1991): 13–19.

A surprising number of airplane accidents have occurred during visual approaches or during the visual segment following an instrument approach. This article gives some interesting case histories, details illusions present and recommends procedures and techniques for flying such approaches safely.

Schiff, Barry. "Black Hole Approach." *Boeing Airliner* (January–March 1994): 16–20.

> Numerous airports are located in areas that present the "black-hole" problem. This article highlights the problems and illusions facing a pilot attempting an approach to an airport with the black-hole problem and suggests techniques to alleviate the problem.

Smith, A.J.; Johnson, D. "The Precision Approach Path Indicator." Technical Report 76123. Farnborough, Hants, U.K.: Defence Evaluation Research Agency (DERA, formerly Royal Aircraft Establishment), December 1976.

> This document explains the differences between the visual approach-slope indicator (VASI) and the precision approach-path indicator (PAPI), and their design and use. The document should be required reading for any pilot who uses these visual aids, since the PAPI, especially, is a much-misunderstood precision visual aid.♦

Order ALAR Reading Material

A 120-page document, which includes photocopies of the material cited in Appendix C, can be ordered from the Foundation. The cost of the document is US$30.00 per copy (member and nonmember), including postage.

Contact:

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Appendix D
Samples of Observations Made by Working Group Members

“Most of the effort (to reduce ALAs) is taking place in the United States and Europe, while accident rates are highest in other regions. We need to involve international participants to achieve a win-win impact on worldwide safety.”

“We must become more focused on prevention and less reactive ... lead instead of react.”

“With scarce resources, we have to focus on the things that will make the most difference. Our conclusions don’t require large investment, but will result in big improvements if accepted and implemented worldwide.”

“To prevent the next accident, it’s important to give pilots the information they need in language they understand.”

“It’s time to stop the misunderstanding between ATC and crews that results in the request for ‘200 knots to the marker’ with weather at minimums. We need a higher recognition that ATC and crews are tied together in this process, but have a gap in their understanding of each other’s challenges. Misguided help is as much of an issue as other problems. A shared mental model for ATC and crews is desperately needed.”

“This is seen as the industry group for the word on approach-and-landing safety — it’s because we have taken the position that the data will prevail.”

“Workload management is critical — crews should ‘take time to make time.’”

“After five independent data studies, the consistency of problems is steady. With the new data, we are still seeing the same old problems.”

On the need for realistic SOPs: “How many ill-fated crews had 21 minutes of checklists to do with only 11 minutes left to live?”

“A company’s culture is defined by how people are rewarded — it’s critical that safety have the highest reward potential.”♦

Flight Safety Foundation
Approach-and-landing Accident Reduction Task Force

Aircraft Equipment Working Group

Final Report (Version 1.2)

Jean-Pierre Daniel
Airbus Industrie

Contents

1. Introduction

As part of Flight Safety Foundation's (FSF) initiative on approach-and-landing accident reduction (ALAR), the Aircraft Equipment Working Group (AEWG) was chartered to examine issues relating to aircraft equipment. It was established after the Controlled-flight-into-terrain (CFIT) Working Group reported its findings. The CFIT group, which worked within parameters broadly similar to those of the present group, provided significant input.

The primary aim of the AEWG was to analyze equipment-related factors that could have an impact on safety in the immediate and near future. This approach led to an overall emphasis on the question of how to make better use of existing equipment. Consequently, there was a degree of overlap with the work of the FSF ALAR Operations and Training Working Group. At the same time, potentially useful new technology is developing so quickly that the group could not afford to ignore it completely — for such situations it was considered appropriate to provide recommendations for further research or design work. In some cases, furthermore, it was relevant to consider safety and efficiency in the context of the integrated environment comprising the aircraft, air traffic control (ATC), equipment and operations. Consequently, ATC equipment and ground-based activities were considered for some specific issues.

In order to emphasize the importance of the relationship between crew and equipment, the issues were addressed using a conventional description of the crew-equipment functions necessary for flight (aviate, navigate, communicate, and manage aircraft systems). Initially, 47 issues were identified by the group as being relevant to the problem. They were documented as a set of data sheets. For each issue, the AEWG addressed three main questions:

- What is the current situation, and what are the areas of risk?
- What aircraft equipment, ground equipment or procedure is involved, and how can it contribute to safety?
- How significant is each area of risk, and how effective are the proposed solutions?

The data sheets were reviewed and refined to produce a final set of 17 significant issues for more detailed discussion. In practice, this was a relatively slow and careful process of refinement that was carried out over most of the lifetime of the group. In order to justify inclusion of the issues for consideration by the AEWG, it was agreed that evidence related to each issue should be documented, where available. Such evidence could include data provided by AEWG members, quantitative and qualitative inputs from the Data Acquisition and Analysis Working Group, and recent accident and incident data. The 17 issues are reported in detail in section 5 of this report.

The report also includes an executive summary (section 3) that includes a list of the significant issues, together with recommendations for both the near term and long term.

2. Aircraft Equipment Working Group

The persons listed in Appendix 1 participated at one or more AEWG meetings. Their varied affiliations facilitated open discussions on all of the operational and technical aspects of the safety of flight.

3. Executive Summary

The primary aim of the AEWG was to provide a set of practical recommendations for modifications to aircraft equipment which might improve safety during the approach-and-landing phase of commercial operations. To fulfill this aim required the group to identify current major areas of concern (the issues) and then to ensure that the recommendations were achievable technically and economically.

From an initial list of 47, the AEWG established a final list of 17 "very significant" equipment-related issues of risk. The significance of each issue was assessed using the group's operational experiences, input from the Data Acquisition and Analysis Working Group, and recent accident and incident data, where relevant.

Each issue is described in the following format (section 5):

- Issue title or subtitle;
- Problem statement — a brief overview of the problem related to the issue;
- Recommendations — the AEWG's recommendations;
- Action — ongoing activities that support the recommendations; and,
- References — supporting documents.

The equipment-related issues shown in Table 1 (page 96) were judged very significant in the context of approach-and-landing operations:

Due to the large variety of the issues considered, the technical status of the fleets operated, and the types and areas of operations, a large number of possible solutions was proposed, ranging from readily available equipment and procedures to futuristic technologies. They were classified according to whether or not they could be implemented immediately.

Table 1
Equipment-related Issues

Approach stability
Visual illusions
Maximizing climb angle
Barometric altimeters
Nonprecision approach procedures
Go-around decision
Aircraft position awareness versus terrain
ATC awareness of aircraft position
Use of global positioning system/global navigational satellite system (GPS/GNSS)
Navigation database accuracy
Terrain-and-obstacles data standards
ATC-aircraft communications
Runway incursion/taxi collision
Knowledge of traffic
Errors in checklist accomplishment
Flight-data availability
Autoflight vertical-mode complexity

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Key Recommendations — for immediate implementation

- **Require the use of instrument approach guidance (instrument landing systems [ILS], global positioning system [GPS]).**

  Comment: Primarily for difficult situations, but also for normal operations.

- **Implement enhanced ground-proximity warning system (EGPWS) and terrain display.**

  Comment: For early awareness and alert of terrain situation, long before a formal alert.

- **Provide a minimum safe altitude warning (MSAW) on radar (or equivalent).**

  Comment: For ATC to monitor the aircraft's actual path, and alert the flight crew.

- **Encourage the use of the radio altimeter (RA).**

  Comment: To monitor height above terrain and check against barometric altitude.

- **Provide electronic and mechanical checklists.**

  Comment: For ensuring compliance with procedures by requiring effective pilot action.

- **Install flight data recording equipment and establish a flight operational quality assurance (FOQA) plan.**

  Comment: For further improvements in the information available concerning each airline's operations.

Key Recommendations — for implementation in the longer term

- **Provide a vertical-navigation display.**

  Comment: To visualize the aircraft's actual path versus the flight plan and terrain.

- **Improve the terminology of charts and the flight management system (FMS) database.**

  Comment: For effective monitoring of flight-plan elements.

- **Provide data link for controller-pilot communications and air data system (ADS) reporting.**

  Comment: For clear, unambiguous communication between ATC and aircraft crew.

- **Improve airport surface detection equipment, position sensing and airfield maps onboard.**

  Comment: For airfield-obstacle avoidance and taxi guidance.

- **Provide local area augmentation system (LAAS) for GPS, and associated aircraft equipment.**

  Comment: For up to Category I to III precision landings with minimal ground equipment.

- **Provide synthetic vision systems, 3-D and 4-D displays, and video.**

  Comment: For visual flight rules (VFR)–like awareness, irrespective of the real flight condition.

4. General References

General references are shown in References 1–3 at then end of this report.

5. Issues

5.1 Approach Stability — Precision and Nonprecision

5.1.1. Problem Statement

Unstable approaches have been identified as a major factor in approach-and-landing accidents (ALAs). An approach can become unstable for any of the following reasons: late clearance to descend, late notification of the landing runway, late selection of landing configuration, pilot misjudged circumstances, rapidly changing weather, and poor prior planning by the crew. Unstable-approach consequences can be busted minimums; busted obstacle-clearance limits; CFIT; low and slow, short landings; high-and-hot, long landings; overruns; runway excursions; excessive maneuvering in pitch, power and roll when close to the earth; and loss of control.

5.1.2. Recommendations

1. Operators should implement and train crews for constant-angle nonprecision approaches as described in Procedures for Air Navigation Services — Operations (PANS-OPS), Volume I, Flight Procedures (Document 8168), Amendment 10;

2. Operators should furnish crews with charts depicting constant-angle profiles and recommended altitudes along the glide path for nonprecision approaches;

3. Operators should install EGPWS for better terrain awareness;

4. Operators should install RAs and activate "smart callouts" at 2,500 feet, 1,000 feet, 500 feet, at the altitude set in the decision height (DH) window, and 50 feet, 40 feet, 30 feet, 20 feet, and 10 feet for better crew terrain awareness;

5. Operators should install head-up displays (HUD) with angle-of-attack (AOA) and velocity vector depicted to provide crews with energy-state and projected-touchdown-point information;

6. Operators should install quick-access recorders (QARs) and implement FOQA programs to detect reasons for unstable approaches;

7. Those operators without electronic checklists should install mechanical checklists with tabs to be toggled after the item is checked to ensure proper takeoff and landing configuration;

8. MSAW should be installed and enabled on all approach-control radar systems; and,

9. The International Civil Aviation Organization (ICAO) and FAA should encourage airport authorities to provide precision approach guidance such as ILS, transponder landing system (TLS), visual approach slope indicator (VASI), precision approach path indicator (PAPI) and CAT I GPS approach systems.

5.1.3. Actions

A major aviation insurer showed how aviation safety is a bottom-line asset to forward-looking airlines willing to invest in safety equipment and training. Insurance companies, ICAO, FAA and civil aviation authorities (CAAs) need to spread this message to encourage operators to make these kinds of investments voluntarily.

Carriers using constant-angle-approach procedures report greater nonprecision-approach success due to stable approach conditions. The Air Transport Association has approved constant-angle-approach procedures after a study by VOLPE, the FAA Human Factors Group. ICAO has defined charting and operations guidance for using constant-angle approaches.

Jeppesen and other chart editors can now provide constant-angle profiles on nonprecision charts.

ICAO, FAA and other CAAs have mandated that ground-proximity warning system (GPWS) be installed because of demonstrated safety benefits.

Some airlines, such as Alaska Airlines, are fitting HUDs to give crews valuable information regarding energy state and projected touchdown point.

Operators using FOQA have discovered economic as well as safety benefits by spotting trends leading to rushed approaches, unstable approaches and missed approaches.

Operators with electronic or mechanical checklists are experiencing fewer accidents caused by improper aircraft configuration.

5.1.4. References

References for this subsection are listed as References 4–7 (data support) and 8–12 (reports) at the end of this report.

5.2 Environmental Visual Illusions on Approach

5.2.1. Problem Statement

A visual illusion can be described as perceiving the environment in a distorted way. The analysis of accidents in the approach-and-landing phase revealed illusions were causal in some instances and contributing factors in many others. Since they are difficult to predict and have different effects on different individuals, visual illusions need to be mitigated using a broad and multifaceted approach.

5.2.2. Recommendations

1. Operators should promote the use of precision approaches to DH in low-light conditions or low-visibility conditions where facilities exist;
2. Operators should promote the use of nonprecision approaches in low-light conditions or low-visibility conditions until adequate visual reference is available or visual aids indicate that a safe approach and landing can be accomplished;
3. Visual approaches in low-light conditions or low-visibility conditions should be discouraged when more precise procedures are available;
4. ICAO and regulators should promote the installation of visual aids at airports with a history of incidents where visual illusions were causal or contributory;
5. Airport authorities should consider the addition of precision approaches for runways that do not have adequate visual references in low-visibility conditions or low-light conditions;
6. Airport authorities should provide visual-approach aids such as VASI, PAPI and approach lighting on runways where illusions are present during low-visibility conditions or low-light conditions;
7. Companies should install and promote the use of EGPWS;
8. Companies should install and promote the use of radio altimeters;
9. Companies should install and promote the use of HUDs, AOA displays and synthetic-vision systems;
10. ICAO, regulators and companies conducting commercial operations should promote the use of flight-data monitoring to determine where visual-illusion-problem approaches and airports exist; and,
11. Regulators should ensure that approach charts display warnings on approaches where visual illusions have been documented or determined through flight-data analysis.

5.2.3 Actions

In addition to the traditional methods of combating visual illusions and approach-and-landing difficulties in low-light conditions and low-visibility conditions, a coordinated effort on behalf of the industry to implement technical solutions is necessary. The technology is available for the aircraft and the airport to reduce the problem; research is required to bring these solutions to all commercial carriers and all airports where the need exists. Tools are available, but finding the right mix is problematic.

To date much of the activity in combating visual illusions on approach has been in the area of education and training. This is also the case where low-visibility conditions exist. One of the most difficult decision points for flight crews is when a landing must be attempted or a go-round must be initiated. It is virtually impossible to prescribe precisely what visual references must be available to conduct a safe approach and landing under these conditions.

Since this is the case, efforts to mitigate or eliminate incidents or accidents as result of visual illusions or low-visibility conditions should be the subject of technical solutions. Aids provided to flight crews along with education and training will provide adequate defenses if used together and at all times. The most promising solutions are based on instrument approaches such as those proposed by Airbus and Boeing.

5.2.4 References

The reference for this section is listed as Reference 13 at the end of this report.

5.3 Nonprecision-approach Procedures

5.3.1 Problem Statement

Accident profiles show that during nonprecision-approach procedures (vertical path is not defined), pilots descend to an incorrect altitude or descend at an incorrect point along the approach path, reducing terrain/obstacle clearance. Stepped vertical paths, most commonly associated with nonprecision approaches, are typically flown by descending to the next-lower altitude as soon as a particular fix is passed. Many approaches have stepped paths both before and after the final approach fix. The complexity of nonprecision-approach procedures can increase pilot workloads and diminish terrain awareness. Frequently, descent rates far in excess of those necessary are used. Although precision approaches (glide-path guidance) are much more prevalent, nonprecision approaches are still commonly used in certain areas of the world and in certain flight operations. The worldwide accident rate for nonprecision approaches is five times the rate of that for precision approaches (reference 14). Three other reference reports (references 15, 16, 17) also identified similar problems with nonprecision approaches.

5.3.2 Recommendations

1. The use of approaches that lack vertical-path guidance should be minimized and eventually eliminated;

2. Aviation authorities should accelerate the implementation of approach procedures that allow the use of both lateral navigation (LNAV) and vertical navigation (VNAV) in current systems, to provide a reliable, predictable and repeatable lateral path along with the improved vertical operations resulting from a stabilized descent path. The application of FAA Notices 8260.40 and 8260.47 should be the basis for the required procedure development;

3. Aviation authorities and industry should coordinate the consistency of guidance for LNAV and VNAV procedure design and operations criteria in developing international standards;

4. The industry should accelerate the development of standards for the LNAV and VNAV functions of flight management computers (FMC), that further advance the performance and assurance necessary for the increasing incidence and reliance on procedures and operations utilizing these functional capabilities. One of the main benefits will be the availability of vertical-approach-path guidance in a variety of navigational-aids environments ranging from very high frequency (VHF) omnidirectional radio range/distance measuring equipment (VOR/DME) to GPS;

5. If nonprecision approaches must be flown, an RA with voice altitude callouts and the new EGPWS should be installed for improved terrain awareness;

6. If nonprecision approaches are to be flown using LNAV and VNAV, flight procedures, avionics-systems operations, and systems functional integration should be advanced to provide the flight crew with more consistency in the conduct of area navigation (RNAV) procedures;

7. The industry should consider development of constant-angle approaches and associated procedures for nonglass and non-LNAV/VNAV-equipped aircraft;

8. The industry should accelerate the development of FOQA programs using QAR data. This should include a process of sharing information among airlines for better industry awareness. This type of program helps the airlines monitor airports and approaches for unsafe trends and make necessary corrections to prevent future accidents; and,

9. The industry should pursue the development of synthetic-vision systems to determine their potential for providing precision-approach-path guidance overlaid on either an enhanced image or completely synthetic reproduction of the external environment.

5.3.3 Actions

The progress in regulatory, standards and industry organizations has recognized the need for the rapid development and implementation of standards, procedures and operational criteria for LNAV and VNAV. Lack of standardization is impeding the effective utilization of RNAV procedures.

The following is a snapshot of some organizations and activities.

U.S. Airlines. Both Delta Air Lines and Northwest Airlines have developed procedures, and are currently training and flying approved VNAV approaches at selected sites in the U.S.

Radio Technical Commission for Aeronautics (RTCA). RTCA Special Committee (SC) 159 has completed the development of standards for GPS/wide-area augmentation-system (WAAS)-based navigators. The intent is to broaden the participation of a significant portion of the domestic aircraft population by advancing beneficial operations predicated on RNAV for lateral operations. The vertical operations have focused primarily on the approach-and-landing phases of flight operations that are viewed as not applicable for FMS-based VNAV. The regulatory priority given to these systems and their operations, along with the differences between these airborne systems and those under the standards for RTCA SC 181, Navigation Standard, has the potential to negatively affect the advancement of LNAV and VNAV operations for air-transport-category systems.

RTCA SC 181 has completed the development of a standard for LNAV for required-navigation-performance (RNP) operations. The associated VNAV and receiver-transmitter-antenna (RTA) requirements are expected to be complete during the first quarter of 1999. The LNAV, VNAV and RTA standards specify changes necessary for performance and operational integrity. The emphasis is reliability, predictability, repeatability and accuracy in design and operation. Much of the work program is influenced by other activities including the Air Transport Association (ATA)/ FAA FMS Task Force and the Eurocontrol Navigation Subgroup. RTCA SC 181 is also developing the industry requirements for navigation data, to provide guidance and standards for the development of LNAV and VNAV procedures.

ICAO. The All Weather Operations Panel (AWOP) completed its *Manual for RNP for Approach, Landing and Departure Operations*. The guidance in the manual has been recognized by others including RTCA SC 181 and the ICAO GNSS Panel in their products. The basic activities of AWOP have been concluded. Follow-on actions are being taken in the GNSS Panel and Obstacle Clearance Panel.

The GNSS Panel is developing standards and recommended practices for GNSS. Additionally, its operations requirements are expected to be reflected in standards and recommended practices (SARPS), PANS-OPS and AIS materials.

The Obstacle Clearance Panel has developed and published PANS-OPS for RNAV. The VNAV guidance-and-procedures criteria are currently in progress, with industry participation.

Eurocontrol. The development of standards for LNAV and VNAV falls under the Navigation Separation Subgroup. The current RNAV standard reflects only LNAV for current systems and those envisaged for RNP operations. The VNAV and Time Control requirements are expected to follow the developments of RTCA SC 181.

Eurocontrol, with the Joint Aviation Authorities (JAA), is developing regulatory guidance material for RNAV in Terminal Area Operations. This is expected to be complete in early 1999. Additionally, coordination is taking place with RTCA and ICAO on navigation-data standards and procedure standards.

5.3.4 References

References for this section are shown as References 14–17 at the end of this report.

5.4 Go-around Decision

5.4.1 Problem Statement

The timely, safe execution of a go-around requires careful coordination by the flight crew. First, the flight crew must recognize the need to go around. In many cases, the flight crew may not have enough information to recognize the need to execute a go-around. If the flight crew knows it is not on the proper approach path or that its terrain clearance is inadequate, it is more capable of making the decision to go around.

Go-around decisions during nonprecision approaches (i.e., no glide-path information) can be more difficult because there is less readily decipherable information to help the flight crew determine whether or not it is on the proper approach path. In low-visibility conditions, the list of acceptable visual cues is long, and some interpretation may be required by the pilot. However, low visibility is not the only reason to go around. The runway must be available for use (unoccupied), and the airplane must be suitably positioned, at the correct speed, in the correct configuration and, in automated aircraft, in the correct mode. In addition to the operational complexity, there is a stigma associated with a go-around. It will be necessary to overcome this stigma before pilots will be as comfortable with a go-around as they currently are with landing. Recent studies (reference 18 and reference 19 below) show that the decision not to go around was a causal factor in over half of the ALAs studied.

5.4.2 Recommendations

1. An RA with voice altitude callouts and the new EGPWS should be installed to provide improved terrain-clearance information;

2. The use of approaches without vertical-path guidance should be minimized and eventually eliminated. Precision approaches provide the flight crew with glide-path deviation information as a measure to determine when a go-around is necessary;

3. Improvements should be made to airport approach-lighting systems, including installation of PAPI or VASI systems. These systems can assist the pilot in determining whether the airplane is in a suitable position to land, particularly in low-visibility conditions;

4. Industry should accelerate the development of FOQA programs using QAR data. This should include a process of sharing information among airlines for better industry awareness. This type of program helps the airlines monitor airports and approaches for unsafe trends and make the necessary corrections to prevent future accidents; and,

5. Industry should pursue evaluations of vertical profile/ situation displays to determine their potential benefit in identifying terrain clearance or path deviation to assist in the go-around decision.

5.4.3 Actions

Several actions were proposed on this topic by the Controlled-flight-into-terrain Working Group.

5.4.4 References

References for this section are shown as References 18 and 19 at the end of this report.

5.5 Aircraft-ATC Communications

5.5.1 Problem Statement

Many factors can affect the quality of aircraft-ATC communication, while this is a key element for a safe, stabilized approach and landing. These factors include:

1. Congestion of radio frequency leading to difficulties in having in-time dialogue;

2. Nonstandard phraseology jeopardizing correct understanding, particularly for people whose native language is not English; and,

3. Poor transmit-receive audio quality due to ATC hardware, aircraft hardware or atmospherics.

Data do not demonstrate this problem to be a significant risk; however, it is a shared opinion of pilots that communications is a prime field for future safety improvements.

5.5.2 Recommendations

1. The use of data-link communication should be encouraged for the exchange of less-tactical information. This would reduce congestion on ATC frequencies;

2. Equipment to warn of or eliminate a stuck-microphone condition should be installed on aircraft radio equipment;

3. The design quality and installation of the audio channels should be considered. In the cabin environment, for public address, the quality is verified by using a RASTI (rapid speech transmission index) or AI (articulation index) and certified procedures. This or similar equipment could be used on the ground and on aircraft to assure the intelligibility of messages; and,

4. The content of the communication should make strict use of standard phraseology. Operators should be recurrently trained in this phraseology, and its use should be assured by proper procedures.

5.5.3 Actions

There are current developments of data-link capabilities (for example, future air-navigation system [FANS] and free-flight studies). ATC aspects are also covered through aircraft communications (CPDLC [controller-pilot data-link communications]) and automatic dependent surveillance (ADS).

5.5.4 References

References for this section are shown as References 20 and 21 at the end of this report.

5.6 ATC Awareness of Aircraft Position

5.6.1 Problem Statement

Despite the use of the traffic-alert collision-avoidance system (TCAS), procedural separation and surveillance radar, midair collisions and near-midair collisions continue to occur.

A number of regions are subject to numerous pilot reports criticizing the quality of ATC and lack of ground-based navigation and communication facilities. The International Federation of Airline Pilots Associations (IFALPA) and the International Air Transport Association (IATA) have acknowledged the extent of the problem in a list of airfields that are considered to be critically deficient.

Favorable political or economic changes have resulted in a sudden and marked increase in air traffic to regions where the current ATS infrastructure has failed to gain a commensurate increase in funding/investment for upkeep and improvement. This deterioration has manifested itself in an increasing incidence of air proximity (AIRPROX) events and procedural incidents.

Controllers' knowledge and awareness of air traffic are often limited by a lack of basic equipment, and often depend on pilot reports. Areas that have been suddenly subjected to a high movement rate without provision of extra facilities run a significantly higher risk of CFIT accidents or collisions. The increase in pilot reports in affected regions is indicative of this heightened risk.

5.6.2 Recommendations

1. Secondary surveillance radar (SSR) and transponders should become part of a basic specification. The benefits of SSR-equipped and transponder-equipped aircraft are well understood, as their wide use in most of the world's regions indicates. However, many international airfields have still failed to harness the benefits of this well-established technology, which has become the norm elsewhere; and,

2. Terrain awareness and avoidance should be enhanced by including the controller in the terrain monitoring-and-warning process. This capability can be brought about by the implementation of MSAW.

5.6.3 Actions

ATC authorities and research establishments worldwide are working to define the future air traffic management system. This is a long process because of the huge expenses involved and the complexity of the organization. The effort should be continued and should actively involve industry.

ICAO has questioned all countries on their use of MSAW. The answers are encouraging, but more effort is needed to obtain effective use of this capability.

5.6.4 References

References for this section are shown as References 22–24 at the end of this report.

5.7 Runway Incursions and Taxi Collisions

5.7.1 Problem Statement

Lack of awareness of traffic on the landing runway by ATC or a flight crew may result in a conflict upon landing. ATC and crew inability to determine exact aircraft position on the ground during instrument meteorological conditions (IMC) or darkness may cause conflict between aircraft-to-aircraft and aircraft-to-ground-vehicle traffic. The FAA recently reported that the number of runway incursions almost doubled from 1992 to 1996. This problem is forecast to become worse with projected increases in air traffic. Night and IMC ground-position information requires radio reports, because one set of navigation lights looks like any other. Radio-frequency saturation causes cross-talk, squeals and call-sign clipping, which lead to misunderstood reports and instructions.

5.7.2 Recommendations

1. FAA should complete the tests scheduled a few years ago to determine the effectiveness of VHF radio

antiblocking devices for all radios used in air traffic operations. FAA has tested airborne radios fitted with CONTRAN, a VHF antiblocking device, and found that it improved communication by stopping cross-talk, squeals and call-sign clipping. Ground radios were not tested;

2. Antiblocking devices are not totally effective unless utilized by all ATC communications radios. Testing should be continued to determine if this technology could solve a major communication problem;

3. Airport surface detection equipment (ASDE) is used at many airports. It is proven technology and available now. ASDE should be fitted at all major airports to aid controllers to track all surface movement during night and IMC;

4. ICAO should require fitting of automatic dependent surveillance-broadcast (ADS-B) equipment on all commercial aircraft when performance standards for the system can be met. This will allow more efficient use of airspace through better position awareness in flight and on the ground for ATC and air crews;

5. Three-dimensional and four-dimensional (3-D and 4-D) primary-flight-display technology should be given priority for development. This system has the promise of providing the crew with a day, VFR-like, synthetic vision display. Air and ground traffic can be shown from ADS-B inputs;

6. RTCA and the European Organization for Civil Aviation Electronics (Eurocae) should set standards for terrain-database integrity and accuracy, and navigation-database accuracy. This will result in improved position sensing and reporting. RTCA and Eurocae have recently agreed on terrain-database and navigation-database standards. Using these standards with World Geodetic Survey 84 (WGS84) survey data will insure proper mapping and position sensing. Proper mapping and position sensing will be required for development of ADS-B, 3-D and 4-D technology;

7. Close coordination is required between ICAO, FAA and other CAAs to define standards suitable for worldwide implementation of communication, navigation, surveillance/air traffic management (CNS/ATM);

8. The U.S. military authorities should disable GPS selective availability (SA) to allow all segments of industry to benefit from the improved accuracy; and,

9. ICAO should encourage all states to release terrain data within 15 nautical miles of commercial airports down to three-meter accuracy for proper mapping and position sensing.

5.7.3 Actions

The ICAO CNS/ATM Implementation Conference (April 1998) in Rio de Janeiro received reports of improved methods for determining position by utilizing the GNSS and the LAAS. Launching these systems in the 2003–2005 time frame is forecast. CNS/ATM development with ADS-B is seen as a replacement for airport surface-surveillance radar at major international airports.

3-D and 4-D primary flight displays are being developed by several companies because they have the promise of changing night IMC into day VFR. Displays being developed range from one that can be projected directly onto the pilot's retina by eye-safe laser, to holographic display on the windows and light-emitting-diode (LED) displays on the instrument panel. Short-range displays show airport field diagrams and a moving map position as the aircraft taxis. This will cut down on inadvertent runway incursions due to disorientation. This technology requires the accurate position sensing and terrain mapping promised by the systems mentioned above.

5.8 Autoflight Vertical-mode Complexity

5.8.1 Problem Statement

Flight crews have difficulty in interpreting FMS vertical-guidance modes and vertical path due to poor or complex presentation of parameters used by the FMS to construct the approach path. Some parameters used to define the vertical path are hidden and make it difficult for flight crews to verify and predict the vertical profile with the required degree of certainty. Comparison of the FMS approaches against instrument-approach charts is further complicated by the use of inconsistent terminology to define approach fixes.

FMS approaches require slow and deliberate programming, particularly where approaches are constructed by crews. The path requires careful verification to ensure that it fulfills the altitude requirements of the instrument approach, stabilized-approach criteria and speed schedule. For terminal-area applications, this process is cumbersome and time consuming, and leads to late implementation or noncompliance with ATC instructions.

In addition to FMS issues, there are several matters of autoflight control to consider. For example, the flight crew's limited understanding of the autoflight modes, in addition to the lack of specific autoflight-mode feedback to the crew, leads to unintended flight-path deviations, which causes terrain encounters and unusual-attitude situations. This limited understanding can be the result of an excessive number of modes, a number of which interact with the autoflight system in a complex manner, making their behavior somewhat less predictable.

Unintended flight-path deviations and terrain encounters are sometimes caused by the incorrect interpretation of autoflight modes that result in untimely or incorrect intervention by the flight crew.

Autoflight modes are often difficult to decipher in complex and sophisticated aircraft. The number of different modes and the complex protocol that dictates their manner of operation often cause the flight crew to "fall out of the loop." Autoflight-mode feedback systems that provide inadequate and insufficient information further exacerbate this problem. A flight crew's ability to predict the autoflight system's intentions and behavior is often impaired by the lack of adequate and conventional visual and tactile cues.

The terminology used to describe autoflight modes does not readily describe the functions, and makes it difficult for flight crews to interface effectively with the autoflight systems.

The result is that there is general concern about a crew's ability to predict and manage advanced autoflight systems effectively during approach phases. This can result in the undesirable scenario of the crew being led by the aircraft systems along an unintended approach path.

5.8.2 Recommendations

1. To manage the autoflight systems, crews need to be able to predict, interface with and interact with the autoflight system in a certain and timely manner;

2. Terminology used to define approach fixes on approach charts and the FMS should be consistent;

3. A pictorial presentation of the planned FMS vertical profiles should be available on the map display to allow crews to preview and compare the planned vertical path to the required instrument-approach and stabilized-approach criteria;

4. A real-time display showing the vertical situation against the planned instrument path should be available to enhance the crew's spatial awareness;

5. Development and implementation of 3-D and 4-D displays should continue, to make detection of flight-path deviations and trajectories towards terrain more timely;

6. FMS databases should be given greater transparency to enable crews to predict vertical-path profiles and anticipate the behavior of the autoflight system;

7. FMS databases should be developed so that they are quick and easy to implement by crews in high-workload situations. Database approaches should contain all the necessary parameters to conduct a safe, stabilized approach and therefore should hence be modifiable; and,

8. Work in the human factors area of the man-machine interface (MMI) should continue in order to develop greater understanding of the dynamics involved between pilots and autoflight systems. Specific recommendations should be produced to influence the design of autoflight systems and certification criteria in order to take account of such human factors issues.

5.8.3 Actions

Generate action through Navigation and Terrain Awareness Harmonization Committee on FMS Standardization.

5.9 Navigation-database Accuracy

5.9.1 Problem Statement

Navigation and terrain awareness are increasingly based on databases rather than solely on charts. Although editorial changes to charts could improve understanding, the equipment using a database requires strict formatting and accurate content.

There is an issue of the conformity of navigation databases embedded within the FMS with aeronautical-information publications from state agencies. There is also an issue of the consistency between the navigation database and charts.

5.9.2 Recommendations

1. The state agencies should provide aeronautical information referenced to a common coordinate system, specifically WGS84 along with ICAO recommendations;

2. The database providers should ensure conformity of data in the database with aeronautical information through an adequate process-quality assurance organization, as defined by RTCA DO-200A/Eurocae ED-76; and,

3. The charts editors, database providers and FMS manufacturers should ensure consistency of naming of similar data in their products, to relieve the user of need of interpretation.

5.9.3 Actions

There has been significant progress in database integrity. RTCA SC 181/Eurocae WG-13 Working Group 3 has completed its document, RTCA DO-200A/Eurocae ED-76, "Requirements for the Aeronautical Information Data Processes." This document will be approved by the RTCA Program Management Committee and will then be published.

This new document reflects the efforts of many industry leaders to create guidelines for the processes used to ensure that the data content retains its integrity from its creation all the way to the installation on board an airplane. In the new document, there are references to DO-201A/ED-77, which states the accuracy, resolution and integrity requirements for virtually all the aeronautical information included in data used for both ground databases and airborne databases.

When the final document is published, it will be used by FAA to create a technical standard order (TSO) that will provide the certification of the processes used by database suppliers. Jeppesen and other database providers plan to have an FAA certification of navigation-data production processes.

In addition to the processing-integrity requirements discussed above, the RTCA DO-201A/Eurocae ED-77 document, "Industry Requirements for Aeronautical Information," will be completed by January 1999. This document includes the requirements that industry has identified to government authorities to help them understand the requirements for databases in FMS and GPS receivers. There has been significant participation by ICAO, and assurance has been given that the RTCA/Eurocae document will be referenced by the appropriate ICAO annexes and other documents. This will enhance the data content in airborne databases.

5.9.4 References

The reference for this section is shown as Reference 25 at the end of this report.

5.10 Limited Knowledge of Traffic

5.10.1 Problem Statement

In controlled airspace the responsibility of traffic separation rests with ATC. However, it is both more comfortable and safer for the aircraft pilots to have an autonomous perception of surrounding traffic. This has been partly acquired by listening on the radio channel in use and recognizing possible conflicts — the so-called party line. More recently, pilots have considered the TCAS as very useful, in visual meteorological conditions (VMC) and non-VMC, for visualizing the traffic environment in addition to its original alerting role. Midair collisions continue to occur when aircraft are not equipped with transponder or TCAS.

5.10.2 Recommendations

1. All aircraft should be equipped with transponders, in order to be "visible" by TCAS in addition to ATC, to establish better-than-VMC knowledge of traffic;

2. All aircraft should be equipped with TCAS or the airborne-collision-avoidance system (ACAS), to get on-board knowledge of surrounding traffic and assure safe separation;

3. Further development of TCAS/ACAS equipment should be pursued to make all traffic "visible"; and,

4. Further developments should be made to provide display of traffic to pilots in 2-D, 3-D or 4-D.

5.10.3 Actions

ICAO has been promoting the TCAS/ACAS concept, and more regions in the world have enforced its use in their air traffic regulations. Even military aircraft might adopt it when in nonclassified flight.

Many studies are being conducted to improve the effectiveness of TCAS II, and to evaluate other promising technologies including ADS-B.

Several applications of cockpit display of traffic information (CDTI) are being developed, monitored by the RTCA SC 186 working group.

5.11 Errors in Checklist Accomplishment

5.11.1 Problem Statement

At times, flight crews are not fully aware when the aircraft is not properly configured (e.g., gear, flaps, speed brakes) for landing. This may lead to improper speed and attitude on approach, and may contribute to an unstable approach, long landing, gear-up landing or tailstrike. Before accomplishing the landing checklist, the flight crew configures the aircraft during the approach procedure. In a high-workload environment, the procedure and checklist may or may not be accomplished at the appropriate time. In addition, the reply to the reading of the checklist may be a rote response rather than the actual visual confirmation of the status of the checklist item. In a 1996 Boeing safety review (reference 26) of ALAs, 12 percent of the accident aircraft were not in the proper landing configuration. The FSF report (reference 27) also recognized the problem of poor checklist accomplishment.

5.11.2 Recommendations

1. Mechanical or electronic checklists should be installed to assist the flight crew in properly accomplishing the landing checklist. The requirement to physically select each item on a mechanical or electronic checklist may help to ensure that the checklist is actually accomplished. However, this does not necessarily correct the problem of a rote response instead of a visual confirmation of a checklist item; and,

2. The industry should accelerate the development of FOQA programs using QAR data. This should include a process of sharing information among airlines for better industry awareness. This type of program helps the airlines monitor airports and approaches for unsafe trends and make the necessary corrections to prevent accidents.

5.11.3 Actions

An advanced checklist with system feedback can indicate which checklist items have actually been accomplished. The visual feedback of the "accomplished" indication on the checklist then provides a second check on the status of each checklist item and will help to ensure the proper completion of all checklist items.

5.11.4 References

References for this section are shown as References 26 and 27 at the end of this report.

5.12 Standardization of Terrain and Obstacle Databases

5.12.1 Problem Statement

New equipment is now designed to provide situational awareness and warnings against terrain encounter that use terrain and obstacle databases. These databases need to cover all areas of potential airplane traffic in order provide homogeneous safety coverage. Sufficient precision and quality of data are necessary.

The correct use of a terrain database requires precise position knowledge, both horizontal (LNAV) and vertical (height above ground).

5.12.2 Recommendations

1. Standards of terrain data should be defined as adequate for use in terrain safety equipment;
2. Terrain data should be provided, or at least validated, by state agencies for assurance of conformity with actual terrain and other obstacles to airplanes;
3. Databases should be elaborated, updated and deployed into safety equipment;
4. Terrain and obstacles database should be elaborated along a process ensuring adequate quality; and,
5. Implementation of terrain database in equipment for improving safety should be associated with adequately precise navigation information, that is, with RNP and vertical position.

5.12.3 Actions

In addition to the traditional aeronautical data, the DO-200A/ED-76 document was modified to reflect the requirements of terrain databases. There has been considerable work to define the terrain-database requirements in a new joint RTCA-Eurocae Terrain and Airport-mapping Database Committee.

An output of this committee has been included in the new DO-200A/ED-76 document, so that it now contains the processing requirements that are applicable for terrain databases.

5.13 Aircraft Position Awareness with Respect to Terrain

5.13.1 Problem Statement

Pilot awareness of aircraft position in approach and landing meets two objectives: to allow the right trajectory down to landing with adequate timing, and to assure safe separation of the flight path relative to terrain.

Navigation aids and guidance associated with autopilot or flight director, explicitly presented on navigation and flight displays, have increased a pilot's efficiency in managing an aircraft's trajectory. However, these are only indirect cues to position relative to terrain, but independent situational information is needed at a level equivalent to that achieved in VFR operations.

Significant "visible" features should include, from the beginning of approach (final approach fix [FAF]) to landing, key points and altitudes, including terrain and runway identification, depending on local approach characteristics. The awareness of the pilot should also begin very early, with a global "view" of the situation, and should deepen with more accurate, independent and unambiguous information when getting closer to the ground.

Although the RA has been in service for many years and is at the heart of newer systems such as GPWS and Category II/III approaches, it has not been fully integrated into the cross-check procedures and often lacks an audio or visual alert. This instrument has the potential to be a defense against ground contact or impact if used properly. Unfortunately little attention has been given to the criticality of the proper use of this instrument. In some older-generation aircraft, which are often flown by a single pilot, it is the only instrument that can give an exact reading of terrain clearance below 2,500 feet.

5.13.2 Recommendations

1. Display of terrain via EGPWS or ground collision avoidance system (GCAS), for example, can provide a VFR-like early awareness of terrain proximity. It must be associated with precision electronic position in space;
2. Vertical situation display based on independent data, terrain database, RA, GNSS or other should be developed and integrated into aircraft, and SOPs should be defined for improved ground awareness on approach in nonvisual conditions;
3. Warning of terrain encounter in the GPWS establishes a last-moment safety net that must be obeyed without

hesitation. False alarms should be reported for system improvement;

4. Visual aids such as VASI/PAPI and airport lighting provide unambiguous cues close to the airfield when conditions allow;

5. Approach charts should indicate DMEs with recommended altitudes along the approach path; and,

6. An RA is a stand-alone instrument indicating height above terrain with good precision, and without dependence on the barometric reference. With appropriate training, pilots could use the RA as a safety sensor to warn of closeness to terrain associated with adequate operations procedures. ICAO and regulators should establish and publish standards for the installation and use of RAs during approach and landing.

5.13.3 Actions

EGPWSs are being developed and certified on aircraft. Many operators have already decided to equip their fleets, notwithstanding the absence of regulatory obligation, for the sake of pilot comfort in low-visibility conditions and for safety.

Some chart editors have introduced contours, milestones and cues. It is hoped that the industry will make further improvements.

The proliferation and integration of RAs in aircraft-equipment avionics suites and operational procedures will reduce the risk of ALAs by warning the crew of actual terrain clearance while there is still sufficient time to react in a careful and cautious way. To maximize the potential for risk mitigation, operators, pilot associations, ICAO and regulators should take every opportunity to encourage and legislate the use of this instrument.

5.13.4 References

Reference for this section are shown as References 28 and 29 at the end of this report.

5.14 Maximizing Climb Angle

5.14.1 Problem Statement

Except when operating aircraft with automated flight-envelope protection, flight crews do not have sufficient information to maximize aircraft wing performance during critical flight maneuvers such as microburst encounters, wind-shear encounters, GPWS warnings, unusual-attitude recoveries and inoperative engines.

An example is the procedure taught for wind-shear encounter and microburst encounter. “Rotate toward a target pitch attitude of 15 degrees. Stop rotation if stick shaker or buffet is encountered. Always respect stick shaker and use intermittent stick shaker as the upper limit for pitch attitude.” Using the stick shaker to define the upper limit of pitch attitude (best climb performance) is very ineffective, because the pilot doesn’t know how close to stall the aircraft really is. Most recoveries using this technique have a saw-tooth profile below the ideal profile because of excess pitch maneuvers. More effective information would be the real flight envelope. A leading cause of fatalities in multi-engine aircraft with engine failure has been stall/spin, usually during turn from base to final with slightly higher G loads. Improper aircraft configuration has contributed to several accidents. Improper aircraft-gross-weight calculation has also caused reference-speed errors. AOA displays will indicate the maximum performance limits of the wing regardless of configuration, weight or G load.

5.14.2 Recommendations

1. Operators should fit their aircraft with a primary flight-display AOA display, visible to both pilots. The display should be analog and normalized for flaps. The system should be isolated from aircraft ADS to prevent corruption of AOA data;

2. Operators should train their crews on capabilities and limitations of AOA systems; and,

3. For so-called fly-by-wire aircraft, flight-control systems can be designed to incorporate automated flight-envelope protections, eliminating the need for an AOA display.

5.14.3 Actions

Several corporate and some major airlines have equipped their aircraft with AOA displays. NTSB has recommended that FAA require all transport-category aircraft to present pilots with AOA information in a visual format, and that all air carriers train their pilots to use the information to obtain maximum possible airplane-climb performance.

Programs such as American Airlines’ Advanced Aircraft Maneuvering Program (AAMP) stress the fact that aircraft operate in a dynamic environment. Abrupt changes in airspeed and attitude happen rarely, but must be dealt with in a timely and proper manner to avoid attitudes and speeds unsafe for flight. AAMP training refreshes pilots on aerodynamic basics and stresses techniques to gain maximum performance from the aircraft.

AOA displays are essential to gain maximum performance during an escape maneuver or unusual-attitude recovery. AOA serves as a truth test of airspeed computations for weight and configuration. Pitot-static malfunctions will be apparent from cross checks with AOA displays. The message needs to be spread that AOA displays have value on all aircraft.

On some fly-by-wire aircraft, mechanisms are embedded in the flight-control design to limit the possible maneuvers within the aircraft's flight envelope. The risk of stall is so minimized that the need for an AOA display is eliminated, except for additional pilot awareness of this essential flight-mechanics parameter.

5.14.4 Reference

The reference for this section is shown as Reference 30 at the end of this report.

5.15 Flight-data Availability

5.15.1 Problem Statement

FOQA programs, which routinely analyze flight data to identify problems in crew operations, flight procedures, airports, flight exceedances, approach procedures, systems and other areas, are currently limited to a few major airlines, and those airlines have clearly benefited from a safety perspective. The installing of QARs in more commercial-carrier aircraft and the encouragement of FOQA programs will enhance safety and accelerate data sharing. An indirect benefit would be the availability of hard data for incident and accident investigation.

5.15.2 Recommendations

1. Operators should equip their aircraft with QARs and implement FOQA programs;

2. Regulators should work with industry to increase the number of aircraft involved in commercial operations with QARs;

3. The airline industry should support the distribution of de-identified data from FOQA-type programs, worldwide;

4. The aircraft-manufacturing industry should ensure that sufficient parameters are captured on QARs to permit effective incident and accident analysis;

5. Regulators should work with the industry to encourage adoption of flight-data recording;

6. The industry should collaborate to ensure that de-identified flight data are used only for safety purposes;

7. Aviation insurance companies should provide premium reductions to companies with active FOQA-type programs; and,

8. ICAO should continue to promote FOQA-type programs and the installation of QARs.

5.15.3 Actions

Major air carriers in North America and Europe have FOQA programs and have validated safety enhancements and savings through their use. Currently the Canadian regulator is sponsoring an industry-wide project to implement similar programs in Canada. In the United States, the regulator is working with industry to expand the use of QARs for flight-monitoring purposes. Progress is being made; however, the programs are regional and are not moving rapidly.

Every opportunity should be taken to develop and implement flight-monitoring programs such as FOQA. Potentially, ICAO could propose standards and recommend practices for such a program. Regulators should actively engage major, regional, air-taxi and commuter airlines in a dialogue with the objective of implementing such programs. Forward-looking companies that are aware of the benefits of FOQA programs should implement them despite the lack of regulation. Insurance companies should use their influence to encourage air carriers to adopt such programs.

5.15.4 References

Reference for this section are shown as References 31–38 at the end of this report.

5.16 Use of the Three-pointer Altimeter and the Drum-pointer Altimeter

5.16.1. Problem Statement

There is ample evidence that the misinterpretation of the three-pointer altimeter and the drum-pointer altimeter can lead to CFIT (and approach-and-landing) accidents. There is a long, documented history of these errors.

5.16.2 Recommendations

1. All states and operators should be informed of the dangers inherent in the use of three-pointer altimeters and drum-pointer altimeters, and usage of these altimeters should be discontinued; and,

2. ICAO should examine the case for discontinuing their usage and should take appropriate action to amend Annex 6 in this respect.

5.16.3 Actions

This topic was addressed in detail in the final report of the FSF CFIT Task Force AEWG. It is, however, equally relevant to the work of the ALAR team and is repeated here for completeness.

Action has been taken by ICAO to amend Annex 6, and these changes became applicable on November 5, 1998. All states should be urged to implement these changes on aircraft operating both nationally and internationally.

5.16.4 Reference

The reference for this section is shown as Reference 39 at the end of this report.

5.17 Use of GPS/GNSS

5.17.1 Problem Statement

This was detailed in the FSF CFIT Aircraft Equipment Team Report. Since then, it appeared that the GPS/GNSS may not become a sole means of navigation, but it remains as a very effective primary means, likely to be complemented by more vertical and horizontal situation data when more fully reliable information is needed.

Such reliability is required for instrument approach-and-landing guidance, and also for situation awareness and warning against terrain encounter.

5.17.2 Recommendations

1. The development and availability of GNSS should be strongly supported;
2. Continue to encourage states and operators to introduce specifically designed GNSS nonprecision-approach procedures; and,
3. Complementary navigation systems should be maintained or installed to allow further use of GNSS, such as augmentation systems and RNAV equipment.

5.17.3 Actions

This topic was addressed in detail in the final report of the FSF CFIT AEWG. It is, however, equally relevant to the work of the ALAR team and is repeated here for completeness.

6. Further Considerations

6.1 Safety Equipment

6.1.1 A Trend on Which to Build

Accident statistics gathered over many years provide evidence of a continuous improvement of accident rates. More specifically, newer aircraft are more reliable and have a lower accident rate. Undoubtedly this is largely due to the evolution of the aircraft equipment — for example, through enhanced sensors, transmitters and integrated systems for data management, and by providing enhanced support for the crew in the areas critical to safe and efficient flight. This accords both with common sense and with engineering expectations that newer on-board systems make the aircraft safer and easier to fly. Similarly, regions of the world in which ATC is supported with sophisticated equipment show lower accident rates despite higher traffic density.

It may be difficult, nonetheless, to establish which specific items of equipment are likely to be of most benefit. For example, automation can produce great improvements in efficiency and safety, but must be introduced with care.

6.1.2 The Role of Equipment for Enhancing Safety

Aircraft equipment is designed by the manufacturer to support the crew in their primary tasks: to aviate, navigate, communicate, and manage the aircraft safely and efficiently. Human factors specialists sometimes describe crew behavior on such tasks at one of three levels — skill based (highly practiced and largely automatic), rule based (procedural) or knowledge based. The equipment can help at each level of all the tasks, either by enhancing the ability of the crew or by detecting deviations from normal, and warn of or even automatically deal with the situation. The extent to which the equipment is designed to be supportive of the crew rather than autonomous is an important component of the manufacturer’s flight-deck philosophy.

The same rationale holds for ATC, whose primary functions in the terminal area are to provide guidance to the aircraft and ensure traffic separation, coupled with efficient approach, landing and taxiing. The information ATC receives about the current air traffic situation should be as good as possible for ATC to provide optimal guidance. Surveillance should also be assisted or automated in order to reduce workload.

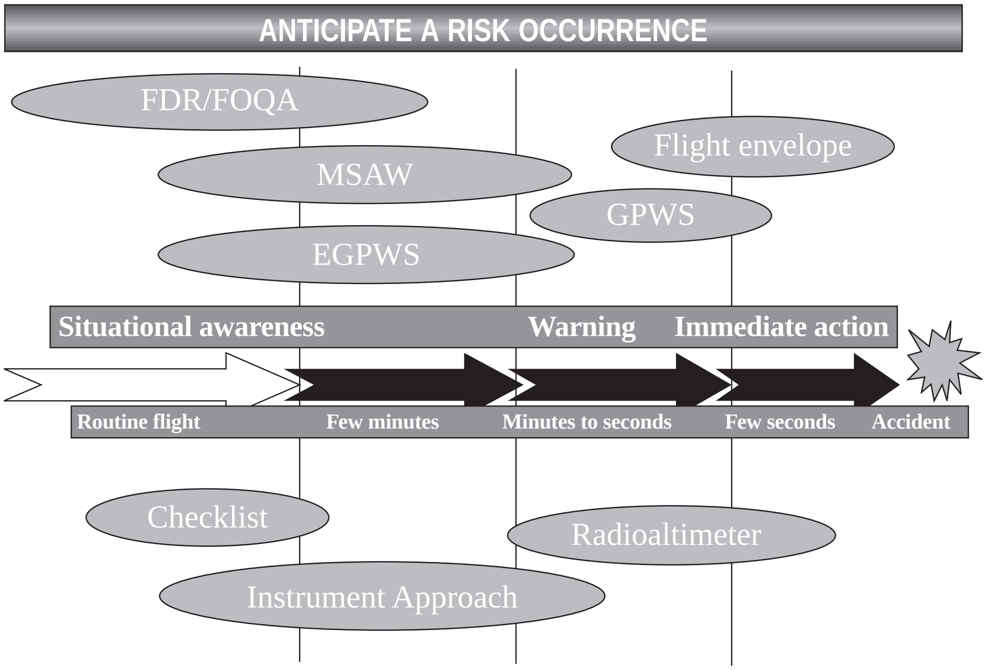
6.1.3 Anticipating a Risk of Accident

Some safety equipment is specifically designed to alert the crew to the risk of an unplanned occurrence. A risk is sometimes described as an abnormal situation or deviation from normal practices that, if combined with another event, or if not adequately taken care of, can ultimately lead to an accident. The criticality of the risk can be referenced to the “time to accident.” An alert should be proportional to this criticality, although false alarms must be avoided (especially for more critical situations).

It is useful to consider the time to accident in three zones, as shown in Figure 1 (page 109).

- When time is not the critical factor, an alert merely provides improved situational awareness to the crew;
- When time gets shorter, the alert becomes a warning, coded in such a way that demands more or less immediate application of a procedure; and,
- When the situation becomes highly critical, immediate response is mandatory or the corrective action must be automated.

The Potential Influence of Equipment in Reducing Risk As a Function of Time before Accident



FDR = Flight data recorder FOQA = Flight operational quality assurance MSAW = Minimum safe altitude warning
GPWS = Ground-proximity warning system EGPWS = Enhanced ground-proximity warning system

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 1

It is suggested here that, for each aircraft, a strategy that accounts for the criticality of the risk, the level of alerting and the probability of false alarms must be defined and implemented.

6.2 Analysis of AEWG Recommendations

Due to the large variety of issues considered, the technical status of the fleets operated, and the types and areas of operations, a large number of ideas were discussed as possible solutions. These ranged from readily available equipment and procedures to futuristic technologies.

Analyzing potential solutions (summarized in section 3), reveals several trends. Two-thirds of the recommendations refer to equipment whose use will help the crew perform its mission in routine operations — for example, by improved control of the machine, accurate navigation and guidance, and better communication and management of the aircraft. The remaining third are more specific safety items that contribute to the establishment of a safety net, protecting the flight against various risks.

Approximately half of the solutions are essentially on board, and give the crew a level of autonomy in dealing with safety. The other half relate to equipment and activities, either on the ground, at the airlines' operational bases, with the regulatory authorities or with ATC. These latter factors contribute primarily to overall flight safety. This demonstrates the intimate concurrence of all actors in the production of flight safety.

The majority of the items recommended could be implemented now, either because the technology is available, and the cost is limited, or because they would require modifications to the operation of existing equipment. Others will require further work, though it is recognized that in some cases such developments are currently close to production.

6.3 A Safety Philosophy

In the AEWG, the uses and influence of various types of equipment have been discussed at length, including equipment that supports routine operations (navigation systems) as well as safety equipment (terrain warning).

However, not all are adaptable to or necessary for every aircraft, depending on current equipment, operational procedures or crew training, and the specific conditions of the airline's operations and culture.

Clearly, there is no ultimate equipment solution for safety. There is merely an association of elements, both airborne and ground-based, and involving all actors, that should optimally concur to reduce risk.

The main goal of a safety philosophy is to document the rationale for the implementation of the equipment for each aircraft type and operating conditions, as a result of a risk analysis. This is achieved by the aircraft manufacturer in conjunction with the operators, culminating in a set of operating procedures and the design of the cockpit. Additionally, the airlines can further refine this philosophy with consideration of their very specific conditions of operations and the cultural background of their personnel.♦

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Appendix 1
AEWG Participants

Name	Affiliation
E. S. Bang	Boeing Commercial Airplanes Group, U.S.
W. Bresley	Boeing Commercial Airplanes Group, U.S.
R. Coleman	National Defence HQ, Canada
J.P. Daniel (Chairman)	Airbus Industrie/Aerospatiale, France
P.G. Emmerson (Secretary)	British Aerospace, Sowerby Research Centre, U .K.
R. Khatwa	NLR (Netherlands)/ Rockwell Collins, U.S.
Capt. D. McKinney	American Airlines (retired), U.S. Air Force (retired)
G.R. Meiser	Boeing Commercial Airplanes Group, U.S.
M. Patel	British Airways, U.K.
B.L. Perry	International Federation of Airworthiness (IFA) Technical Committee, U.K.
J. Sciera	Air Line Pilots Association, International
J.L. Sicre	Sextant Avionique, France
J. Terpstra	Jeppesen Sanderson, U.S.
A. Wargh	Saab, Sweden
T. Yaddaw	Bombardier, Canada

Flight Safety Foundation
Approach-and-landing Accident Reduction Task Force

Air Traffic Control
Training and Procedures/Airport Facilities
Working Group

Final Report (Version 1.2)

Robert Vandel
Flight Safety Foundation

History of Flight Safety Foundation's Controlled-flight-into-terrain and Approach-and-landing Accident Reduction Effort

In April 1992, Flight Safety Foundation's International Advisory Committee (IAC) met in Washington D.C., U.S., to develop strategies to bring controlled-flight-into-terrain (CFIT) accidents and approach-and-landing accidents (ALA) under control. The workshop was divided into four working groups: technology, training, flight-deck management and procedures, and ground facilities and support. This section is derived from "Reducing Approach-and-landing and CFIT Accidents," a report of the IAC Workshop, April 28–29, 1992.

1. The **technology** working group concluded that ground-proximity warning system (GPWS) technologies offer both short-term and long-term benefits. For the near term, they recommended that all aircraft be equipped with GPWS of at least second-generation or later capability. In addition, strong influence should be brought to bear on the worldwide operating community to adopt strict procedures for complying with GPWS commands.

   For the long term, the aviation community should work through the International Civil Aviation Organization (ICAO) to change worldwide requirements for GPWS.

2. The **training** working group identified three objectives through which training should be reviewed and evaluated.

   a. Develop and provide guidance to reduce accident rate, and make training recommendations;

   b. Promote the concept of stabilized approaches, which should take precedence over all; and,

   c. Promote the importance of total situational awareness.

3. The **flight-deck management and procedures** working group identified a number of factors, classified as enabling factors and associative factors, that must be addressed for safety improvement.

   Enabling factors include:

   a. Human performance with respect to following standard operating procedures (SOPs) (procedural noncompliance);

   b. Communicating effectively (listening as well as talking); and,

   c. Maintaining a high state of situational awareness.

Associative factors include:

   d. Presentation of flight-deck information (e.g., layout, design, etc.);

   e. Nonstandard reactive procedures (human behavior not as assumed);

   f. Training effectiveness (glass/electromechanical cockpit);

   g. GPWS: standard mandatory action and stabilized approach;

   h. Education of the flight crew (behavioral problems, psychological profile, crew resource management [CRM], etc.);

   i. Management support and policies (as affected by commercial pressures and dispatch procedures, integrated policies and responsibility-evading mission statements); and,

   j. External support (e.g., air traffic control [ATC] training, tolerances for standard mandatory action).

4. **Ground facilities and support** working group identified two vital requirements:

   a. Establishment of worldwide standards for ground facilities and equipment; and,

   b. The ability to audit compliance with these standards.

In September 1992, an agenda development subcommittee of the IAC met in Long Beach, California, U.S., to address the challenge of international standards. One of the results of that meeting was the development of a steering committee for oversight of the entire CFIT and ALAR effort. The CFIT Steering Committee was charged with developing goals, working-group structures and methodologies that could be used effectively to combat both CFIT and ALA.

The CFIT Steering Committee met in Seattle, Washington, U.S., in September under the chairmanship of Earl Weener, Ph.D., Boeing Commercial Airplane Group (BCAG). The steering committee accomplished four actions:

1. **Established the Composition of the CFIT Steering Committee:**

   a. Earl Weener, Ph.D., BCAG (chairman);

   b. John O’Brien, Air Line Pilots Association, International (ALPA);

   c. Don Bateman, Sundstrand Data Control;

   d. Paul Russell, BCAG;

   e. Capt. Paul Woodburn, British Airways;

   f. Everett Palmer, U.S. National Aeronautics and Space Administration (NASA), Ames Research Center;

   g. Dick Slatter, ICAO;

   h. Bob Vandel, Flight Safety Foundation; and,

   i. Chairman of each working group.

2. **Established CFIT and ALA reduction goals:**

   a. Reduce CFIT and ALA rates by 50 percent over a five-year period; and,

   b. Limit the worldwide accident rate in either category to no more than twice the rate of the geographical region with the lowest rate.

3. **Formed working groups:**

   a. Air-crew Training and Procedures Working Group;

   b. Data and Data Dissemination Working Group;

   c. Aircraft Equipment Working Group; and,

   d. ATC Training and Procedures/Airport Facilities Working Group.

4. **Developed initial guidance for each working group.**

In November 1993, the annual IAC business meeting was held in conjunction with the International Air Safety Seminar. The CFIT Steering Committee presented its plan for approval. The IAC approved the plan and made selections for chairmen for three working groups. Doug Schwartz (FlightSafety International) agreed to chair the Air-crew Training and Procedures Working Group, Bill Hendricks (director of the Office of Accident Investigation, U.S. Federal Aviation Administration [FAA]) agreed to chair the ATC Working Group and Don Bateman (AlliedSignal, formerly of Sundstrand Data Controls) agreed to chair the Data Working Group. Some five months later, Capt. Dave Walker (Air Canada, retired) was selected to chair the Aircraft Equipment Working Group.

It was initially determined that addressing both CFIT and ALAR would be too great a task, so the Steering Committee decided to focus on CFIT in this initial phase. When that work was completed, they would then set up working groups for ALAR.

During the second Steering Committee meeting in June 1993, the need for another working group was identified. This group was needed to deal with the flight training and procedures for both corporate aircraft operations and regional airlines. This working group was chartered under the leadership of Ted Mendenhall (Gulfstream Aerospace).

In September 1994, Bill Hendricks retired from the FAA and was not able to continue as chair of the ATC Working Group. The ATC Working Group was inactive for about 16 months. Due to this lag in activity, the remainder of the working groups had completed their product development and had ended their work. At this point the Steering Committee asked the ATC Training and Procedures/Airport Facilities Working Group (ATC/AFWG) to address both CFIT-reduction and ALAR issues.

[Editorial note: The areas of interest of some of the working groups have evolved since they were established, and some working group names were changed after this report was written in 1997.]

Steering Committee Guidance

The Steering Committee provided the ATC/AFWG with 18 specific topics to review, listed in Appendix A. These 18 topics were divided into five basic areas of focus: charting, equipment, phraseology, training and facilities.

Working Group Membership

Although the working group membership varied, a core of individuals attended all meetings. The entire membership with affiliations is in Appendix B.

Working Group Meetings

Meetings were held in February 1995 in Washington, D.C., September 1995 in Montreal, Quebec, Canada, and in June 1996 in Washington, D.C.

Working Group Mission Statement

The working group established the following mission statement: "Develop and present guidelines and recommendations which will leverage a reduction in CFIT and approach-and-landing accidents with an emphasis on:

"1. Air traffic services training and procedures; and,

"2. Ground-based aviation support."

Working Group Process

With the Steering Committee's guidance, the group set about developing a strategy for working within the five areas of focus. An impact/changeability technique, which had been used by other working groups, was used to evaluate and prioritize the various topics. The premise was that ATC/AFWG could determine where the greatest leverage existed to reduce CFIT and ALAs.

The system called for the working group to reach consensus on, first, the impact of a suggested change/strategy and then on the relative ease with which the change could be implemented. A simple rating scheme of 1 to 3 was employed to describe two factors: changeability and opportunity. A rating of 1 signified most difficult or least opportunity to effect. A rating of 3 signified least difficult or greatest opportunity to effect. The basic premise was that, when the rating was completed, the ratings would optimize the efforts of working group by focusing on those items that were rated 3-3 or 3-2.

Utilizing this procedure, the group reached a consensus concerning which topics offered the greatest opportunity to reduce CFIT and ALAs. Those subjects were the focus of the working group's efforts. The areas chosen to focus on were ground-based equipment (minimum safe altitude warning [MSAW] system), approach procedure design, phraseology and altimeter settings.

MSAW System

Discussion

The first area addressed was the use of the MSAW system. MSAW is a radar-based system that was developed and fielded in 1976. It has the capability to warn the air traffic controller of an aircraft that is either too close, or projected to be too close, to terrain. MSAW alerts the air traffic controller with both a visual and audio alarm when an aircraft either penetrates, or is predicted to penetrate, a predetermined altitude.[1] When a potentially unsafe condition is detected, the controller alerts the pilot. The FAA *Air Traffic Handbook,* FAA Order 7110.69, requires the controller to warn the pilot with, "Low altitude alert — check altitude. Your altitude should be ____." MSAW is provided for aircraft automatically if operating under instrument flight rules and on request for aircraft operating under visual flight rules in the United States.[2]

MSAW 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.[3]

MSAW is widely available yet sparingly operational. It has been described as the air traffic controller's GPWS.

MSAW has been available for about the same time as GPWS; however, according to our research, it is being used only in the United States, Israel and parts of Japan and Italy. It is recognized that MSAW has limitations and will not prevent all CFIT and ALAs, but it can be very effectively used as another tool to break the accident chain.

Specifically, requirements for an operational MSAW system include an automated radar terminal system (ARTS III), a three-dimensional grid map stored in the ARTS III computer, Mode C–equipped aircraft, and a general-terrain-monitoring program that has been activated. (See Figure 1.)

Generally speaking, the ARTS III radar is capable of providing MSAW service outward from the airport some 60 nautical miles (111 kilometers). MSAW utilizes a three-dimensional terminal-area grid system stored in the ARTS III computer. Each grid is two nautical miles on a side and is assigned an altitude that is 500 feet above the highest terrain in the grid. (See Figure 2, page 116.) The designated grid system is coupled with a general-terrain-monitoring system and the MSAW system is activated. The general-terrain-monitoring program makes altitude checks each time a valid altitude report is received from an aircraft. This occurs once per radar scan. The monitoring program makes three types of analysis:

1. **Current status.** The reported altitude is checked to see if the designated aircraft is 500 feet or less above the altitude assigned the four-square-nautical-mile grid below the aircraft.

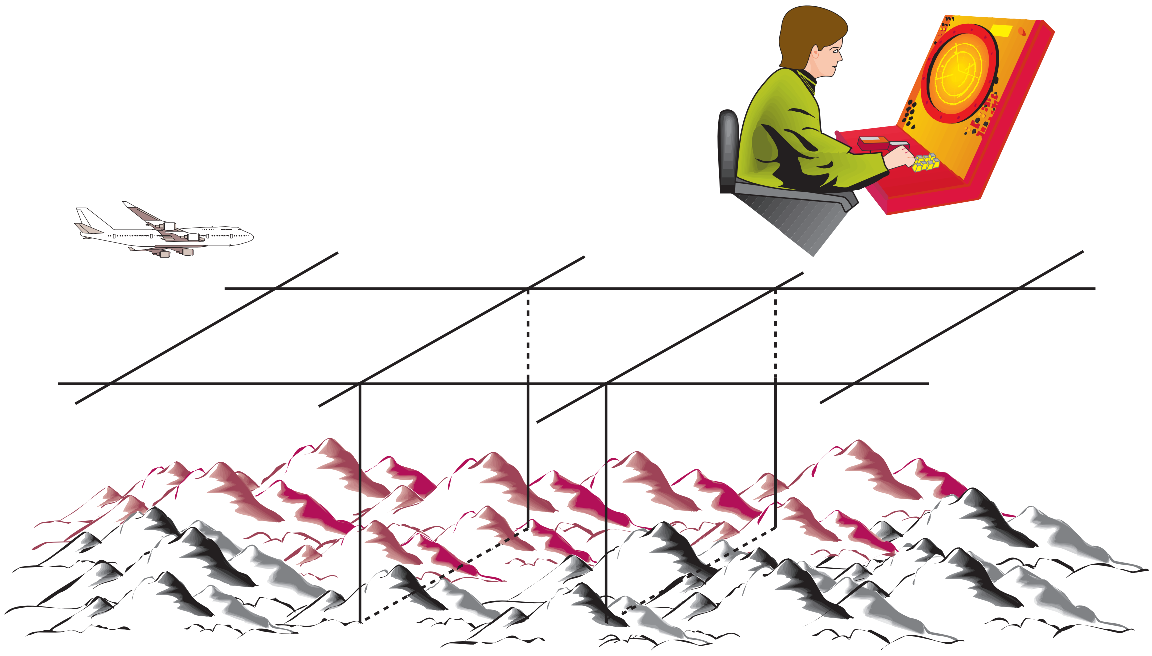
2. **Predicted status.** The next analysis is conducted to predict where the aircraft will be in 30 seconds if its flight path remains unchanged. At this point in the analysis a determination is made as to whether or not the aircraft will be 300 feet (92 meters) or less above the squares along its flight path. If no alerts are triggered by the current-status or the predicted-status programs, then a third check is conducted.

3. **Projected status.** This analysis is made along a five-degree climbing path to determine if the aircraft will be 300 feet or less above any square along its projected path within the radar coverage area.[4]

The second feature of MSAW is airport-approach-path monitoring, which begins when a properly equipped aircraft enters one of the rectangular areas, called “capture boxes.” These boxes are two nautical miles wide and extend outward from the runway threshold approximately five nautical miles. During the final approach phase, MSAW utilizes parameters of 100 feet (30 meters) below the minimum descent altitude (MDA) for the current check. The prediction check analyzes the aircraft’s flight path to determine if it will be 200 feet (61 meters) or more below the MDA within 15 seconds. The approach-path monitoring ends two nautical miles from the end of the runway, as it is not practical to monitor the aircraft during the final seconds of landing.[5]

A listing of countries with MSAW technology capability is in Appendix C.

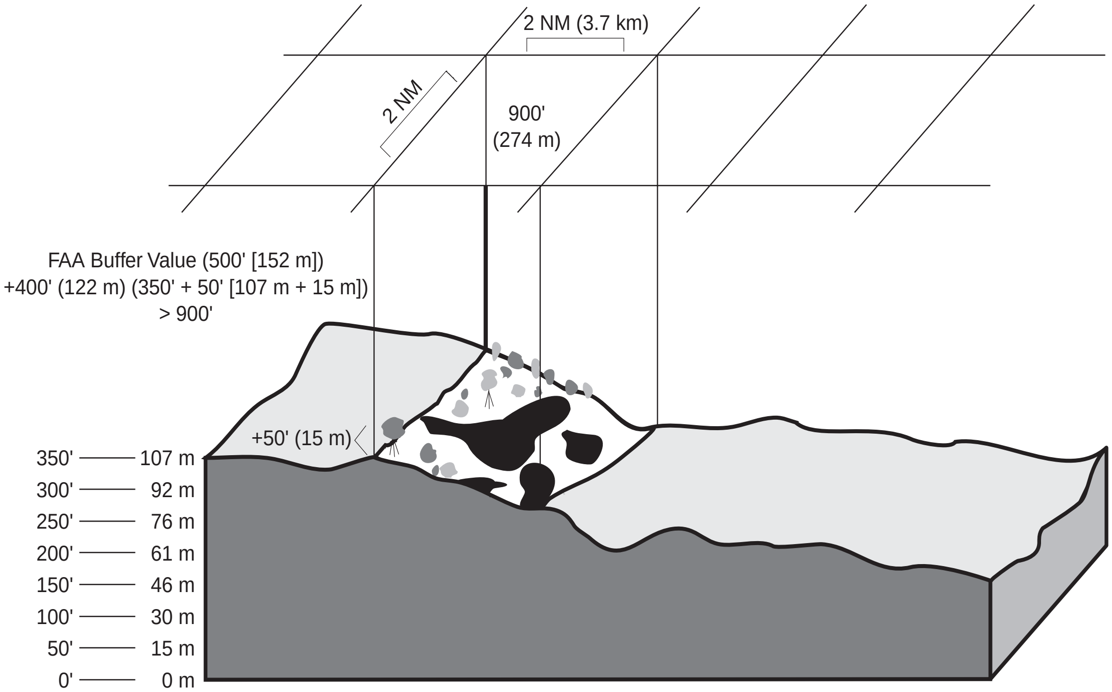
Schematic of the Minimum Safe Altitude Warning System Requirements



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 1

Terrain Overlay with Two-square-mile Grids



NM = Nautical miles FAA = U.S. Federal Aviation Administration m = Meters

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 2

Conclusions

The ATC/AFWG concluded that:

1. MSAW can be an effective tool in preventing both CFIT and ALA accidents;

2. MSAW is currently used in only the United States and Israel, with limited application in Japan and Italy;

3. MSAW has limitations but provides another opportunity to break the chain of events leading to CFIT and ALA; and,

4. Many ARTS III radars in use around the world have the MSAW capability resident in the system, but the capability is not being utilized. It is a tragedy that this equipment is in place, available and not being used to prevent accidents.

Recommendations

It is recommended that immediate worldwide application of MSAW be accomplished.

1. All air traffic control facilities having the automatic safety alert capabilities should utilize those features; and,

2. Every effort should be made to add MSAW capability to those ATC facilities currently without MSAW.

Approach Procedure Design

Analysis by the working group focused on standard descent profiles for straight-in nonprecision approaches and minimum-vector-altitude (MVA) charts. Because the group had the luxury of completing deliberations following the submission of the Aircraft Equipment Working Group, it was able to review their recommendations. The following recommendations made by the Aircraft Equipment Working Group are strongly endorsed:

1. That nonprecision-approach procedures should be constructed, whenever possible, in accordance with established stabilized-approach criteria;

2. There should be one final-approach segment per navigation aid/runway combination;

3. The final-approach glide path should be a nominal three degrees where terrain permits; where a steeper glide path is necessary, up to a maximum angle permitted. A continuous descent is preferred to a stepped approach; and,

4. Nonprecision-approach charts should show the descent profile to be flown.

Discussion

Currently there is a hazardous disconnect between the vectoring charts used by the air traffic controller and those available in the cockpit. The pilot has minimum-sector-altitude (MSA) charts that provide the lowest usable altitude in a sector surrounding an airport. The air traffic controller has MVA charts designed and maintained by air traffic control. These charts are centered around radar-antenna sites, which in most cases are different from the center point of the MSA charts. As the MSA and MVA charts are based on different criteria, a pilot can become confused when vectored at an altitude that is below the MSA charted altitude. The pilot is not sure whether he is being vectored at an approved MVA altitude or whether a mistake has been made concerning the MSA. This is especially critical in high-density traffic areas where radio congestion may preclude further and immediate clarification with ATC. This is a classic “latent situation” or “enabling factor” in the potential error chain.

Conclusion

With the implementation of the global positioning system (GPS) and flight management system (FMS), it is now possible to display MVA information in an electronic form on the flight deck. The one missing action is for ATC to make this information available to pilots who want or need it.

Recommendation

The ATC/AFWG strongly recommends that MVA information be made available for use.

Phraseology

Discussion

The safety implications that may result from pilot–air traffic controller misunderstandings are well documented. Some of these problems are related to the nature of English-language ATC applications, which involve radio exchanges of often highly formatted communications by individuals whose native language may not be English. Though ICAO recognizes other languages, English is most widely used by ATC communications and is a de facto standard. Other problems may result from lack of adequate air traffic controller English-language skills and nonstandard use of certain terminology. Because of the sensitive political and cultural aspects of this situation, the international aviation community has not adopted international standards or recommendations for English-language skill levels. Utilization of standardized terminology, although established and encouraged, is not enforced. The following are some language-related initiatives that the ATC/AFWG believes should be undertaken to improve the safety factors in English-language use for ATC communications:

1. Conduct a review of a range of English-language training and testing programs for controllers in selected countries to compare these programs’ content and design;

2. Evaluate the above English-language training and testing programs based on standardized testing to measure the English-language proficiency which these programs produce;

3. Assess international aviation-community interest in the development of English-language training and testing-program guidelines specifically addressing ATC applications; and,

4. Based on the outcome of the above, develop a test program to measure both general English-language skills and proficiency in ATC-specific applications for the use of national air traffic control organizations to test controller proficiencies.

Conclusion

The ATC/AFWG believes that before common phraseology between air crews and ATC can be addressed, a basic level of English-language comprehension and usage must be specified. This is also true for guidelines on phraseology among air traffic control specialists, fire brigades, airport authorities and aircraft rescue and fire-fighting (ARFF) centers.

Recommendations

1. Minimum performance standards need to be developed and adopted which address general English-language skill levels and the use of ATC terminology;

2. Testing programs need to be established to measure baseline skills to identify training priorities and to monitor proficiency levels over time; and,

3. Language training programs need to be standards-driven. Controllers must be trained to have at least a minimum proficiency, and a training program must be established to maintain controller skills to prevent their degradation.

Altimeter Settings

When aircraft are flying below the transition altitude/level, the aircraft’s altimeters are set in relation to the air pressure at the ground or, more commonly, at the corresponding sea level. ATC provides the altimeter settings to the pilot either directly or through automated terminal information service (ATIS). The ICAO standard is for altimeter settings to be given in hectopascals (millibars). Some countries ignore this standard and provide altimeter settings in inches of mercury or in some cases both inches of mercury and hectopascals.

Discussion

The ATC/AFWG research indicates the following:

1. The United States, Bermuda and Canada provide altimeter settings only in inches of mercury;
2. The Bahamas, Belize, Colombia, El Salvador, Japan, Korea and Mexico City provide altimeter settings in inches of mercury and on request in hectopascals (millibars); and,
3. Barbados, Bhutan, Grenada, Guatemala, Guyana, Indonesia, Jamaica, Malaysia, Mexico (except Mexico City), New Zealand, Papua New Guinea, Paraguay and Uruguay provide altimeter settings in hectopascals and on request in inches of mercury.

Standards

ICAO, Annex 3 — Meteorological Service for International Air Navigation, Chapter 4.11 recommends the use of hectopascals.

ICAO, Doc 8896 — Manual of Aeronautical Meteorological Practice says: "Pressure values are given in hectopascals … ." Examples are given in three or four digits. ICAO, Doc 8896, Appendix C, Abbreviated decode of meteorological aeronautical radio code (METAR) says that the pressure is given by a Q (for QNH in hectopascals) or an A (for altitude in inches of mercury) followed by four digits (e.g., Q1008 or Q0998 when in hectopascals and A2998 when in inches of mercury).

The ATC/AFWG believes using four digits when expressing altimeter settings both in communication between aircraft and ATC and on the ATIS would be within the intent of the current ICAO standards.

In practice, both air traffic controllers and pilots frequently refer to altimeter settings using only the last three digits. There is a significant CFIT and ALA risk in this, especially when flying between countries that use different standards. This risk has been demonstrated through incidents such as the one at Copenhagen, Denmark, airport. An aircraft arriving from Boston, Massachusetts, U.S., on a special very high frequency omnidirectional radio range–distance measuring equipment (VOR-DME) approach (the instrument landing system [ILS] was out of service) to runway 22L flew about 640 feet lower than intended and nearly collided with the water. The altimeter was set to (2)991 inches of mercury instead of (0)991 hectopascals.

Conclusion

As incidents are badly underreported, it is difficult to quantify the risk. It is, however, obvious that CFIT and ALA risks exist and must be addressed.

Short term: Establish a term to identify hectopascals (e.g., hex) and inches of mercury (e.g., inches) to help address the problem. Also, ATIS should always give the setting in both hectopascals and inches of mercury *using four digits*.

Long term: Having the same standard worldwide would be the best solution, but may not be realistic. It would require support from the states that are heavy users of the system that traditionally uses inches of mercury.

Recommendations

1. That all states standardize the use of hectopascals for altimeter settings in accordance with established international standards;
2. That four digits be used when expressing altimeter settings. This should apply to pilots, ATC and meteorological (MET) offices and should include written information as well as natural and artificial voice communication;
3. That ICAO recommend the use of four digits when expressing barometric-pressure information; and,
4. That checklists provide reminders to pilots concerning hectopascals vs. inches of mercury when passing the transition altitude or level.♦

References

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2. U.S. National Oceanographic and Atmospheric Administration (NOAA), Minimum Safe Altitude Warning Program, undated
3. FSF CFIT Education and Training Aid, page 3.17
4. NOAA, Minimum Safe Altitude Warning Program, undated
5. NOAA, Minimum Safe Altitude Warning Program, undated

Appendix A
Recommended Areas of Concentration

Charting

- Navigation chart symbology and terrain presentation standardization (except contours);
- Radio altitude information at the initial approach fix/final approach fix (IAF/FAF) shown on all approach charts;
- Method established for analyzing and disseminating information on poorly designed approaches; and,
- Minimum vector altitude vs. minimum sector altitude.

Equipment

- Minimum ground-station-equipment standards established (not limited to existing equipment): examples are GPS and MSAW;
- All runways have glideslope guidance: precision, visual-approach-slope indicator (VASI), etc.; and,
- Improved methods of data and communication exchange between ATC and flight crews (examples: data link and mode S).

Phraseology

- Common communication phraseology between airplane crew and ATC, worldwide;
- Expand the information on in-flight emergencies in appropriate guidance material to include advice on how to ensure that pilots and air traffic controllers are aware of the importance of exchanging information in case of in-flight emergencies. The use of standard phraseology should be emphasized; and,
- Evaluate and, where necessary, develop common guidelines on emergency procedures and phraseology to be used by ATC, fire brigades, airport authorities and rescue-coordination centers. (Very-high-frequency [VHF] communication procedures between the flight deck and the CFR agencies are not standardized around the world.)

Training

- Air traffic controllers’ training aid for stabilized approaches;
- Training aid to assist ATC personnel understand the capabilities and requirements of the airplanes;
- Vectoring techniques over high terrain — awareness of GPWS and its detection and alerting rationale; and,
- Operations in low temperatures — applications and corrections.

Facilities

- Improved worldwide notice to airmen (NOTAM) dissemination process established with standards for dissemination and timeliness;
- Airport lighting standards to permit easy identification of runway lights distinct from surrounding lights;
- Provisions for better runway-surface information to crews from maintenance and operations (friction measurement). Standards for runway-surface-contamination reporting and for an acceptable runway-surface condition;
- International standards for approach-light systems and runway-marking lights; and,
- Runway-contamination-removal standards.♦

Appendix B
Working Group Members

Don Bateman, AlliedSignal

Cay Boquist, International Civil Aviation Organization (Air Traffic Management)

Rob Bowen, American Airlines

Jerry Broker, U.S. Air Force

Bob Conyers, Associated Aviation Underwriters

Barry Cooper, Air Line Pilots Association, International (America West)

Darren Gaines, U.S. Federal Aviation Administration

Pat Gallagher, Allied Pilots Association

Norm LeBlanc, Transport Canada

Mike Maekawa, All Nippon Airways

Dick McKinney, American Airlines

Ben Rich, Allied Pilots Association

Paul Smith, National Business Aviation Association

Ed Stevens, Raytheon Co.

Ted Thompson, Jeppesen

Simon Tyas, Guild of Air Traffic Control Officers

Shannon Uplinger, Uplinger Translation Services

Bob Vandel, Flight Safety Foundation

Paul Van Tulder, Boeing Commercial Airplanes Group

Tom Young, Air Line Pilots Association, International (US Airways)

Bendt Zinck, Copenhagen Airports♦

Appendix C
Countries with MSAW Technology Available

[Updated, November 1998]

In response to an ICAO survey dated Dec. 12, 1997, 14 member countries indicated that they provided MSAW in varying degrees of implementation. Those countries are listed below by region.

Asia and Pacific

China

Malaysia

Republic of Korea

Singapore

Europe and North Atlantic

France

Germany

Italy

Poland

Switzerland

Tunisia

Uzbekistan

Middle East

Israel

North America, Central America and Caribbean

United States

South America

Ecuador♦

Reprinted from *Flight Safety Digest*, February–March 1998.

A Study of Fatal Approach-and-landing Accidents Worldwide, 1980–1996

A study commissioned by the U.K. Civil Aviation Authority for Flight Safety Foundation examined in detail 287 fatal approach-and-landing accidents. Among the findings were that 75 percent of the accidents occurred when a precision approach aid was not available or was not used; a disproportionate number of the accidents occurred at night; there were significant differences in the accident rates among world regions; and the leading causal factors were continuing the approach below decision height or minimum descent altitude in the absence of visual cues, and lack of positional awareness in the air.

Ronald Ashford
Aviation and Safety Consultant
Accident Analysis Group
U.K. Civil Aviation Authority

1.0 Introduction

Flight Safety Foundation (FSF) has focused attention on approach-and-landing accidents (ALAs) as one of its major safety initiatives. In discussion in the FSF international Approach-and-landing Accident Reduction (ALAR) Task Force, it was agreed that the U.K. Civil Aviation Authority (CAA) database for its *Global Fatal Accident Review*[1] could be used as a starting point for a study of the global fatal-accident experience during approach and landing of jet and turboprop airplanes having greater than 5,700 kilograms/ 12,500 pounds maximum takeoff weight (MTOW). The *Global Fatal Accident Review* analyzed 621 fatal accidents that occurred between 1980 and 1996 inclusive and, from these, 287 (46 percent) were judged to be in the approach-and-landing phases of flight; the database of these 287 accidents forms the basis of this study, which was commissioned by the CAA for the Foundation.

2.0 The Accident Analysis Group

To conduct its accident review, the CAA formed an Accident Analysis Group (AAG) early in 1996. The group comprised seven researchers, each having extensive aeronautical experience gained in both the aviation industry and the regulatory environment. The researchers brought to the AAG first-hand knowledge, for example, in the following areas:

- Commercial airline operations;
- Flight testing, handling and performance;
- Systems and structural design;
- Human factors and flight-deck design;
- Risk/safety analysis techniques;
- Cabin safety and survivability;
- Regulatory/legal procedures; and,
- Maintenance.

The AAG was established to study all worldwide fatal accidents to jet and turboprop airplanes having greater than 5,700 kilograms MTOW that occurred since 1980 during public transport, business, commercial training and ferry/positioning flights. The following were excluded from the study:

- Piston-engine aircraft;
- Accidents resulting from acts of terrorism or sabotage;
- Fatalities to third parties not caused by the aircraft or its operation;
- Eastern-built aircraft and operators from the Union of Soviet Socialist Republics (U.S.S.R.) or Commonwealth of Independent States (C.I.S.) prior to 1990, because information from these countries was unavailable or limited at that time; and,
- Military-type operations or test flights.

Summaries of the accidents were obtained from the *World Aircraft Accident Summary*.[2] The summaries were usually brief and were supplemented with other information when required and available. At the AAG meetings, causal and circumstantial factors were discussed for each accident, and a consensus was reached on the factors to be allocated. These factors and any consequences were then recorded for each accident and entered in a fatal-accident database for future analysis. The AAG decided to assess all worldwide fatal accidents, unlike other studies in which only accidents where substantial information was available were reviewed; this was done to avoid any bias in the analysis toward accidents that have occurred in nations where detailed investigations are conducted and reports are issued. More details of the AAG approach are contained in Reference 1.

3.0 Accident Assessment

3.1 The Review Process

The review process accomplished by the AAG involved reaching consensus views to establish which causal factors, circumstantial factors and consequences occurred in each accident, together with an assessment of the level of confidence in the information available. In addition, a single primary causal factor was selected from the number of causal factors identified. Numbers of flights were also obtained from Airclaims (publisher of the *World Aircraft Accident Summary*) and other available sources.

3.2 Causal Factors

A causal factor was an event or item that was judged to be directly instrumental in the causal chain of events leading to the accident. An event might be cited in the accident summary as being a causal factor, or it might be implicit in the text. Whenever an official accident report was quoted in the accident summary, the AAG used any causal factors stated therein for consistency; additionally, as stated above, the AAG selected *one primary causal factor for each accident* (though this proved to be difficult for some accidents). Where the choice was contentious, the group agreed on a particular method to select one primary causal factor, and then applied this method consistently to all other similar situations.

The causal factors were listed in generic groups and then broken down into specific factors, e.g., one causal group was “aircraft systems” and one of the several specific factors in this group was “system failure affecting controllability.” The full list is shown in Appendix 1.

An accident could be allocated any number of causal factors from any one group and any combination of groups. In a single accident, the highest number of causal factors recorded was 10, which was allocated to an aircraft that undershot the runway.

3.3 Circumstantial Factors

A circumstantial factor was an event or item that was judged not to be directly in the causal chain of events but could have contributed to the accident. These factors were present in the situation and were believed to be relevant to the accident, although not directly causal. For example, it was useful to note when an aircraft had made a controlled flight into terrain (CFIT) and it was not fitted with a ground-proximity warning system (GPWS). Because GPWS was not mandatory for all aircraft in the study and an aircraft can be flown safely without it, the nonfitment of GPWS in a CFIT accident was classed as a circumstantial factor rather than a causal factor.

“Failure in crew resource management (CRM),” when judged to be relevant, was in some situations allocated as a circumstantial factor and in others as a causal factor. The former was chosen when the accident summary did not clearly cite, or the data point to, CRM as a causal factor, but the AAG felt that had the CRM been to a higher standard, the accident might have been prevented. For example, CFIT during descent might have been avoided by good crew CRM (cross-checking by crew members, better coordination and division of duties, etc.), but the accident report or data might not have given sufficient evidence that CRM failure was a causal factor.

Circumstantial factors, like causal factors, were listed in generic groups and then broken down further into specific factors. The full list is shown in Appendix 1. For causal factors, an accident could be allocated any number of circumstantial factors from any one group and any combination of groups. The highest number of circumstantial factors recorded in a single accident was seven.

3.4 Consequences

A list of consequences was used to record the outcomes of the fatal accidents in terms of collisions, structural failure, fire, fuel exhaustion and other events. It was important to keep a record of the consequences because all fatal accidents consist of a chain of events with a final outcome resulting in fatalities. In some accidents, it can be just as important to know what happened as why or how it happened, because a particular combination of causal factors on one day may lead to a fatal accident, while on another day, result in only a minor incident. In many events, the consequence is all that is remembered about a particular accident. The consequences are listed in Appendix 1. The highest number of consequences recorded in a single accident was five.

3.5 Level of Confidence

The AAG also recorded the level of confidence for each accident. This could be high, medium or low and reflected the group's confidence in the accident summary and the factors allocated. It was not a measure of confidence in the allocation of individual factors but of the group's analysis of the accident as a whole. Alternatively, if the group believed that there was not enough substantive information in the accident summary (and there was no possibility of obtaining an official accident report), then there was a fourth level of confidence — insufficient information. For these accidents, no attempt was made to allocate causal factors, although there might have been circumstantial factors such as poor visibility that appeared to be relevant. Accidents with insufficient information were included in the analysis with allocated consequences (and sometimes circumstantial factors), even though there were no primary or other causal factors.

3.6 Summary of Assessments

There were 64 possible causal factors, 15 possible circumstantial factors and 15 possible consequences, and each accident was allocated as many factors and consequences as were considered relevant. The group could allocate any combination of factors, although some factors are mutually exclusive. For example, factors A2.3 ("failure to provide separation in the air") and A2.4 ("failure to provide separation on the ground") would not be allocated to the same accident because the aircraft involved were either in the air or on the ground.

The recording of factors was based on judgments made on the available data, to ascertain the cause of the accident rather than to apportion blame.

3.7 Accident Rates

Absolute numbers of accidents are obviously not a good indication of safety standards and are of no comparative value until they are converted to accident rates. For this purpose, it is possible to present the number of accidents per hour, per passenger-kilometer, per tonne-kilometer, etc., but the rate per flight is considered to be clearly the most useful indicator[3] and is used in this study.

The great majority of accidents (90 percent) occur in the phases of flight associated with takeoff and landing, and the length of the cruise phase has little influence on the risk. If you consider two operations with similar safety in the context of takeoff, approach and landing, of which one involves 10-hour flights and the other one-hour flights, to use a "per-hour" basis for the accident rate would give the former operation an accident rate that is close to one tenth of the latter (short-haul) operation; this was felt to be misleading. The fundamental objective is to complete each flight safely, regardless of its duration.

4.0 Limitations of the AAG's Database

As with all statistics, care should be taken when drawing conclusions from the data provided. Only fatal accidents have been included in this study and therefore important events, including nonfatal accidents, serious incidents and "airprox" (insufficient separation between aircraft during flight) reports have not been covered. It is important to recognize these limitations when using the data.

The aggregated nature of the accident data, based on 287 accidents, tends to overcome errors of judgment, if any, made in analyzing individual accidents. A few errors of judgment would be unlikely to change the overall conclusions, especially because such errors might tend to balance one another.

5.0 Worldwide Results

Because of the lack of information on the numbers of flights worldwide, accident rates have not been included in this section. Nevertheless, utilization data were available for Western-built jets, and accident rates are included in section 10.

5.1 Fatal Accidents by Year

The group studied 287 worldwide fatal accidents during approach and landing that occurred between 1980 and 1996 inclusive. The numbers of fatal ALAs are shown by year in Figure 1 (page 128).

ALAs to Eastern-built aircraft and operators from the U.S.S.R. or C.I.S. were not included prior to 1990 because information was not available, was limited or was scarce.

There was an average of 12.1 accidents per year for the non-C.I.S. accidents in the first eight years of the study and 16.6 accidents per year in the last eight years; this shows a marked growth in the number of accidents. The average growth (best mean line) is 0.37 accidents per year; if this growth continued one could expect 23 fatal accidents to Western-built and Western-operated jets and turboprops (including business jets) annually by 2010.

5.2 Fatalities by Year

The total ALAs resulted in 7,185 fatalities to passengers and crew members, an average of 25 fatalities per accident or 63 percent of the aircraft occupants, as shown in Figure 2 (page 129).

(continued page 128)

Data Support Safety Actions Recommended by FSF Approach-and-landing Accident Reduction Task Force

Flight Safety Foundation (FSF) presented the conclusions and recommendations of its work-in-progress to prevent approach-and-landing accidents (ALAs), during its 43rd annual Corporate Aviation Safety Seminar (CASS), May 5–7, 1998, in Hartford, Connecticut, U.S.

"There is a high level of confidence in these conclusions and recommendations," said Pat Andrews, manager, global aircraft services, Mobil Business Resources Corp., and co-chair of the Operations and Training Working Group under the FSF international Approach-and-landing Accident Reduction (ALAR) Task Force. "Our confidence is based upon analysis of ALAs and a confidence check accomplished through the assessment of crew performance in line audits conducted under Professor Robert Helmreich at the University of Texas."

The task force's primary goal is to reduce commercial jet aircraft ALAs by 50 percent within five years after the task force's final recommendations, which are applicable to most aircraft operations, including business/corporate jet operations. Comprehensive ALA data have been collected and analyzed by the U.K. Civil Aviation Authority (CAA) in the study commissioned for the Foundation: "Study of Fatal Approach-and-landing Accidents 1980–1996." The study includes fatal ALAs worldwide for both jet and turboprop aircraft with a maximum takeoff weight greater than 12,500 pounds (5,700 kilograms).

"Available data make clear that our greatest efforts to prevent ALAs must be in Africa, Latin America and Asia," said Andrews.

The operations group, in developing its conclusions and recommendations, targeted all operations occurring from the commencement of an instrument approach or a visual approach, including circling, landing and missed-approach procedure.

Included in the group's recommendations are proposed tools to further help prevent ALAs. A document would provide comprehensive principles and guidelines to reduce risk associated with approach and landing operations, including specific information for management, flight operations, flight crews, dispatch/schedulers, air traffic controllers and airport managers. Planning guides for risk assessment, an educational video program and a CEO briefing are other proposed tools.

The nine conclusions and their respective recommendations are below:

1. **Establishing and adhering to adequate standard operating procedures (SOPs) and crew resource management (CRM) processes improves approach and landing safety.**

    - States should mandate and operators should develop/implement SOPs for approach and landing operations;
    - Operators should develop SOPs that permit their practical application in a normal operating environment; input from flight crews is essential in the development and evaluation of SOPs;
    - Operators should provide education and training that enhance flight crew decision-making and risk management (error management); and,
    - Operators should implement routine and critical evaluation of SOPs to determine the need for change.

2. **Improving communication and mutual understanding between air traffic control personnel and flight crews of each other's operational environment will improve approach and landing safety.**

    Specific recommendations are being developed to support this conclusion. Nevertheless, this conclusion suggests that CRM must be broadened to include a better-managed interface between flight crews and air traffic control personnel. Analysis reveals that compromises to approach and landing safety (e.g., rushed approaches) often result from misunderstanding or lack of knowledge about each other's operational environment.

3. **Unstabilized and rushed approaches contribute to ALAs. Operators should define in their flight operations manuals the parameters of a stabilized approach and include at least the following:**

    1. Intended flight path;
    2. Speed;
    3. Power setting;
    4. Attitude;
    5. Sink rate;
    6. Configuration; and,
    7. Crew readiness.

A suggested definition or policy that might be considered by operators:

All flights shall be stabilized by 1,000 feet (305 meters) height above touchdown (HAT). An approach is considered stabilized when the following criteria are met:

- The aircraft is on the correct flight path;
- Only small changes in heading and pitch are required to maintain the flight path;
- The aircraft speed is not more than V_{ref} +20 knots indicated airspeed (KIAS) and not less than V_{ref} -5 KIAS;
- The aircraft is in approach or landing configuration. Note that many light twin-engine airplanes have limited single-engine go-around capability and that they should not be configured for landing until the landing is assured;
- Sink rate is no more than 1,500 feet (457.5 meters) per minute;
- Power setting is minimum specified for type of aircraft; and,
- All briefings and checklists have been performed.

Specific types of approaches are considered stabilized if they also fulfill the following:

- Instrument landing system (ILS) approaches — must be flown within one dot of the glide path or localizer, and a Category II approach or Category III approach must be flown within the expanded localizer band;
- Visual approaches — wings must be level on final when the aircraft reaches 500 feet (152.5 meters) HAT;
- Circling approaches — wings must be level on final when the aircraft reaches 300 feet (91.5 meters) HAT.

- Corporate policy should state that a go-around is required if the aircraft becomes unstabilized during the approach. Training should reinforce this policy.
- Before descent, a checklist-triggered risk assessment by the crew for the upcoming approach should be company SOP. Prior to commencement of the approach, the crew should confirm the risk assessment;
- The implementation of constant-angle and rate-of-descent procedures for nonprecision approaches should be expedited globally; and,
- Training should be made available to flight crews for learning proper use of constant-angle descent procedures as well as approach-design criteria and obstacle-clearance requirements.

4. **Failure to recognize the need for and to execute a missed approach when appropriate is a major cause of ALAs.**

   - Company policy should specify go-around gates for approach and landing operations. Parameters should include:
     - Visibility minimums required prior to proceeding past the final approach fix (FAF) or the outer marker (OM);
     - Assessment at FAF or OM of crew readiness and aircraft readiness for the approach;
     - Minimum altitude at which the aircraft must be stabilized; and,
   - Companies should declare and support no-fault go-around and missed-approach policies.

5. **The risk of ALAs is higher in operations conducted during conditions involving:**

   1. Low light;

   2. Poor visibility;

   3. The likelihood of optical illusions; and,

   4. Wet or otherwise contaminated runways.

   - Tactical use should be made of a risk-assessment tool/checklist to identify hazards, the associated risks and appropriate procedures to reduce risks;
   - Operators should develop procedures to assist crews in planning and controlling approach angle and rate of descent during approaches; and,
   - Operators should develop a policy requiring the use of all available navigation and approach aids for each approach flown.

6. **Using the radio altimeter as an effective tool will prevent ALAs.**

   - Educational tools are needed to improve crew awareness of radio-altimeter operation and benefits;
   - Companies should state that the radio altimeter is to be used, and specify procedures for its use; and,
   - Manufacturers should design equipment that allows for native-language callouts.

7. **When the pilot-in-command (PIC) is the pilot flying (PF), and the operational environment is complex, the task profile and workload reduce PF flight management efficiency and decision-making capability in approach and landing operations.**

   - There should be a clear policy in the operator's manual defining the role of the PIC in complex and demanding flight situations; and,

   - Training should address the practice of transferring PF duties during operationally complex situations.

8. **In-flight monitoring of crew/aircraft parameters (e.g., flight operations quality assurance [FOQA] program) identifies performance trends that operators can use to improve the quality of approach and landing operations. Performance improvement will result only if these data are managed sensitively and deidentified.**

   - FOQA should be implemented worldwide in tandem with information-sharing partnerships such as Global Analysis and Information Network (GAIN), British Airways Safety Information System (BASIS) and Aviation Safety Action Programs (ASAP). Deidentification of data (i.e., pilots cannot be identified) must be a cardinal requirement;

   - Examples of FOQA benefits (safety and cost reductions) should be publicized widely; and,

   - A process should be developed to bring FOQA and information-sharing partnerships to regional airlines and business aviation.

9. **Global sharing of aviation information decreases the risk of ALAs.**

   - Standardized global aviation phraseology should be used by all pilots and air traffic control personnel;

   - FOQA and information-sharing partnerships should be implemented worldwide;

   - Deidentification of aviation information data sources must be a cardinal requirement; and,

   - Public awareness of the importance of information sharing must be increased in a coordinated, professional and responsible way.

The FSF ALAR Task Force was created in June 1996 as a follow-on to the FSF international Controlled-flight-into-terrain (CFIT) Task Force. Both task forces have received widespread support from the aviation industry worldwide, including the International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA).

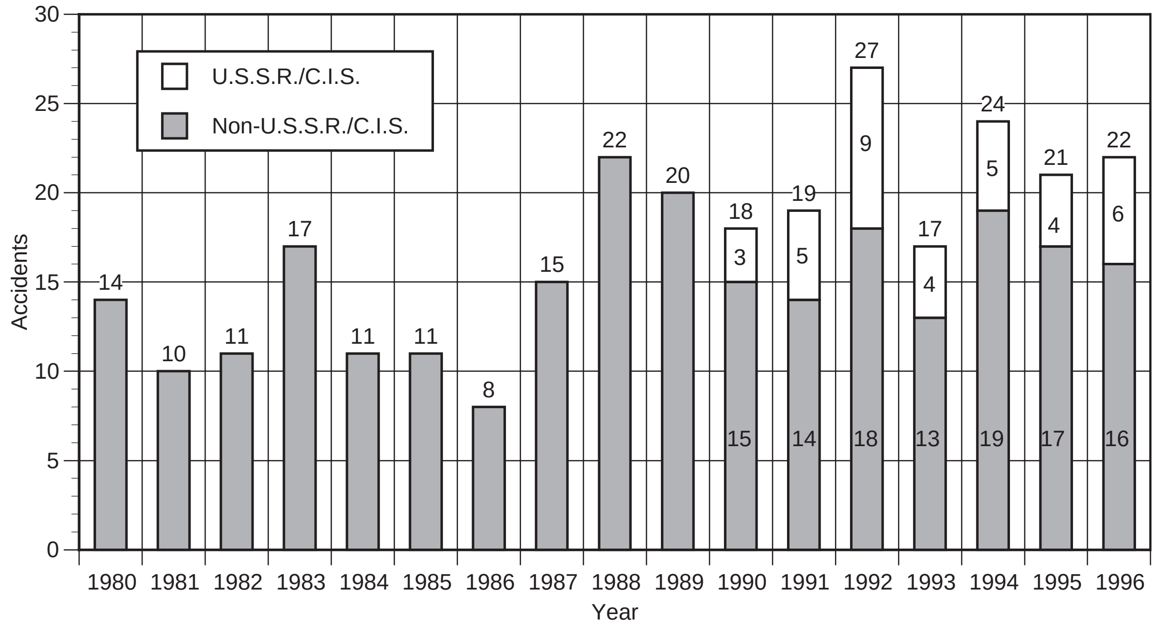
Capt. Erik Reed Mohn, manager, governmental and external affairs, Scandinavian Airlines System (SAS) Flight Academy, co-chairs the operations group, which later created the Data Acquisition and Analysis Working Group to focus on analysis of ALA data and associated research. The data group is co-chaired by Ratan Khatwa, Ph.D., Rockwell-Collins, and Helmreich. Jean-Pierre Daniel, Airbus Industrie, chairs the Equipment Working Group, which was created in 1996 with the operations group, and will present detailed findings later this year.

The operations group includes representatives from AlliedSignal, Airbus Industrie, Air Line Pilots Association International (ALPA), Air Transport Association of America, American Airlines, AMR Eagle, Amsterdam Airport Tower, Amsterdam Airport Schiphol, Avianca, Avianca-SAM, Boeing Commercial Airplane Group, British Airways, China Southern Airlines, Delta Air Lines, Garuda Airlines, Hewlett-Packard, ICAO, KLM Cityhopper, Mexicana Airlines, National Research Laboratory (NLR)–Netherlands, Pakistan International Airlines, Rockwell-Collins, SAS, Transportation Safety Board (TSB) of Canada, University of Texas, U.S. National Transportation Safety Board (NTSB), US Airways and U.S. Aviation Underwriters.

The data group has undertaken three separate studies: the U.K. CAA's study of ALAs; a separate comprehensive study of 75 official ALA investigation reports, using a methodology that included CAA taxonomy, and found a high correlation between the CAA study of ALAs and the comprehensive study of 75 specific ALA accidents; and a study of 3,000 line audits that aimed to identify pre-cursors of accidents during normal flight operations.

Based on the three studies, the data group formulated conclusions and recommendations in air traffic control, airport authorities, flight crews, flight operations management, regulatory authorities and accident-incident investigation authorities. All these data have been used to develop other task force recommendations.

The data group includes representatives from Airbus Industrie, ALPA International, American Airlines, Amsterdam Airport Schiphol, Amsterdam Airport Tower, Australian Bureau of Air Safety Investigation, Aviacsa Aeroexo, The Boeing Co., British Aerospace, British Airways, Continental Airlines, Cranfield University Safety Center, Dutch ALPA, FlightSafety Boeing, Honeywell, IATA, ICAO, International Federation of Air Line Pilot's Association, KLM Cityhopper, NLR - Netherlands, NTSB, Rockwell-Collins, Southwest Airlines, TSB of Canada, U.K. Air Accidents Investigation Branch, U.K. CAA, and University of Texas.♦


287 Fatal ALAs Worldwide, by Year
1980-1996

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Figure 1

In 1992, there were 970 fatalities, almost twice the annual average of 540 of the years 1990–1996 (in which U.S.S.R./C.I.S. data are included).

In the first eight years of the study, there was an average of 300 fatalities per year for the non-U.S.S.R./C.I.S. accidents, compared with 428 for the last eight years. The “best mean line” growth was 6 percent per year. Though such growth continuing would lead to an annual average of 495 by 2010, there is reason to believe that the figures since 1992 may indicate improvement.

5.3 Phase of Flight

The group allocated one of 14 phases of flight to its analysis of worldwide accidents, based on accident information from Airclaims.[2] This study looks more closely at the accidents in just three of these phases of flight, as shown in Table 1. The selection of flight phase was based on judgment rather than precise criteria.

Those accidents that occurred in other closely related phases, i.e., descent, hold and go-around, were not included. The accidents are fairly evenly distributed among the three phases of flight considered.

Table 1
287 Fatal ALAs Worldwide, By Phase of Flight 1980–1996

Phase of Flight	**Fatal ALAs**
Approach	108
Final approach	82
Landing	97
Total	**287**

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

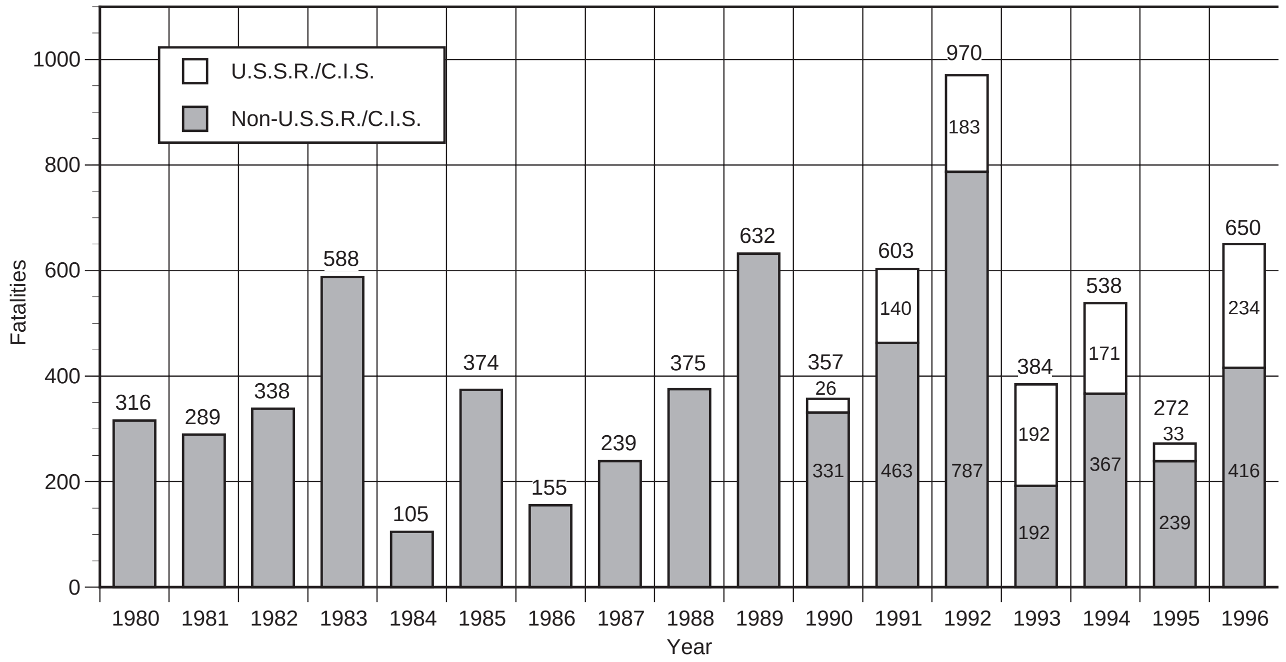
Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

5.4 Accident Locations by Region

The number of ALAs in each of the world regions in which the 287 fatal accidents occurred is shown in Table 2 (page 129). The figures in the right-hand column show the percentage

Fatalities in 287 ALAs Worldwide, by Year, 1980–1996



ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/ 12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Figure 2

Table 2
287 Fatal ALA Locations, by Region* 1980–1996

Region	Fatal ALAs	Percent of Region's Fatal Accidents
North America	74	44%
South/Central America	67	49%
Asia	43	35%
Africa	34	49%
Europe	62	57%
Australasia	7	50%
Total	**287**	

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

*Regions defined by Airclaims and shown in Appendix 2.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

of the fatal accidents in *all* phases of flight in the region that occurred during the three approach-and-landing flight phases.

The regions are those defined by Airclaims (Appendix 2). "Europe," however, includes the U.S.S.R. and C.I.S.

To understand the full significance of these figures, one needs to know the numbers of relevant flights in each region and hence the accident rates; these figures are not currently available. (See section 10, page 134, for more comprehensive data on Western-built jets.)

The percentage of accidents occurring during approach and landing might be expected to reflect the frequency of bad weather, terrain problems and availability of precision approach aids. All regions, however, have figures of 50 percent ± 7 percent, except Asia, where such accidents are clearly a lower proportion of the total (35 percent).

5.5 Accidents by Region of Operator

The accidents are shown in Table 3 (page 130) by region of operator. Because of the marked difference in regulatory arrangements between the two groups, Europe has been divided into the Joint Aviation Authorities (JAA) full-member countries (see Appendix 3) and the "rest of Europe," which includes JAA candidate members and nonmembers. (See 10.7, page 140.)

Table 3
287 Fatal ALAs Worldwide, By Region* of Operator 1980–1996

Region	Fatal ALAs
North America	78
South/Central America	67
Asia	42
Africa	31
Europe	64
JAA full-member countries	30
All other European countries	34
Australasia	5
Total	**287**

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds.

U.S.S.R. – Union of Soviet Socialist Republics
C.I.S. – Commonwealth of Independent States

JAA – Joint Aviation Authorities

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

* Regions defined by Airclaims and shown in Appendix 2.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

The distribution of fatal accidents by region of operator is not markedly different from the distribution of accident locations by region.

Again, the numbers of flights flown by all of the classes of aircraft covered and by region are not currently available, so that it was not possible to present accident rates.

5.6 Service Type

The 287 fatal accidents occurred during the types of service shown in Table 4.

Though the actual numbers of flights for all classes of aircraft are not available, data indicate that there is a much higher accident rate on freight/ferry/positioning flights than on passenger flights. During the period 1990–1996 inclusive, 3.6 percent of the international and domestic flights during scheduled services of International Air Transport Association (IATA) members involved all-cargo flights.[4] CAA's data on fixed-wing air transport movements at U.K. airports[5] from 1986 to 1996 for aircraft having greater than 5,700 kilograms/12,500 pounds MTOW showed that an average of 5 percent were all-cargo flights; there was a steady increase in this period from 4.4 percent in 1986 to 5.6 percent in 1996. The average for the period covered in this study (1980–1996) is therefore estimated to be about 4.6 percent for U.K. airports.

These indications suggest that, overall, the freight/cargo operations together with ferry and positioning flights represent about 5 percent of the number of flights carried out in commercial transport operations. This indicates that the fatal accident rate on freight, ferry and positioning flights (i.e., when no fare-paying passengers are on board the aircraft) is some eight times higher than that for passenger flights. This is a surprising and important conclusion considering that the safety and operational standards that should be applied to such flights are generally no different from those for passenger flights.

Table 4
287 Fatal ALAs Worldwide, By Type of Service 1980–1996

Service	Fatal ALAs	Percent of 287 Fatal ALAs
Passenger	177	62%
Freight/ferry/positioning	73	25%
Business/other revenue	30	10%
Training/other nonrevenue	7	3%
Total	**287**	**100%**

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds.
U.S.S.R. – Union of Soviet Socialist Republics
C.I.S. – Commonwealth of Independent States
Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

5.7 Aircraft Classes

The classes of aircraft involved in the accidents analyzed are shown in Table 5.

Table 5
287 Fatal ALAs Worldwide, By Class of Aircraft 1980–1996

Class	Fatal ALAs	Percent of 287 Fatal ALAs
Western-built jets	92	32%
Eastern-built jets	16	6%
Western-built turboprops	84	29%
Eastern-built turboprops	19	7%
Business jets	76	26%
Total	**287**	**100%**

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds.

U.S.S.R. – Union of Soviet Socialist Republics
C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Accidents involving Western-built jets are reviewed in more detail in section 10.

5.8 Type of Approach

In 169 (59 percent) of the accidents, the type of approach used was not known. The breakdown of the remainder is shown in Table 6.

Table 6
118 Fatal ALAs Worldwide, By Type of Approach 1980–1996

Type of Approach	Fatal ALAs	Percent of 118 Fatal ALAs*
Visual	49	41%
ILS or ILS/DME	30	25%
VOR/DME	16	13%
NDB	11	9%
VOR	10	8%
Other (SRA or DME)	2	4%
Total	**118**	**100%**

*Where the type of approach was known.

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds.
U.S.S.R. – Union of Soviet Socialist Republics
C.I.S. – Commonwealth of Independent States
ILS – instrument landing system
DME – distance measuring equipment
VOR – very high frequency omnidirectional radio
NDB – nondirectional beacon
SRA – surveillance-radar approach

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Of those accidents where the type of approach was known, only 25 percent occurred during approaches and landings where a precision approach aid was available. It is suspected that precision approach aids were not available in some of the accidents where no information on the type of approach was found; if so, then much more than 75 percent of ALAs occurred when a precision approach aid was not available or not used.

5.9 Night, Day, Twilight

It might be assumed that night approaches result in more difficulties caused, for example, by fewer visual cues or by spatial disorientation. Similarly, it is possible that the twilight hours could present particular problems. Where known, the ALAs have been allocated to day, night or twilight — the latter being broadly defined as times close to local sunrise and sunset. The results are shown in Table 7.

Table 7
287 Fatal ALAs Worldwide, by Time of Day 1980–1996

Time	Fatal ALAs	Percent of 287 Fatal ALAs
Day	143	50%
Night	112	39%
Twilight	5	2%
Not known	27	9%
Total	**287**	**100%**

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds.
U.S.S.R. – Union of Soviet Socialist Republics
C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

A global figure for the proportion of landings made at night is not known, but discussions with airlines and airfield operators suggest that the figure is about 20 percent to 25 percent. If this is correct, then the rate for ALAs at night is nearly three times that for day. No conclusion can be drawn from the twilight figure.

When ALAs are broken down by aircraft class, business jets — with 76 ALAs — suffered an even higher proportion of accidents at night. Of those 66 business-jet ALAs (87 percent) where the lighting conditions were known, 36 ALAs (55 percent) occurred at night and 27 ALAs (41 percent) occurred during daylight.

5.10 Level of Confidence

The level of confidence reflected the group's confidence in the completeness of the accident summary and consequently the factors allocated for each accident, as detailed in 3.5. Of the 287 fatal ALAs, 152 were allocated a high level of confidence, as shown in Table 8 (page 132).

Causal factors were allocated to all but the eight accidents (3 percent) where there was believed to be insufficient information. The factors from all of the other accidents (279) were used in the analysis. There was little difference in the proportion of accidents allocated given levels of confidence for each aircraft class, e.g., 53 percent and 61 percent of those involving Western-built jets and turboprops, respectively, were allocated high levels of confidence.

6.0 Analysis of Primary Causal Factors

6.1 Primary Causal Factors — Overall

In the accident review carried out by the AAG, any number of causal factors may have been allocated, with one identified to

Table 8
Level of Confidence in Completeness of Accident Summary of 287 Fatal ALAs Worldwide
1980–1996

Level	Fatal ALAs	Percent of 287 Fatal ALAs
High	152	53%
Medium	104	36%
Low	23	8%
Insufficient information	8	3%
Total	**287**	**100%**

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds.
U.S.S.R. – Union of Soviet Socialist Republics
C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

be the primary causal factor. Of the 287 ALAs, eight were judged to have insufficient information available, leaving 279 for which causal factors were allocated.

The most frequently identified primary causal factors in the overall sample of 279 accidents are shown in Table 9.

Table 9
Most Frequent Primary Causal Factors In 279 Fatal ALAs Worldwide
1980–1996

Primary Causal Factor*/**	Fatal ALAs	Percent of 279 Fatal ALAs
Omission of action/ inappropriate action	69	24.7%
Lack of positional awareness in the air	52	18.6%
Flight handling	34	12.2%
"Press-on-itis"	31	11.1%
Poor professional judgment/airmanship	12	4.3%
Total	**198****	

*For which sufficient information was known to allocate causal factors.

**Some ALAs had primary causal factors not among the five most frequent primary causal factors.

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds.
U.S.S.R – Union of Soviet Socialist Republics
C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

These five most frequently identified primary causal factors (out of a possible 64) account for 71 percent of the accidents. All five primary causal factors are from the "crew" causal group, indicating that crew factors were involved.

In these ALAs, the most common primary causal factor, "omission of action/inappropriate action," generally referred to the crew continuing the descent below the decision height (DH) or minimum descent altitude (MDA) without visual reference, or when visual cues were lost. The second most frequent factor, "lack of positional awareness in the air," generally involved a lack of appreciation of the aircraft's proximity to high ground, frequently when the aircraft was not equipped with a GPWS and/or when precision approach aids were not available; these were generally CFIT accidents.

Considering the causal groups ("A" in Appendix 1), rather than individual factors, "crew" featured in 228 of the 279 accidents (82 percent), followed by "environmental" in 14 (5 percent).

The complete summaries of causal factors allocated, including primary causal factors, are shown in Appendix 4.

6.2 Primary Causal Factors by Aircraft Class

When each aircraft class is considered separately, there are considerable differences in the most frequently identified primary causal factors. Table 10 (page 133) shows the ranking of various primary factors for each class; the figures in parentheses are the percentages of the accidents for that aircraft class.

It is noteworthy that for the aircraft built and operated in the U.S.S.R./C.I.S., "press-on-itis" is the most frequent primary cause, but this is generally fourth in the ranking for other aircraft classes. "Flight handling" ranks first for Western-built turboprops, even though it is only third overall.

7.0 Analysis of All Causal Factors

7.1 All Causal Factors — Overall

As stated, the AAG allocated any number of causal factors to each accident. Frequently, an accident results from a combination of causal factors, and it is important to see the overall picture (the other contributing factors as well as the primary causal factor) rather than just the single primary factor. For this part of the analysis, primary factors have been included along with all others. The average number of causal factors allocated was 3.8. The largest number of causal factors allocated was 10.

The most frequently identified causal factors in the sample of 279 accidents are shown in Table 11 (page 134).

Table 10
Ranking of Primary Causal Factors in 279 Fatal ALAs Worldwide, by Aircraft Class 1980–1996

Primary Causal Factor	Overall Ranking	Western-built Jets	Eastern-built Jets	Western-built Turboprops	Eastern-built Turboprops	Business Jets
Omission of action/ inappropriate action	1 (24.7%)	1 (27.4%)	= 2 (12.5%)	3 (17.1%)	2 (18.7%)	1 (31.1%)
Lack of positional awareness in the air	2 (18.6%)	2 (16.5%)	= 2 (12.5%)	= 1 (19.5%)	3 (12.5%)	2 (20.3%)
Flight handling	3 (12.2%)	= 3 (9.9%)	= 4 (6.3%)	= 1 (19.5%)	= 4 (6.3%)	3 (9.5%)
“Press-on-itis”	4 (11.1%)	= 3 (9.9%)	1 (31.2%)	4 (8.5%)	1 (37.5%)	= 4 (5.4%)
Poor professional judgment/airmanship	5 (4.3%)	5 (5.5%)	•	= 6 (3.7%)	•	= 4 (5.4%)
Deliberate nonadherence to procedures	6 (2.9%)	= 7 (2.2%)	•	= 8 (2.4%)	= 4 (6.3%)	= 6 (4.1%)
Wind shear/upset/ turbulence	7 (2.2%)	= 7 (2.2%)	= 4 (6.3%)	= 6 (3.7%)	•	•
Failure in CRM (cross-check/coordinate)	8 (1.8%)	= 14 (1.1%)	•	5 (4.9%)	•	•
Icing	= 9 (1.4%)	•	•	= 11 (1.2%)	= 4 (6.3%)	= 8 (2.7%)
System failure • flight deck information	= 9 (1.4%)	= 14 (1.1%)	= 4 (6.3%)	= 11 (1.2%)	•	=10 (1.4%)

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/ 12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States CRM – crew resource management • – No fatal ALAs were attributed to this primary causal factor in this class of aircraft.

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Note: The complete list of primary causal factors has been shortened for this table. Factors that ranked high in the overall list (first column) sometimes ranked lower for specific types of aircraft. In some instances, two or more primary causal factors occurred in equal numbers of accidents, and the factors were assigned equal rankings. For example, some columns may contain two 3s, three 4s, etc.
In several instances, a factor shown in the table occurred in equal numbers of accidents with a factor not shown because the factor not shown was not among those ranked 1 through 9 in the “overall ranking” column.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

The figures in the right-hand column indicate the proportion of the 279 accidents to which the particular causal factor was allocated; remember that each accident usually has several factors applied to it. Once again, all the five causal factors most frequently selected were in the “crew” causal group.

The three most frequently identified causal factors each appear in about 40 percent or more of all accidents.

7.2 All Causal Factors by Aircraft Class

The ranking of the various most frequent causal factors is shown for each aircraft class in Table 12 (page 135).

Again, “press-on-itis” appears as the most frequent, or equally most frequent, causal factor for aircraft built and operated in the C.I.S., whereas it ranked only sixth overall. “Deliberate nonadherence to procedures” is seen also to be more frequent for the C.I.S. aircraft than for Western-built and -operated jets; to a lesser extent, business jets also rank higher on this factor.

8.0 Analysis of Circumstantial Factors

8.1 Circumstantial Factors — Overall

As stated in 3.3, a circumstantial factor was an event or aspect that was not directly in the causal chain of events but could have contributed to the accident. The average number of circumstantial factors was 2.7. The most frequently identified circumstantial factors in the sample of 279 accidents are shown in Table 13 (page 136).

The “nonfitment of presently available safety equipment” referred, in the great majority of accidents, to the lack of GPWS or, in some cases, lack of enhanced GPWS of the type that is now (even if not at the time of the accident) available; this was intended to estimate how many accidents such equipment might prevent in the future.

“Failure in CRM” also ranked high as a causal factor. A judgment was made as to whether the lack of good CRM was actually one of the causes that led to the accident, in

Table 11
Most Frequent Causal Factors In 279 Fatal ALAs Worldwide 1980–1996

Causal Factor*	Cited in Fatal ALAs	Percent of 279 Fatal ALAs
Lack of positional awareness in the air	132	47.3%
Omission of action/ inappropriate action	121	43.4%
Slow and/or low on approach	109	39.1%
Flight handling	81	29.0%
Poor professional judgment/airmanship	68	24.3%
Total	**511****	

* For which sufficient information was known to allocate causal factors.

** Most ALAs had multiple causal factors.

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds.

U.S.S.R. – Union of Soviet Republics

C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

which case it was allocated as a causal factor, or inadequate CRM appeared to be present, and if it had been to a higher standard, might have helped to prevent the accident (i.e., a circumstantial factor).

8.2 Circumstantial Factors by Aircraft Class

The ranking of the most frequent circumstantial factors is shown for each aircraft class in Table 14 (page 136).

There is some consistency in the five circumstantial factors that occur most frequently, except for Eastern-built turboprops. The "nonfitment of presently available safety equipment" (essentially GPWS) was judged to be a factor in 47 percent of all ALAs. "Failure in CRM" was also a factor in at least 37 percent of all the aircraft groups. Lack of ground aids — basically, the lack of a precision approach aid or navigational aid — was an important factor (at least 25 percent of the accidents) across aircraft classes.

9.0 Analysis of Consequences

9.1 Consequences — Overall

As stated before, consequences are not seen as part of the causes of accidents, but are relevant to a complete understanding of the accident history. A full list of the 15 consequences considered is shown in Appendix 1. The average number of consequences allocated was 1.9. Consequences were allocated even to those accidents (eight) that the AAG considered to have insufficient information for the selection of causal or circumstantial factors. The most frequently identified consequences in this sample of 287 ALAs are shown in Table 15 (page 137).

"Collision with terrain/water/obstacle" and "CFIT" were the most frequent consequences. The former implied that control of the aircraft had been lost (i.e., "loss of control in flight" would also have been allocated), or severe weather or some other factor had contributed to the impact; "CFIT," on the other hand, was allocated when the aircraft was flown into the ground and under full control. Where the impact with terrain occurred in circumstances where it was not clear whether or not the aircraft was under control, the former consequence was applied; this almost certainly underestimates the number of CFIT accidents.

Postimpact fire occurred in nearly a quarter of the accidents (and probably occurred in more). It should be noted that "postimpact fire" was given as a consequence whenever it was known to have occurred. It also appears for some accidents as a causal factor; this indicates that in these accidents it was judged to have contributed to the fatalities. (See 7.2, page 133.)

"Undershoots" can be seen to have been involved in many fatal accidents; "overruns" were features of about half as many accidents — presumably because overruns are less often fatal, rather than because they occur less often.

9.2 Consequences by Aircraft Class

The ranking of the most frequent consequences is shown for each aircraft class in Table 16 (page 137).

The pattern of consequences is moderately consistent. "Collision with terrain/water/obstacle" is the most frequently cited consequence overall and in three of the five aircraft classes. But Eastern-built jets have "overrun" as a consequence at nearly twice the frequency of the overall sample.

10.0 Analysis of Western-built Jets

This section presents an analysis of Western-built jet airliner operations by world regions; business jets are in a separate class. Airclaims has provided utilization data, including numbers of flights flown annually for this category of aircraft. The fatal accident rates are shown in relation to the number of flights, which provide the most useful and valid criterion to indicate safety standards. (See 3.7, page 124.)

Ninety-two of the 287 fatal ALAs (32 percent) involved Western-built jets.

Table 12
Ranking of All Causal Factors in 279 Fatal ALAs Worldwide, by Aircraft Class 1980–1996

Causal Factor	Overall Ranking	Western-built Jets	Eastern-built Jets	Western-built Turboprops	Eastern-built Turboprops	Business Jets
Lack of positional awareness in the air	1 (47.3%)	1 (44.0%)	= 1 (43.7%)	2 (42.7%)	2 (37.5%)	1 (59.5%)
Omission of action/ inappropriate action	2 (43.4%)	1 (44.0%)	3 (37.5%)	1 (43.9%)	= 3 (31.2%)	3 (45.9%)
Slow and/or low on approach	3 (39.1%)	3 (35.2%)	4 (31.2%)	4 (39.0%)	= 3 (31.2%)	2 (47.3%)
Flight handling	4 (29.0%)	5 (27.5%)	= 6 (18.7%)	3 (40.2%)	= 5 (25.0%)	5 (21.6%)
Poor professional judgment/airmanship	5 (24.3%)	4 (30.8%)	= 9 (12.5%)	7 (19.5%)	= 7 (18.7%)	4 (25.7%)
"Press-on-itis"	6 (21.5%)	6 (17.6%)	= 1 (43.7%)	6 (20.7%)	1 (50.0%)	6 (16.2%)
Failure in CRM (cross-check/coordinate)	7 (15.8%)	7 (16.5%)	= 6 (18.7%)	5 (22.0%)	•	8 (10.8%)
Postimpact fire	= 8 (11.8%)	= 8 (14.3%)	= 9 (12.5%)	= 8 (13.4%)	= 10 (12.5%)	12 (6.8%)
Deliberate nonadherence to procedures	= 8 (11.8%)	= 17 (6.6%)	= 6 (18.7%)	10 (11.0%)	= 5 (25.0%)	7 (14.9%)

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/ 12,500 pounds. C.I.S. – Commonwealth of Independent States CRM – crew resource management • – No fatal ALAs were attributed to this causal factor in this class of aircraft.

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Note: The complete list of all causal factors has been shortened for this table. Factors that ranked high in the overall list (first column) sometimes ranked lower for specific types of aircraft. In some instances, two or more factors occurred in equal numbers of accidents, and the factors were assigned equal rankings. For example, some columns may contain two 3s, three 4s, etc. In several instances, a factor shown in the table occurred in equal numbers of accidents with a factor not shown because the factor not shown was not among those ranked 1 through 8 in the "overall ranking" column.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

10.1 Fatal Accidents by Year

The 92 fatal accidents are shown in Figure 3 (page 138).

The number of accidents per year in Western-built jets averages between five per year and six per year, with an increasing trend over the period of the study; the average growth (best mean line) is 0.11 accidents per year. One might hope, however, that the figures since 1992 indicate a decreasing trend.

10.2 Fatalities by Year

The 92 fatal accidents during approach and landing to Western-built jets between 1980 and 1996, inclusive, resulted in 4,696 fatalities to passengers and crew, as shown in Figure 4 (page 139). This gives averages of 51 fatalities per accident and 276 fatalities per year. The overall number of fatalities divided by the number of occupants (passengers and crew) in all the accidents gives a measure of average survivability; this figure is 61 percent.

In the first eight years of the 17-year period, there were 1,804 fatalities compared with 2,662 in the last eight years; this suggests a significantly worsening trend. The growth rate overall (best mean line) averages 4.5 fatalities per year. Both the number of accidents and the number of fatalities are growing by between 1 percent and 2 percent per year. A continuing increase in the number of accidents and the number of fatalities is likely to become unacceptable to the public, unless the trend is definitely checked or reversed.

10.3 Fatal Accidents by Region of Operator

The fatal ALAs for Western-built jets between 1980 and 1996 are shown in Figure 5 (page 139) by region of the operator; there were no such accidents in Australasia.

Europe is shown by the 19 full-member JAA countries in Europe and the other European countries. (See 10.7, page 140.)

10.4 Fatal Accident Rates by Region of Operator

When the numbers of flights are applied to give the fatal accident rates per million flights of Western-built jets for ALAs, the comparisons are different, as shown in Figure 6 (page 140).

Table 13
Ranking of Most Frequent Circumstantial Factors in 279 Fatal ALAs Worldwide 1980–1996

Circumstantial Factor*	Cited in Fatal ALAs	Percent of 279 Fatal ALAs
Nonfitment of presently available safety equipment (GPWS, TCAS, wind-shear warning, etc.)	132	47.3%
Failure in CRM (cross-check/coordinate)	131	47.0%
Weather (other than poor visibility, runway condition)	103	36.9%
Poor visibility	89	31.9%
Lack of ground aids	81	29.0%
Total	**536****	

*For which sufficient information was known to allocate circumstantial factors.
**More than one circumstantial factor could be allocated to a single accident.

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/ 12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States
GPWS – ground-proximity warning system TCAS – traffic-alert and collision avoidance system CRM – crew resource management

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Table 14
Ranking of Most Frequent Circumstantial Factors in 279 Fatal ALAs Worldwide, By Aircraft Class 1980–1996

Circumstantial Factor	Overall Ranking	Western-built Jets	Eastern-built Jets	Western-built Turboprops	Eastern-built Turboprops	Business Jets
Nonfitment of presently available safety equipment (GPWS, TCAS, wind-shear warning, etc.)	1 (47.3%)	1 (44.0%)	= 1 (50.0%)	2 (46.3%)	7 (12.5%)	1 (59.5%)
Failure in CRM (cross-check/coordinate)	2 (47.0%)	2 (41.8%)	= 1 (50.0%)	3 (45.1%)	= 3 (37.5%)	2 (56.8%)
Other weather (other than poor visibility, runway condition)	3 (36.9%)	4 (28.6%)	3 (43.7%)	1 (50.0%)	1 (50.0%)	5 (28.4%)
Poor visibility	4 (31.9%)	3 (31.9%)	= 5 (25.0%)	4 (30.5%)	6 (31.2%)	3 (35.1%)
Lack of ground aids	5 (29.0%)	= 5 (25.3%)	4 (31.2%)	= 5 (26.8%)	= 3 (37.5%)	4 (33.8%)
Inadequate regulatory oversight	6 (23.7%)	= 5 (25.3%)	= 5 (25.0%)	5 (26.8%)	2 (43.7%)	7 (13.5%)

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/ 12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States
GPWS – ground-proximity warning system CRM – crew resource management TCAS – traffic-alert and collision avoidance system

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./ C.I.S. were not included for years before 1990.

Note: The complete list of most frequent circumstantial factors has been shortened for this table. Factors that ranked high in the overall list (first column) sometimes ranked lower for specific types of aircraft. In some instances, two or more factors occurred in equal numbers of accidents, and the factors were assigned equal rankings. For example, some columns may contain two 3s, three 4s, etc. In several instances, a factor shown in the table occurred in equal numbers of accidents with a factor not shown because the factor not shown was not among those ranked 1 through 6 in the "overall ranking" column.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Table 15
Most Frequently Identified Consequences in 287 Fatal ALAs Worldwide 1980–1996

Consequence	Cited in Fatal ALAs	Percent of 287 Fatal ALAs
Collision with terrain/water/obstacle	131	45.6%
Controlled flight into terrain (CFIT)	120	41.8%
Loss of control in flight	74	25.8%
Postimpact fire	65	22.6%
Undershoot	50	17.4%
Total	**440***	

*Some accidents had multiple consequences.

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R. and C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Table 16
Ranking of Identified Consequences in 287 Fatal ALAs Worldwide, by Aircraft Class 1980–1996

Consequence	Overall Ranking	Western-built Jets	Eastern-built Jets	Western-built Turboprops	Eastern-built Turboprops	Business Jets
Collision with terrain/water/obstacle	1 (44.6%)	1 (48.9%)	= 2 (31.2%)	1 (50.0%)	1 (47.8%)	2 (39.5%)
Controlled flight into terrain (CFIT)	2 (41.8%)	2 (34.8%)	1 (56.2%)	2 (40.5%)	= 2 (31.6%)	1 (51.3%)
Loss of control in flight	3 (25.8%)	4 (22.8%)	= 6 (6.2%)	3 (38.1%)	= 2 (31.6%)	4 (18.4%)
Postimpact fire	4 (22.6%)	3 (27.2%)	= 4 (18.7%)	4 (17.9%)	= 5 (12.5%)	3 (26.3%)
Undershoot	5 (17.4%)	5 (18.5%)	= 2 (31.2%)	5 (16.7%)	= 5 (12.5%)	5 (15.8%)
Overrun	6 (9.8%)	6 (14.1%)	4 (18.7%)	6 (6.0%)	= 5 (12.5%)	= 6 (6.6%)
Ground collision with object/obstacle	7 (7.0%)	7 (10.9%)	= 6 (6.2%)	= 9 (2.4%)	= 5 (12.5%)	= 6 (6.6%)

ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

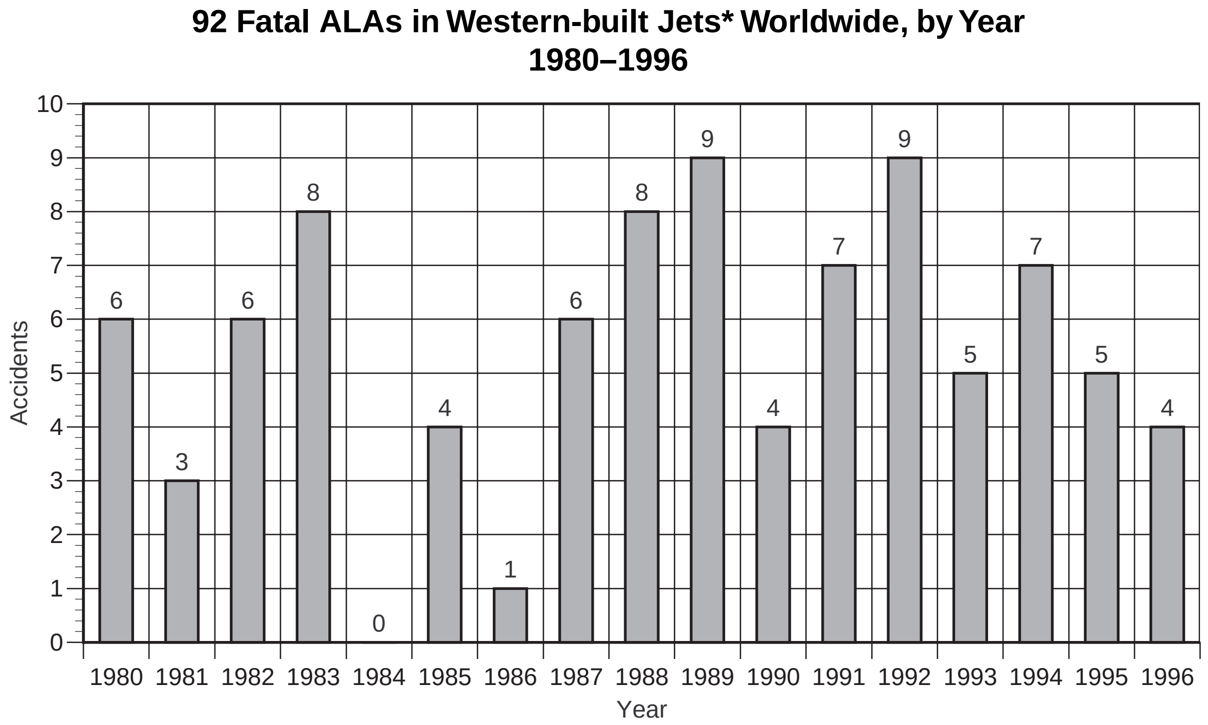
Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Note: The complete list of identified consequences has been shortened for this table. Identified consequences that ranked high in the overall list (first column) sometimes ranked lower for specific types of aircraft. In some instances, two or more identified consequences occurred in equal numbers of accidents, and the identified consequences were assigned equal rankings. For example, some columns may contain two 3s, three 4s, etc. In several instances, a factor shown in the table occurred in equal numbers of accidents with a factor not shown because the factor not shown was not among those ranked 1 through 7 in the “overall ranking” column.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Africa, South and Central America, and Asia are well above the world average, Africa by a factor of more than five. Australasia, North America and, to a lesser extent, Europe are below the world average. Europe is broken down into the JAA and the other European countries in section 10.7.

Australasia’s excellent record of zero fatal accidents merits further consideration. This is against a background of 5.3 million flights; this can be compared, for example, with the North American sample of 14 fatal accidents in 110.8 million flights. If Australasia had the same underlying accident rate



92 Fatal ALAs in Western-built Jets* Worldwide, by Year 1980–1996

*Excludes business jets. ALAs – approach-and-landing accidents involving jet aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Figure 3

as North America, one would expect, on average, one accident every 7.9 million flights; not having had an accident in 5.3 million flights does not necessarily indicate that the Australasian region is any better than North America. Though the record in Australasia is good, one must be very cautious in interpreting this result. (See also 10.5.)

10.5 Fatal Accident Rates "Unlikely to Be Exceeded," by Region of Operator

When analyzing a small number of events, the accident rates derived may not be a reliable indication of the true underlying rates. An accepted method in such a situation is to employ the Poisson distribution to determine the maximum fatal accident rates, to a given level of confidence, within which range the underlying rates are likely to fall. For this analysis, this method was applied to determine the accident rate which, to a 95 percent confidence level, is unlikely to be exceeded. This provides pessimistic figures for the accident rates, for which there is only a 5 percent probability that the true underlying rates will exceed.

These rates unlikely to be exceeded are determined by:

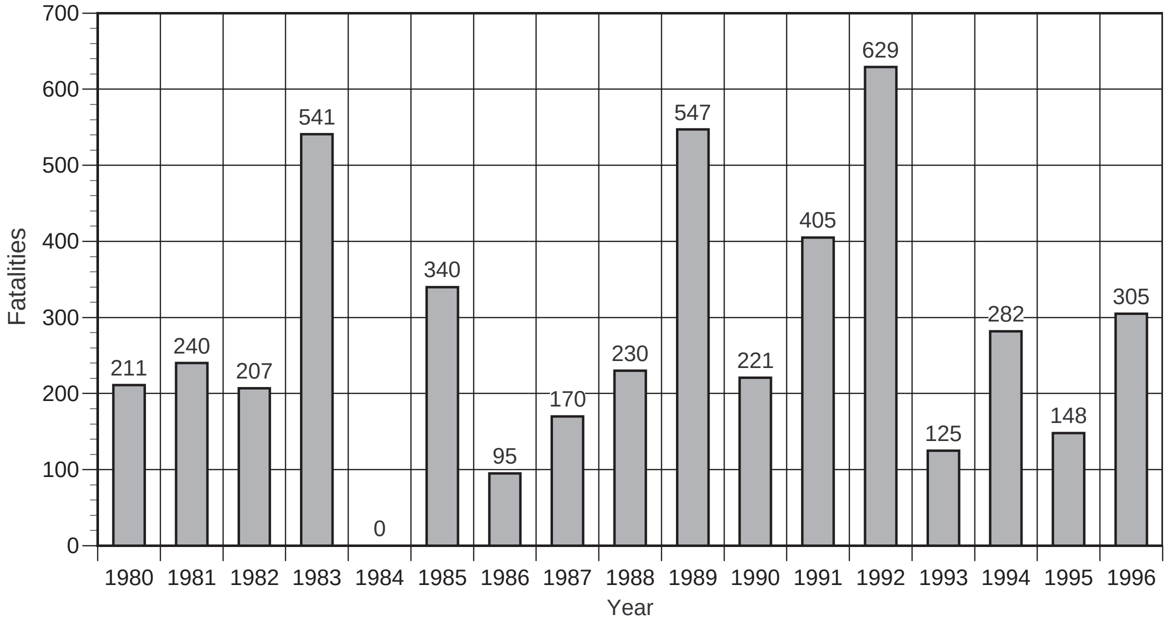
- Considering the number of fatal accidents for each population;
- Determining, using Poisson distribution data, the number of fatal accidents that is unlikely to be exceeded to the defined level of confidence (95 percent); and,
- Dividing this latter figure by the number of flights to obtain a fatal accident rate that is equally unlikely to be exceeded.

The accident rates that the underlying rates are unlikely to exceed are shown in Figure 7 (page 141).

Note that when a 95 percent level of confidence is applied to the fatal accident rates, Australasian operators have a notional accident rate figure, which is unlikely to be exceeded, of 0.57 per million flights rather than the actual rate of zero. This takes into account the relatively few flights accrued by operators in that region.

10.6 Fatalities by Region of Operator

The number of fatalities occurring in Western-built jets in ALAs between 1980 and 1996 inclusive was 4,696. The figures are shown by region of operator in Figure 8 (page 142).



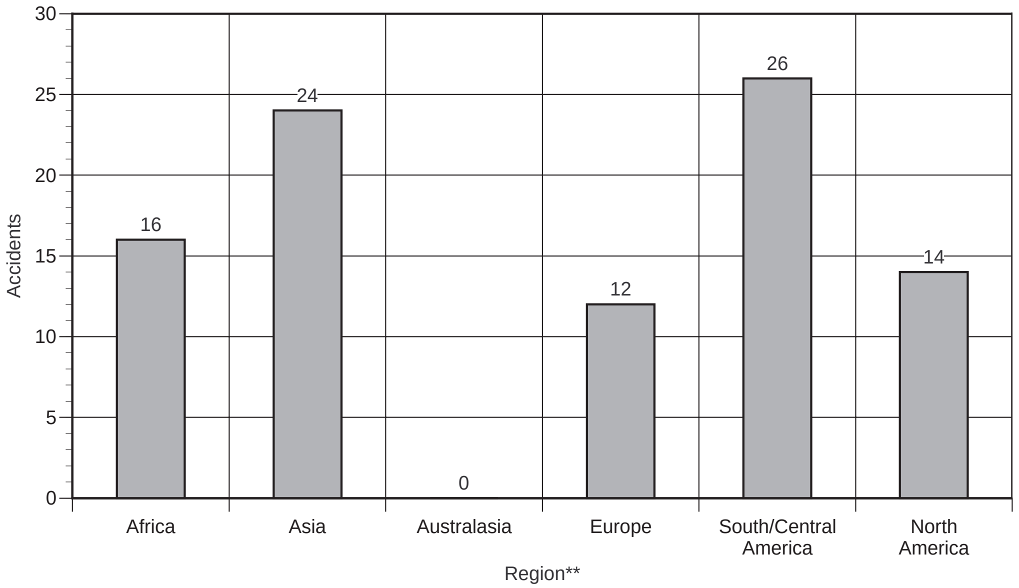
Fatalities in 92 Fatal ALAs in Western-built Jets,* by Year 1980–1996

*Excludes business jets. ALAs – approach-and-landing accidents involving jet aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Figure 4



92 Fatal ALAs in Western-built Jets,* by Region of Operator

*Excludes business jets. JAA – Joint Aviation Authorities ALAs – approach-and-landing accidents involving jet aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

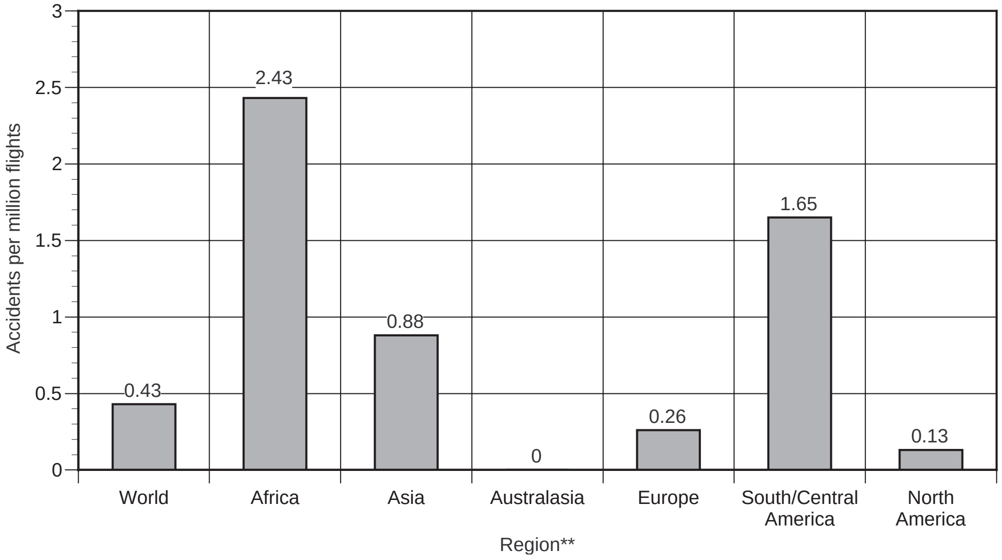
Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

**Regions defined by Airclaims and shown in Appendix 2.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Figure 5

92 Fatal ALAs in Western-built Jets,* Rates by Region of Operator



*Excludes business jets. ALAs – approach-and-landing accidents involving jet aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

**Regions defined by Airclaims and shown in Appendix 2.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Figure 6

10.7 Fatal Accident Rates for the JAA Countries and Other European Countries

As mentioned earlier, Europe is divided into the JAA countries, which use a common set of safety regulations and comprise 19 full-member countries, and the other European countries. Of the 12 fatal ALAs involving European operators (Figure 5, page 139), seven involved JAA operators and five involved operators from the other European countries. The numbers of flights for each group of countries were 42.8 million and 3.04 million respectively. This gives the following fatal accident rates for approach-and-landing accidents:

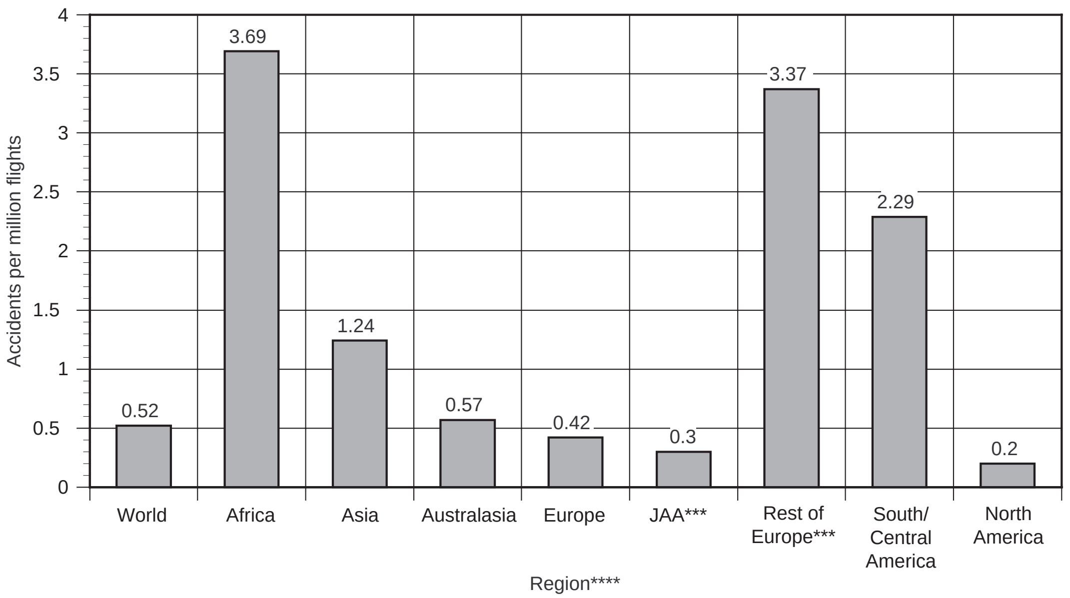
- JAA full-member countries: 0.164 per million flights; and,
- Other European countries: 1.640 per million flights.

The JAA full-member countries, therefore, have an accident rate 10 times better than the other European countries, and comparable with North America.

11.0 Conclusions

An analysis has been carried out to establish the primary causal factors, causal factors, circumstantial factors and consequences of the 287 fatal accidents recorded on the U.K. CAA database for its *Global Fatal Accident Review* that occurred during approach, final approach and landing.[1] This covered all such known accidents to jet and turboprop airplanes having greater than 5,700 kilograms/12,500 pounds MTOW, including business jets, between 1980 and 1996. It excluded test flights and accidents resulting from terrorism and sabotage; Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were excluded prior to 1990. The following main conclusions were drawn:

1. There was an average of 14.8 fatal accidents during approach and landing per year for non-U.S.S.R./C.I.S. aircraft. There was an increasing trend that, if continued, would result in 23 fatal accidents annually by 2010;
2. The overall number of fatalities to passengers and crew members from all ALAs in the period was 7,185. The non-C.I.S. aircraft can be expected to suffer 495 fatalities annually by 2010 if the overall trend continues;
3. Of the 287 accidents, the majority occurred to aircraft used by operators from North America, South and Central America and Europe; most flights occurred in these regions. Only five accidents involved operators from Australasia;
4. Sixty-two percent of the accidents occurred during passenger operations and 25 percent occurred during freight, ferry and positioning flights when no passengers were carried. These figures cannot reflect the relative number of flights flown for these purposes



Fatal ALA Rates of Western-built Jets* Unlikely to Be Exceeded**

*Excludes business jets. JAA – Joint Aviation Authorities ALAs – approach-and-landing accidents involving jet aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

**At 95 percent confidence level

***Data for Europe are divided to show rates for the 19 full-member JAA countries and the other European countries.

****Regions defined by Airclaims and shown in Appendix 2.

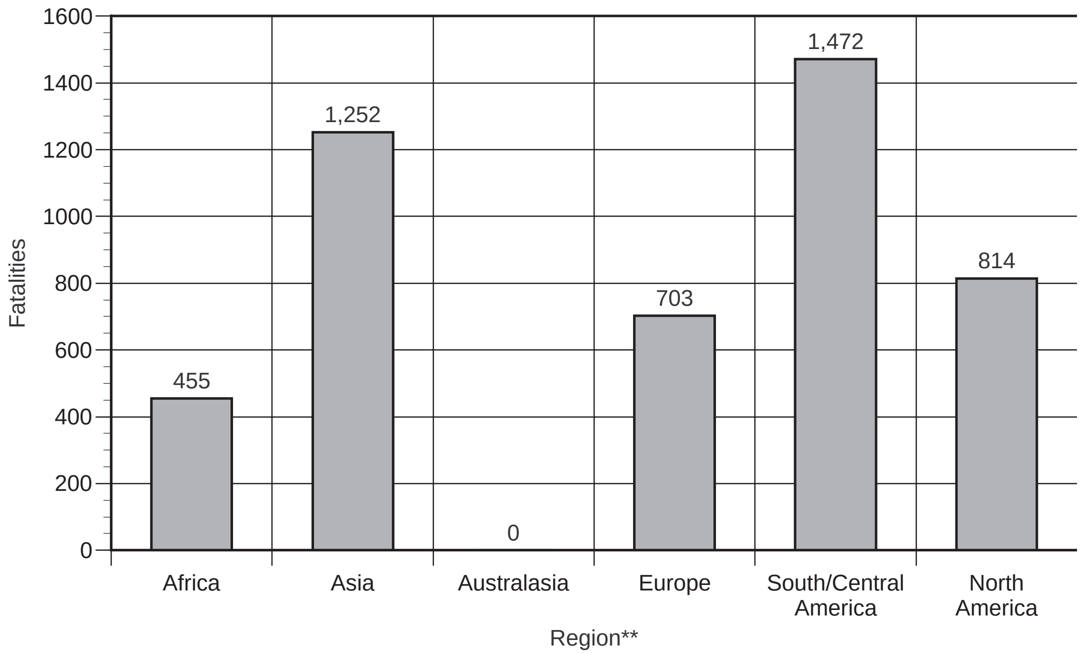
Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Figure 7

and suggest a far higher accident rate on freight, ferry and positioning flights — possibly eight times higher;

5. For accidents where the type of approach was known, 75 percent occurred when a precision approach aid was not available or was not used;
6. Fifty percent of the accidents occurred during daylight, 39 percent occurred during night and 2 percent occurred during twilight. Though the exact proportions of night and day approaches are not known, it seems likely that the accident rate at night is close to three times that for day;
7. Business jets suffered more accidents on night approaches and landings than by day;
8. Fatal accidents to Western-built jets on approach and landing average five per year to six per year, and there is an overall increasing trend during the period of the study. Fatalities average 276 per year and are increasing. The average number of fatalities is 51 per accident, and 61 percent of the aircraft occupants;
9. Most fatal accidents to Western-built jets occurred to operators from South and Central America and Asia. (See 10 below.);
10. The fatal accident rate for Western-built jets was highest for Africa (2.43 per million flights) and South and Central America (1.65 per million flights). Australasia had no fatal accidents to Western-built jets;
11. When Europe is divided into the 19 full-member JAA countries and the other European countries, JAA countries have an accident rate for Western-built jets (0.16 per million flights) that is 10 times lower than that for the other European countries;
12. The most common primary causal factor was judged to be “omission of action/inappropriate action.” This most often referred to the crew continuing the descent below the DH or MDA without visual reference or when visual cues were lost;
13. The second most common primary causal factor, “lack of positional awareness in the air,” generally related to CFIT accidents;
14. When all causal factors (primary and contributory) are considered, the most frequent are those referred to above as primary causal factors, plus “slow and/or low on approach,” “flight handling” and “poor professional judgment/airmanship”;
15. Aircraft built and operated in the U.S.S.R./C.I.S. had “press-on-itis” as the most frequent causal factor, even though this was only sixth in the overall ranking;

Fatalities in 92 ALAs in Western-built Jets,* by Region of Operator



*Excludes business jets. ALAs – approach-and-landing accidents involving jet and turboprop aircraft with a maximum takeoff weight greater than 5,700 kilograms/12,500 pounds. U.S.S.R. – Union of Soviet Socialist Republics C.I.S. – Commonwealth of Independent States

Note: Accidents to Eastern-built aircraft and operators from the U.S.S.R./C.I.S. were not included for years before 1990.

**Regions defined by Airclaims and shown in Appendix 2.

Source: U.K. Civil Aviation Authority/Flight Safety Foundation

Figure 8

16. The most frequent circumstantial factors were "nonfitment of presently available safety equipment" (generally GPWS) and "failure in CRM." "Lack of ground aids" was cited in at least 25 percent of accidents for all classes of aircraft; and,
17. The most frequent consequences were "collision with terrain/water/obstacle," and "CFIT." These were followed by "loss of control in flight," "postimpact fire" and "undershoot." Eastern-built (U.S.S.R./C.I.S.) jets had fatal overruns as a consequence at nearly twice the frequency of the overall sample.♦

References

1. U.K. Civil Aviation Authority (CAA). Global Fatal Accident Review, 1980–1996. Report no. CAP 681. March 1998.

2. Airclaims Ltd. World Aircraft Accident Summary, 1980–1996.

3. Ashford, R. Global Airline Safety — The Problem and Possible Solutions. Report no. RA/9703. November 1997.

4. International Air Transport Association (IATA). World Air Transport Statistics — IATA Members' Air Transport Operations.

5. U.K. CAA Economic Regulation Group. "Fixed Wing Air Transport Movements at U.K. Airports" (unpublished note, Dec. 22, 1997).

Further Reading from FSF Publications

Enders, J.H. et al. "Airport Safety: A Study of Accidents and Available Approach-and-landing Aids." *Flight Safety Digest* Volume 15 (March 1996): 1–36.

Khatwa, R.; Roelen, A.L.C. "An Analysis of Controlled-flight-into-terrain (CFIT) Accidents of Commercial Operators, 1988 through 1994." *Flight Safety Digest* Volume 15 (April–May 1996): 1-45.

Flight Safety Foundation. "Dubrovnik-bound Flight Crew's Improperly Flown Nonprecision Instrument Approach Results in Controlled-flight-into-terrain Accident." *Flight Safety Digest* Volume 15 (July–Aug. 1996): 1–25.

Appendix 1
Factors and Consequences Attributed to Fatal Approach-and-landing Accidents

A	Causal Group		Causal Factor
A.1	Aircraft systems	1.1	System failure — affecting controllability
		1.2	System failure — flight deck information
		1.3	System failure — other
A.2	Air traffic control/Ground aids	2.1	Incorrect or inadequate instruction/advice
		2.2	Misunderstood/missed communication
		2.3	Failure to provide separation in the air
		2.4	Failure to provide separation on the ground
		2.5	Ground aid malfunction or unavailable
A.3	Environmental	3.1	Structural overload
		3.2	Wind shear/upset/turbulence
		3.3	Icing
		3.4	Wake turbulence — aircraft spacing
		3.5	Volcanic ash/sand/precipitation, etc.
		3.6	Birds
		3.7	Lightning
		3.8	Runway condition unknown to crew
A.4	Crew	4.1	Lack of positional awareness in the air
		4.2	Lack of positional awareness on the ground
		4.3	Lack of awareness of circumstances in flight
		4.4	Incorrect selection on instrument/navaid
		4.5	Action on wrong control/instrument
		4.6	Slow/delayed action
		4.7	Omission of action/inappropriate action
		4.8	“Press-on-itis”
		4.9	Failure in crew resource management (cross-check/coordinate)
		4.10	Poor professional judgment/airmanship
		4.11	Disorientation or visual illusion
		4.12	Fatigue
		4.13	State of mind
		4.14	Interaction with automation
		4.15	Fast and/or high on approach
		4.16	Slow and/or low on approach
		4.17	Loading incorrect
		4.18	Flight handling
		4.19	Lack of qualification/training/experience
		4.20	Incapacitation/medical or other factors reducing crew performance
		4.21	Failure in look-out
		4.22	Deliberate nonadherence to procedures
A.5	Engine	5.1	Engine failure or malfunction
		5.2	Propeller failure
		5.3	Damage due to noncontainment
		5.4	Fuel contamination
		5.5	Engine failure simulated
A.6	Fire	6.1	Engine fire or overheat
		6.2	Fire due to aircraft systems
		6.3	Fire — other cause
		6.4	Postimpact fire
A.7	Maintenance/Ground handling	7.1	Failure to complete due maintenance
		7.2	Maintenance or repair error/oversight/inadequacy
		7.3	Ground staff or passenger(s) struck by aircraft
		7.4	Loading error
		7.5	Bogus parts

Appendix 1

Factors and Consequences Attributed to Fatal Approach-and-landing Accidents

(continued)

A	Causal Group		Causal Factor
A.8	Structure	8.1	Corrosion/fatigue
		8.2	Overload failure
		8.3	Flutter
A.9	Infrastructure	9.1	Incorrect, inadequate or misleading information to crew
		9.2	Inadequate airport support
A.10	Design	10.1	Design shortcomings
		10.2	Unapproved modification
		10.3	Manufacturing defect
A.11	Performance	11.1	Unable to maintain speed/height
		11.2	Aircraft becomes uncontrollable
A.12	Other	12.1	Caused by other aircraft
		12.2	Nonadherence to cabin safety procedures

B	Circumstantial Group		Circumstantial Factor
B.1	Aircraft systems	1.1	Nonfitment of presently available safety equipment (ground-proximity warning system, traffic-alert and collision avoidance system, wind-shear warning, etc.)
		1.2	Failure/inadequacy of safety equipment
B.2	Air traffic control/Ground aids	2.1	Lack of air traffic control
		2.2	Lack of ground aids
B.3	Environmental	3.1	Poor visibility
		3.2	Weather
		3.3	Runway condition (ice, slippery, standing water, etc.)
B.4	Crew	4.1	Training inadequate
		4.2	Presented with situation beyond training
		4.3	Failure in crew resource management (cross-check/coordinate)
B.5	Infrastructure	5.1	Incorrect/inadequate procedures
		5.2	Company management failure
		5.3	Inadequate regulation
		5.4	Inadequate regulatory oversight
B.6	Other	6.1	Illegal/unauthorized/drug smuggling flight

C	Consequence
C.1	Controlled flight into terrain (CFIT)
C.2	Collision with terrain/water/obstacle
C.3	Midair collision
C.4	Ground collision with other aircraft
C.5	Ground collision with object/obstacle
C.6	Loss of control in flight
C.7	Fuel exhaustion
C.8	Overrun
C.9	Undershoot
C.10	Structural failure
C.11	Postimpact fire
C.12	Fire/smoke during operation
C.13	Emergency evacuation difficulties
C.14	Forced landing — land or water
C.15	Other cause of fatality

Level of confidence* ☐ **High** ☐ **Medium** ☐ **Low** ☐ **Insufficient information**

* The AAG recorded the level of confidence for each accident to reflect the group’s confidence in its analysis as a whole, not for individual factors and circumstances.

Appendix 2
Regions* and Countries

Africa

Algeria
Angola
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Cape Verde Islands
Central African Republic
Chad
Ciskei
Comoros
Congo
Democratic Republic of Congo
Djibouti
Egypt
Ethiopia
Gabon
Gambia
Ghana
Guinea
Guinea-Bissau
Ivory Coast
Kenya
Lesotho
Liberia
Libya
Madagascar
Malawi
Mali
Mauritania
Mauritius
Morocco
Mozambique
Namibia
Niger
Nigeria
Republic of Bophuthatswana
Rwanda
Sao Tome and Principe
Senegal
Seychelles
Sierra Leone
Somalia
South Africa
Sudan
Swaziland
Tanzania
Togo
Tunisia
Uganda
Zambia
Zimbabwe

Asia

Afghanistan
Bahrain
Bangladesh
Bhutan
Brunei
Cambodia
China
Hong Kong
India
Indonesia
Iran
Iraq
Israel
Japan
Jordan
Korea
Kuwait
Laos
Lebanon
Macau
Malaysia
Maldives
Mongolia
Myanmar
Nepal
Oman
Pakistan
Palestine
Philippines
Qatar
Saudi Arabia
Singapore
Sri Lanka
Syria
Taiwan
Thailand
Vietnam
Yemen

Australasia

American Samoa
Australia
Cook Islands
Fiji
French Polynesia
Guam
Kiribati
Marshall Islands
Nauru
New Caledonia
New Zealand
Northern Marianas Islands
Pacific Islands
Palau
Papua New Guinea
Solomon Islands
Tonga
Vanuatu
Western Samoa

Europe

JAA full-member countries in **bold** and C.I.S. countries in *italic*:

Albania
Armenia
Austria
Azerbaijan
Belarus
Belgium
Bosnia-Herzegovina
Bulgaria
Croatia
Cyprus
Czechoslovakia
Czech Republic
Denmark
Estonia
Faroe Islands
Finland
France
Georgia
Germany
Gibraltar
Greece
Greenland
Hungary
Iceland
Ireland
Italy
Kazakstan
Kyrgyzstan
Latvia
Lichtenstein
Lithuania
Luxembourg
Macedonia
Malta
Moldova
Monaco
Montenegro
Netherlands
Norway
Poland
Portugal
Romania

Appendix 2
Regions and Countries *(continued)*

Russia
Serbia
Slovakia
Slovenia
Spain
Sweden
Switzerland
Tajikistan
Turkey
Turkmenistan
Ukraine
United Kingdom
U.S.S.R.
Uzbekistan
Yugoslavia

North America

Anguilla
Antigua & Barbuda
Aruba
Bahamas
Barbados
Bermuda
Canada
Cayman Islands
Cuba
Dominica
Dominican Republic
Grenada
Guadeloupe
Haiti
Jamaica
Martinique
Montserrat
Puerto Rico
St. Kitts & Nevis
St. Lucia
St. Pierre & Miquelon
Trinidad & Tobago
St. Vincent & the Grenadines
Turks & Caicos Islands
United States
Virgin Islands (U.S. and British)

South/Central America

Argentina
Belize
Bolivia
Brazil
Chile
Colombia
Costa Rica
Ecuador
El Salvador
Falkland Islands
French Guyana
Guatemala
Guyana
Honduras
Mexico
Nicaragua
Panama
Paraguay
Peru
Suriname
Uruguay
Venezuela

*Regions defined by Airclaims

Appendix 3
Joint Aviation Authorities Full-member Countries

- Austria
- Belgium
- Denmark
- Finland
- France
- Germany
- Greece
- Iceland
- Ireland
- Italy
- Luxembourg
- Monaco
- Netherlands
- Norway
- Portugal
- Spain
- Sweden
- Switzerland
- United Kingdom

Appendix 4.1
Factors and Consequences Attributed to 92 Fatal Approach-and-landing Accidents in Western-built Jets*

A	Causal Factor			Number of Times Cited in Accidents		
				Primary	Causal	Total
A.1	Aircraft systems	1.1	System failure — affecting controllability	2	7	9
		1.2	System failure — flight deck information	1	2	3
		1.3	System failure — other	0	4	4
A.2	Air traffic control/Ground aids	2.1	Incorrect or inadequate instruction/advice	1	9	10
		2.2	Misunderstood/missed communication	0	4	4
		2.3	Failure to provide separation in the air	0	2	2
		2.4	Failure to provide separation on the ground	1	1	2
		2.5	Ground aid malfunction or unavailable	0	2	2
A.3	Environmental	3.1	Structural overload	0	0	0
		3.2	Wind shear/upset/turbulence	2	8	10
		3.3	Icing	0	0	0
		3.4	Wake turbulence — aircraft spacing	0	0	0
		3.5	Volcanic ash/sand/precipitation, etc.	0	2	2
		3.6	Birds	0	0	0
		3.7	Lightning	0	0	0
		3.8	Runway condition unknown to crew	1	3	4
A.4	Crew	4.1	Lack of positional awareness in the air	15	25	40
		4.2	Lack of positional awareness on the ground	0	0	0
		4.3	Lack of awareness of circumstances in flight	0	1	1
		4.4	Incorrect selection on instrument/navaid	0	2	2
		4.5	Action on wrong control/instrument	0	1	1
		4.6	Slow/delayed action	2	9	11
		4.7	Omission of action/inappropriate action	25	15	40
		4.8	“Press-on-itis”	9	7	16
		4.9	Failure in crew resource management (cross-check/coordinate)	1	14	15
		4.10	Poor professional judgment/airmanship	5	23	28
		4.11	Disorientation or visual illusion	0	3	3
		4.12	Fatigue	0	3	3
		4.13	State of mind	1	0	1
		4.14	Interaction with automation	2	5	7
		4.15	Fast and/or high on approach	0	9	9
		4.16	Slow and/or low on approach	0	32	32

* Excluding business jets

Appendix 4.1

Factors and Consequences Attributed to 92 Fatal Approach-and-landing Accidents in Western-built Jets* *(continued)*

				Number of Times Cited in Accidents		
A	**Causal Factor**			**Primary**	**Causal**	**Total**
		4.17	Loading incorrect	0	0	0
		4.18	Flight handling	9	16	25
		4.19	Lack of qualification/training/experience	0	6	6
		4.20	Incapacitation/medical or other factors reducing crew performance	0	1	1
		4.21	Failure in look-out	0	2	2
		4.22	Deliberate nonadherence to procedures	2	4	6
A.5	Engine	5.1	Engine failure or malfunction	0	4	4
		5.2	Propeller failure	0	0	0
		5.3	Damage due to noncontainment	0	1	1
		5.4	Fuel contamination	0	0	0
		5.5	Engine failure simulated	0	0	0
A.6	Fire	6.1	Engine fire or overheat	1	0	1
		6.2	Fire due to aircraft systems	1	0	1
		6.3	Fire — other cause	3	0	3
		6.4	Postimpact fire	0	13	13
A.7	Maintenance/Ground handling	7.1	Failure to complete due maintenance	0	0	0
		7.2	Maintenance or repair error/oversight/inadequacy	2	0	2
		7.3	Ground staff or passenger(s) struck by aircraft	0	0	0
		7.4	Loading error	0	0	0
		7.5	Bogus parts	0	0	0
A.8	Structure	8.1	Corrosion/fatigue	2	1	3
		8.2	Overload failure	0	7	7
		8.3	Flutter	0	0	0
A.9	Infrastructure	9.1	Incorrect, inadequate or misleading information to crew	0	7	7
		9.2	Inadequate airport support	1	3	4
A.10	Design	10.1	Design shortcomings	1	12	13
		10.2	Unapproved modification	0	0	0
		10.3	Manufacturing defect	0	1	1
A.11	Performance	11.1	Unable to maintain speed/height	0	4	4
		11.2	Aircraft becomes uncontrollable	0	8	8
A.12	Other	12.1	Caused by other aircraft	1	0	1
		12.2	Nonadherence to cabin safety procedures	0	0	0

* Excluding business jets

Appendix 4.1

Factors and Consequences Attributed to 92 Fatal Approach-and-landing Accidents in Western-built Jets* *(continued)*

B	Circumstantial Factor			Number of Times Cited in Accidents
B.1	Aircraft systems	1.1	Nonfitment of presently available safety equipment (ground-proximity warning system, traffic-alert and collision avoidance system, wind-shear warning, etc.)	40
		1.2	Failure/inadequacy of safety equipment	2
B.2	Air traffic control/Ground aids	2.1	Lack of air traffic control	2
		2.2	Lack of ground aids	23
B.3	Environmental	3.1	Poor visibility	29
		3.2	Weather	26
		3.3	Runway condition (ice, slippery, standing water, etc.)	7
B.4	Crew	4.1	Training inadequate	7
		4.2	Presented with situation beyond training	9
		4.3	Failure in crew resource management (cross-check/coordinate)	38
B.5	Infrastructure	5.1	Incorrect/inadequate procedures	13
		5.2	Company management failure	18
		5.3	Inadequate regulation	8
		5.4	Inadequate regulatory oversight	23
B.6	Other	6.1	Illegal/unauthorized/drug smuggling flight	0

C	Consequence	Number of Times Cited in Accidents
C.1	Controlled flight into terrain (CFIT)	32
C.2	Collision with terrain/water/obstacle	45
C.3	Midair collision	1
C.4	Ground collision with other aircraft	1
C.5	Ground collision with object/obstacle	10
C.6	Loss of control in flight	21
C.7	Fuel exhaustion	5
C.8	Overrun	13
C.9	Undershoot	17
C.10	Structural failure	2
C.11	Postimpact fire	25
C.12	Fire/smoke during operation	4
C.13	Emergency evacuation difficulties	4
C.14	Forced landing — land or water	3
C.15	Other cause of fatality	0

* Except business jets

Level of confidence **49 High** **36 Medium** **6 Low** **1 Insufficient information**

Appendix 4.2
Factors and Consequences Attributed to 16 Fatal Approach-and-landing Accidents in Eastern-built Jets

A	Causal Factor			Number of Times Cited in Accidents		
				Primary	Causal	Total
A.1	Aircraft systems	1.1	System failure — affecting controllability	0	0	0
		1.2	System failure — flight deck information	1	1	2
		1.3	System failure — other	0	1	1
A.2	Air traffic control/Ground aids	2.1	Incorrect or inadequate instruction/advice	0	0	0
		2.2	Misunderstood/missed communication	0	0	0
		2.3	Failure to provide separation in the air	0	0	0
		2.4	Failure to provide separation in the ground	0	0	0
		2.5	Ground aid malfunction or unavailable	0	0	0
A.3	Environmental	3.1	Structural overload	0	0	0
		3.2	Wind shear/upset/turbulence	1	0	1
		3.3	Icing	0	0	0
		3.4	Wake turbulence — aircraft spacing	0	0	0
		3.5	Volcanic ash/sand/precipitation, etc.	0	0	0
		3.6	Birds	0	0	0
		3.7	Lightning	0	0	0
		3.8	Runway condition unknown to crew	0	0	0
A.4	Crew	4.1	Lack of positional awareness in the air	4	3	7
		4.2	Lack of positional awareness on the ground	0	0	0
		4.3	Lack of awareness of circumstances in flight	0	0	0
		4.4	Incorrect selection on instrument/navaid	0	0	0
		4.5	Action on wrong control/instrument	0	0	0
		4.6	Slow/delayed action	0	1	1
		4.7	Omission of action/inappropriate action	4	2	6
		4.8	“Press-on-itis“	5	2	7
		4.9	Failure in crew resource management (cross-check/coordinate)	0	3	3
		4.10	Poor professional judgment/airmanship	0	2	2
		4.11	Disorientation or visual illusion	0	0	0
		4.12	Fatigue	0	1	1
		4.13	State of mind	0	0	0
		4.14	Interaction with automation	0	0	0
		4.15	Fast and/or high on approach	0	4	4
		4.16	Slow and/or low on approach	0	5	5

Appendix 4.2

Factors and Consequences Attributed to 16 Fatal Approach-and-landing Accidents in Eastern-built Jets *(continued)*

A	Causal Factor			Number of Times Cited in Accidents		
				Primary	Causal	Total
		4.17	Loading incorrect	0	0	0
		4.18	Flight handling	1	2	3
		4.19	Lack of qualification/training/experience	0	0	0
		4.20	Incapacitation/medical or other factors reducing crew performance	0	0	0
		4.21	Failure in look-out	0	0	0
		4.22	Deliberate nonadherence to procedures	0	3	3
A.5	Engine	5.1	Engine failure or malfunction	0	0	0
		5.2	Propeller failure	0	0	0
		5.3	Damage due to noncontainment	0	0	0
		5.4	Fuel contamination	0	0	0
		5.5	Engine failure simulated	0	0	0
A.6	Fire	6.1	Engine fire or overheat	0	0	0
		6.2	Fire due to aircraft systems	0	1	1
		6.3	Fire — other cause	0	0	0
		6.4	Postimpact fire	0	2	2
A.7	Maintenance/Ground handling	7.1	Failure to complete due maintenance	0	0	0
		7.2	Maintenance or repair error/oversight/inadequacy	0	0	0
		7.3	Ground staff or passenger(s) struck by aircraft	0	0	0
		7.4	Loading error	0	0	0
		7.5	Bogus parts	0	0	0
A.8	Structure	8.1	Corrosion/fatigue	0	0	0
		8.2	Overload failure	0	1	1
		8.3	Flutter	0	0	0
A.9	Infrastructure	9.1	Incorrect, inadequate or misleading information to crew	0	1	1
		9.2	Inadequate airport support	0	2	2
A.10	Design	10.1	Design shortcomings	0	2	2
		10.2	Unapproved modification	0	0	0
		10.3	Manufacturing defect	0	0	0
A.11	Performance	11.1	Unable to maintain speed/height	0	0	0
		11.2	Aircraft becomes uncontrollable	0	0	0
A.12	Other	12.1	Caused by other aircraft	0	0	0
		12.2	Nonadherence to cabin safety procedures	0	0	0

Appendix 4.2
Factors and Consequences Attributed to 16 Fatal Approach-and-landing Accidents In Eastern-built Jets *(continued)*

B	Circumstantial Factor			Number of Times Cited in Accidents
B.1	Aircraft systems	1.1	Nonfitment of presently available safety equipment (ground proximity warning (system, traffic-alert and collision avoidance system, wind-shear warning, etc.)	8
		1.2	Failure/inadequacy of safety equipment	0
B.2	ATC/Ground aids	2.1	Lack of air traffic control	0
		2.2	Lack of ground aids	5
B.3	Environmental	3.1	Poor visibility	4
		3.2	Weather	7
		3.3	Runway condition (ice, slippery, standing water, etc.)	1
B.4	Crew	4.1	Training inadequate	1
		4.2	Presented with situation beyond training	0
		4.3	Failure in crew resource management (cross-check/coordinate)	8
B.5	Infrastructure	5.1	Incorrect/inadequate procedures	1
		5.2	Company management failure	3
		5.3	Inadequate regulation	1
		5.4	Inadequate regulatory oversight	4
B.6	Other	6.1	Illegal/unauthorized/drug smuggling flight	0

C	Consequence	Number of Times Cited in Accidents
C.1	Controlled flight into terrain (CFIT)	9
C.2	Collision with terrain/water/obstacle	5
C.3	Midair collision	0
C.4	Ground collision with other aircraft	1
C.5	Ground collision with object/obstacle	1
C.6	Loss of control in flight	1
C.7	Fuel exhaustion	0
C.7	Overrun	3
C.9	Undershoot	5
C.10	Structural failure	0
C.11	Postimpact fire	3
C.12	Fire/smoke during operation	1
C.13	Emergency evacuation difficulties	0
C.14	Forced landing — land or water	0
C.15	Other cause of fatality	0

Level of confidence 9 High 5 Medium 2 Low 0 Insufficient information

Appendix 4.3
Factors and Consequences Attributed to 84 Fatal Approach-and-landing Accidents in Western-built Turboprops

				Number of Times Cited in Accidents		
A	**Causal Factor**			**Primary**	**Causal**	**Total**
A.1	Aircraft systems	1.1	System failure — affecting controllability	1	2	3
		1.2	System failure — flight deck information	1	5	6
		1.3	System failure — other	0	4	4
A.2	ATC/Ground aids	2.1	Incorrect or inadequate instruction/advice	0	4	4
		2.2	Misunderstood/missed communication	0	1	1
		2.3	Failure to provide separation in the air	0	1	1
		2.4	Failure to provide separation on the ground	0	1	1
		2.5	Ground aid malfunction or unavailable	0	2	2
A.3	Environmental	3.1	Structural overload	0	0	0
		3.2	Wind shear/upset/turbulence	3	5	8
		3.3	Icing	1	3	4
		3.4	Wake turbulence — aircraft spacing	0	0	0
		3.5	Volcanic ash/sand/precipitation, etc.	0	2	2
		3.6	Birds	0	0	0
		3.7	Lightning	1	0	1
		3.8	Runway condition unknown to crew	0	1	1
A.4	Crew	4.1	Lack of positional awareness in the air	16	19	35
		4.2	Lack of positional awareness the on ground	0	0	0
		4.3	Lack of awareness of circumstances in flight	0	1	1
		4.4	Incorrect selection on instrument/navaid	1	0	1
		4.5	Action on wrong control/instrument	0	0	0
		4.6	Slow/delayed action	0	3	3
		4.7	Omission of action/inappropriate action	14	22	36
		4.8	“Press-on-itis”	7	10	17
		4.9	Failure in crew resource management (cross-check/coordinate)	4	14	18
		4.10	Poor professional judgment/airmanship	3	13	16
		4.11	Disorientation or visual illusion	1	1	2
		4.12	Fatigue	0	0	0
		4.13	State of mind	0	1	1
		4.14	Interaction with automation	0	0	0
		4.15	Fast and/or high on approach	0	8	8
		4.16	Slow and/or low on approach	0	32	32

Appendix 4.3
Factors and Consequences Attributed to 84 Fatal Approach-and-landing Accidents in Western-built Turboprops *(continued)*

A	Causal Factor			Number of Times Cited in Accidents		
				Primary	Causal	Total
		4.17	Loading incorrect	1	2	3
		4.18	Flight handling	16	17	33
		4.19	Lack of qualification/training/experience	0	6	6
		4.20	Incapacitation/medical or other factors reducing crew performance	0	2	2
		4.21	Failure in look-out	1	2	3
		4.22	Deliberate nonadherence to procedures	2	7	9
A.5	Engine	5.1	Engine failure or malfunction	0	5	5
		5.2	Propeller failure	1	0	1
		5.3	Damage due to noncontainment	2	0	2
		5.4	Fuel contamination	0	0	0
		5.5	Engine failure simulated	0	1	1
A.6	Fire	6.1	Engine fire or overheat	0	1	1
		6.2	Fire due to aircraft systems	0	0	0
		6.3	Fire — other cause	1	0	1
		6.4	Postimpact fire	0	11	11
A.7	Maintenance/Ground handling	7.1	Failure to complete due maintenance	0	0	0
		7.2	Maintenance or repair error/oversight/inadequacy	1	4	5
		7.3	Ground staff or passenger(s) struck by aircraft	0	0	0
		7.4	Loading error	1	2	3
		7.5	Bogus parts	0	0	0
A.8	Structure	8.1	Corrosion/fatigue	1	1	2
		8.2	Overload failure	0	3	3
		8.3	Flutter	0	1	1
A.9	Infrastructure	9.1	Incorrect, inadequate or misleading information to crew	0	2	2
		9.2	Inadequate airport support	0	4	4
A.10	Design	10.1	Design shortcomings	2	9	11
		10.2	Unapproved modification	0	0	0
		10.3	Manufacturing defect	0	0	0
A.11	Performance	11.1	Unable to maintain speed/height	0	4	4
		11.2	Aircraft becomes uncontrollable	0	3	3
A.12	Other	12.1	Caused by other aircraft	0	0	0
		12.2	Nonadherence to cabin safety procedures	0	0	0

Appendix 4.3
Factors and Consequences Attributed to 84 Fatal Approach-and-landing Accidents in Western-built Turboprops *(continued)*

B	Circumstantial Factor			Number of Times Cited in Accidents
B.1	Aircraft systems	1.1	Nonfitment of presently available safety equipment (ground-proximity warning system, traffic-alert and collision avoidance system, wind-shear warning, etc.)	38
		1.2	Failure/inadequacy of safety equipment	3
B.2	Air traffic control/Ground aids	2.1	Lack of air traffic control	1
		2.2	Lack of ground aids	22
B.3	Environmental	3.1	Poor visibility	25
		3.2	Weather	41
		3.3	Runway condition (ice, slippery, standing water, etc.)	3
B.4	Crew	4.1	Training inadequate	7
		4.2	Presented with situation beyond training	1
		4.3	Failure in crew resource management (cross-check/coordinate)	37
B.5	Infrastructure	5.1	Incorrect/inadequate procedures	7
		5.2	Company management failure	21
		5.3	Inadequate regulation	8
		5.4	Inadequate regulatory oversight	22
B.6	Other	6.1	Illegal/unauthorized/drug smuggling flight	0

C	Consequence	Number of Times Cited in Accidents
C.1	Controlled flight into terrain (CFIT)	34
C.2	Collision with terrain/water/obstacle	42
C.3	Midair collision	1
C.4	Ground collision with other aircraft	2
C.5	Ground collision with object/obstacle	2
C.6	Loss of control in flight	32
C.7	Fuel exhaustion	0
C.8	Overrun	5
C.9	Undershoot	14
C.10	Structural failure	3
C.11	Postimpact fire	15
C.12	Fire/smoke during operation	2
C.13	Emergency evacuation difficulties	4
C.14	Forced landing — land or water	2
C.15	Other cause of fatality	1

Level of confidence **51 High** **27 Medium** **4 Low** **2 Insufficient information**

Appendix 4.4
Factors and Consequences Attributed to 19 Fatal Approach-and-landing Accidents in Eastern-built Turboprops

A	Causal Factor			Number of Total Cited in Accidents		
				Primary	**Causal**	**Total**
A.1	Aircraft systems	1.1	System failure — affecting controllability	0	0	0
		1.2	System failure — flight deck information	0	0	0
		1.3	System failure — other	0	0	0
A.2	Air traffic control/Ground Aids	2.1	Incorrect or inadequate instruction/advice	0	0	0
		2.2	Misunderstood/missed communication	0	0	0
		2.3	Failure to provide separation in the air	0	0	0
		2.4	Failure to provide separation on the ground	0	0	0
		2.5	Ground aid malfunction or unavailable	0	0	0
A.3	Environmental	3.1	Structural overload	0	0	0
		3.2	Wind shear/upset/turbulence	0	0	0
		3.3	Icing	1	2	3
		3.4	Wake turbulence — aircraft spacing	0	0	0
		3.5	Volcanic ash/sand/precipitation, etc.	0	3	3
		3.6	Birds	0	0	0
		3.7	Lightning	0	0	0
		3.8	Runway condition unknown to crew	0	0	0
A.4	Crew	4.1	Lack of positional awareness in the air	2	4	6
		4.2	Lack of positional awareness the on ground	0	0	0
		4.3	Lack of awareness of circumstances in flight	0	0	0
		4.4	Incorrect selection on instrument/navaid	0	0	0
		4.5	Action on wrong control/instrument	0	0	0
		4.6	Slow/delayed action	0	1	1
		4.7	Omission of action/inappropriate action	3	2	5
		4.8	“Press-on-itis”	6	2	8
		4.9	Failure in crew resource management (cross-check/coordinate)	0	0	0
		4.10	Poor professional judgment/airmanship	0	3	3
		4.11	Disorientation or visual illusion	0	0	0
		4.12	Fatigue	0	0	0
		4.13	State of mind	0	0	0
		4.14	Interaction with automation	0	0	0
		4.15	Fast and/or high on approach	0	0	0
		4.16	Slow and/or low on approach	0	5	5

Appendix 4.4
Factors and Consequences Attributed to 19 Fatal Approach-and-landing Accidents in Eastern-built Turboprops *(continued)*

A	Causal Factor			Number of Times Cited in Accidents		
				Primary	Causal	Total
		4.17	Loading incorrect	0	0	0
		4.18	Flight handling	1	3	4
		4.19	Lack of qualification/training/experience	0	0	0
		4.20	Incapacitation/medical or other factors reducing crew performance	0	0	0
		4.21	Failure in look-out	0	0	0
		4.22	Deliberate nonadherence to procedures	1	3	4
A.5	Engine	5.1	Engine failure or malfunction	0	0	0
		5.2	Propeller failure	0	0	0
		5.3	Damage due to noncontainment	0	0	0
		5.4	Fuel contamination	0	0	0
		5.5	Engine failure simulated	0	0	0
A.6	Fire	6.1	Engine fire or overheat	0	0	0
		6.2	Fire due to aircraft systems	0	0	0
		6.3	Fire — other cause	0	0	0
		6.4	Postimpact fire	0	2	2
A.7	Maintenance/Ground handling	7.1	Failure to complete due maintenance	0	0	0
		7.2	Maintenance or repair error/oversight/inadequacy	0	0	0
		7.3	Ground staff or passenger(s) struck by aircraft	0	0	0
		7.4	Loading error	1	0	1
		7.5	Bogus parts	0	0	0
A.8	Structure	8.1	Corrosion/fatigue	0	0	0
		8.2	Overload failure	0	0	0
		8.3	Flutter	0	0	0
A.9	Infrastructure	9.1	Incorrect, inadequate or misleading information to crew	1	1	2
		9.2	Inadequate airport support	0	1	1
A.10	Design	10.1	Design shortcomings	0	0	0
		10.2	Unapproved modification	0	0	0
		10.3	Manufacturing defect	0	0	0
A.11	Performance	11.1	Unable to maintain speed/height	0	0	0
		11.2	Aircraft becomes uncontrollable	0	1	1
A.12	Other	12.1	Caused by other aircraft	0	0	0
		12.2	Nonadherence to cabin safety procedures	0	0	0

Appendix 4.4

Factors and Consequences Attributed to 19 Fatal Approach-and-landing Accidents in Eastern-built Turboprops *(continued)*

B	**Circumstantial Factor**			**Number of Times Cited in Accidents**
B.1	Aircraft systems	1.1	Nonfitment of presently available safety equipment (ground-proximity warning system, traffic-alert and collision avoidance system, wind-shear warning, etc.)	2
		1.2	Failure/inadequacy of safety equipment	0
B.2	Air traffic control/Ground aids	2.1	Lack of air traffic control	1
		2.2	Lack of ground aids	6
B.3	Environmental	3.1	Poor visibility	5
		3.2	Weather	8
		3.3	Runway condition (ice, slippery, standing water, etc.)	0
B.4	Crew	4.1	Training inadequate	0
		4.2	Presented with situation beyond training	0
		4.3	Failure in Crew resource management (cross-check/coordinate)	6
B.5	Infrastructure	5.1	Incorrect/inadequate procedures	1
		5.2	Company management failure	6
		5.3	Inadequate regulation	0
		5.4	Inadequate regulatory oversight	7
B.6	Other	6.1	Illegal/unauthorized/drug smuggling flight	0

C	**Consequence**	**Number of Times Cited in Accidents**
C.1	Controlled flight into terrain (CFIT)	6
C.2	Collision with terrain/water/obstacle	9
C.3	Midair collision	0
C.4	Ground collision with other aircraft	0
C.5	Ground collision with object/obstacle	2
C.6	Loss of control in flight	6
C.7	Fuel exhaustion	2
C.8	Overrun	2
C.9	Undershoot	2
C.10	Structural failure	0
C.11	Postimpact fire	2
C.12	Fire/smoke during operation	0
C.13	Emergency evacuation difficulties	0
C.14	Forced landing — land or water	3
C.15	Other cause of fatality	0

Level of confidence **8 High** **7 Medium** **1 Low** **3 Insufficient information**

Appendix 4.5
Factors and Consequences Attributed to 76 Fatal Approach-and-landing Accidents in Business Jets

A	Causal Factor			Number of Times Cited in Accidents		
				Primary	Causal	Total
A.1	Aircraft systems	1.1	System failure — affecting controllability	1	0	1
		1.2	System failure — flight deck information	1	1	2
		1.3	System failure — other	0	0	0
A.2	Air traffic control/Ground aids	2.1	Incorrect or inadequate instruction/advice	0	2	2
		2.2	Misunderstood/missed communication	0	0	0
		2.3	Failure to provide separation in the air	1	0	1
		2.4	Failure to provide separation on the ground	0	0	0
		2.5	Ground aid malfunction or unavailable	0	2	2
A.3	Environmental	3.1	Structural overload	0	0	0
		3.2	Wind shear/upset/turbulence	0	3	3
		3.3	Icing	2	0	2
		3.4	Wake turbulence — aircraft spacing	1	1	2
		3.5	Volcanic ash/sand/precipitation, etc.	0	2	2
		3.6	Birds	1	0	1
		3.7	Lightning	0	0	0
		3.8	Runway condition unknown to crew	0	0	0
A.4	Crew	4.1	Lack of positional awareness in the air	15	29	44
		4.2	Lack of positional awareness on the ground	0	0	0
		4.3	Lack of awareness of circumstances in flight	0	1	1
		4.4	Incorrect selection on instrument/navaid	3	1	4
		4.5	Action on wrong control/instrument	0	0	0
		4.6	Slow/delayed action	0	7	7
		4.7	Omission of action/inappropriate action	23	11	34
		4.8	“Press-on-itis”	4	8	12
		4.9	Failure in crew resource management (cross-check/coordinate)	0	8	8
		4.10	Poor professional judgment/airmanship	4	15	19
		4.11	Disorientation or visual illusion	0	2	2
		4.12	Fatigue	0	5	5
		4.13	State of mind	0	1	1
		4.14	Interaction with automation	0	0	0
		4.15	Fast and/or high on approach	0	7	7
		4.16	Slow and/or low on approach	1	34	35

Appendix 4.5
Factors and Consequences Attributed to 76 Fatal Approach-and-landing Accidents in Business Jets *(continued)*

A	Causal Factor			Number of Times Cited in Accidents		
				Primary	Causal	Total
		4.17	Loading incorrect	0	2	2
		4.18	Flight handling	7	9	16
		4.19	Lack of qualification/training/experience	1	5	6
		4.20	Incapacitation/medical or other factors reducing crew performance	2	0	2
		4.21	Failure in look-out	1	0	1
		4.22	Deliberate nonadherence to procedures	3	8	11
A.5	Engine	5.1	Engine failure or malfunction	1	1	2
		5.2	Propeller failure	0	0	0
		5.3	Damage due to noncontainment	0	1	1
		5.4	Fuel contamination	1	0	1
		5.5	Engine failure simulated	0	0	0
A.6	Fire	6.1	Engine fire or overheat	0	2	2
		6.2	Fire due to aircraft systems	0	0	0
		6.3	Fire — other cause	0	0	0
		6.4	Postimpact fire	0	5	5
A.7	Maintenance/Ground handling	7.1	Failure to complete due maintenance	0	0	0
		7.2	Maintenance or repair error/oversight/inadequacy	0	0	0
		7.3	Ground staff or passenger(s) struck by aircraft	0	0	0
		7.4	Loading error	0	0	0
		7.5	Bogus parts	0	0	0
A.8	Structure	8.1	Corrosion/fatigue	0	0	0
		8.2	Overload failure	0	0	0
		8.3	Flutter	0	0	0
A.9	Infrastructure	9.1	Incorrect, inadequate or misleading information to crew	1	2	3
		9.2	Inadequate airport support	0	2	2
A.10	Design	10.1	Design shortcomings	0	1	1
		10.2	Unapproved modification	0	0	0
		10.3	Manufacturing defect	0	0	0
A.11	Performance	11.1	Unable to maintain speed/height	0	2	2
		11.2	Aircraft becomes uncontrollable	0	1	1
A.12	Other	12.1	Caused by other aircraft	0	0	0
		12.2	Nonadherence to cabin safety procedures	0	2	2

Appendix 4.5

Factors and Consequences Attributed to 76 Fatal Approach-and-landing Accidents in Business Jets *(continued)*

B	**Circumstantial Factor**			**Number of Times Cited in Accidents**
B.1	Aircraft systems	1.1	Nonfitment of presently available safety equipment (ground-proximity warning system, traffic-alert and collision avoidance system, wind-shear warning, etc.)	44
		1.2	Failure/inadequacy of safety equipment	0
B.2	Air traffic control/Ground aids	2.1	Lack of air traffic control	1
		2.2	Lack of ground aids	25
B.3	Environmental	3.1	Poor visibility	26
		3.2	Weather	21
		3.3	Runway condition (ice, slippery, standing water, etc.)	3
B.4	Crew	4.1	Training inadequate	1
		4.2	Presented with situation beyond training	2
		4.3	Failure in crew resource management (cross-check/coordinate)	42
B.5	Infrastructure	5.1	Incorrect/inadequate procedures	5
		5.2	Company management failure	12
		5.3	Inadequate regulation	3
		5.4	Inadequate regulatory oversight	10
B.6	Other	6.1	Illegal/unauthorized/drug smuggling flight	2

C	**Consequence**	**Number of Times Cited in Accidents**
C.1	Controlled flight into terrain (CFIT)	39
C.2	Collision with terrain/water/obstacle	30
C.3	Midair collision	2
C.4	Ground collision with other aircraft	0
C.5	Ground collision with object/obstacle	5
C.6	Loss of control in flight	14
C.7	Fuel exhaustion	4
C.8	Overrun	5
C.9	Undershoot	12
C.10	Structural failure	0
C.11	Postimpact fire	20
C.12	Fire/smoke during operation	2
C.13	Emergency evacuation difficulties	0
C.14	Forced landing — land or water	1
C.15	Other cause of fatality	0

Level of confidence **35 High** **29 Medium** **10 Low** **2 Insufficient information**

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An Analysis of Controlled-flight-into-terrain Accidents of Commercial Operators, 1988 through 1994

Contents

An Analysis of Controlled-flight-into-terrain Accidents of Commercial Operators, 1988 through 1994

Seventy-five percent of the accident aircraft, where the data were known, lacked a ground-proximity warning system. For scheduled flights of major operators, North America and the Middle East had the lowest CFIT rates. And a significant percentage of CFIT accidents occurred in areas without high terrain.

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1.0 Introduction

1.1 Background

Air travel is one of the safest means of modern mass transportation, but the safety rate has remained approximately constant in recent years.[1–3] The challenge is to further reduce this safety rate so that the projected increase in air traffic, which is expected to almost double during the next decade, does not increase the number of aircraft accidents.

Accident statistics suggest that controlled flight into terrain (CFIT) remains one of the leading categories of air carrier accidents.[1, 3–5] According to one widely quoted definition, a controlled-flight-into-terrain (CFIT) accident is one in which an otherwise serviceable aircraft, under the control of the crew, is flown (unintentionally) into terrain, obstacles or water, with no prior awareness on the part of the crew of the impending collision.[6]

The escalating costs of each accident in financial and human terms are significant and are not tolerable by the industry or the traveling public. Refs. 1–2 suggest that maintaining adequate aviation safety in the future will require new measures even if the current accident rate continues.

The number of recent CFIT accidents justifies further scrutiny of the problem, which could provide an opportunity for accident prevention and safety enhancement. The initial impulse to conduct CFIT research at the Netherlands National Aerospace Laboratory (NLR) stemmed directly from deliberations with Flight Safety Foundation (FSF) and the Netherlands Directorate-General of Civil Aviation (RLD). The objective of the investigation reported here was to identify and analyze factors associated with CFIT accidents. The research focused on evaluation of 156 CFIT accidents of commercial operators that occurred from 1988 through 1994. A previous NLR study developed a taxonomy of CFIT causal factors.[7] The results of that study provided a convenient starting point for the present investigation.

1.2 CFIT Prevention Activities

In the early 1970s, there was a spate of CFIT accidents, and a number of airline operators voluntarily began installing ground-proximity warning systems (GPWSs) aboard their aircraft. In 1972, the U.S. National Transportation Safety Board (NTSB) recommended to the U.S. Federal Aviation Administration (FAA) that GPWS be mandatory for all U.S. Federal Aviation Regulations (FARs) Part 121 aircraft operations. At that time, U.S. operators were experiencing several CFIT accidents each year. By 1974, GPWS was standard in all new Boeing aircraft. As a result of one accident near Washington, D.C., U.S., in 1974, the FAA required all large turbine aircraft engaged in international operations to be equipped with GPWS within one year. *International Civil*

Aviation Organization (ICAO) Standard and Recommended Practices concerning GPWS became applicable Aug. 10, 1978. The Standard in Annex 6, "Operation of Aircraft, Part I, International Air Transport — Aeroplanes," 6.15.1,[8] required aircraft (in international operations), with maximum certified takeoff mass (MCTM) in excess of 33,069 pounds (15,000 kilograms) or authorized to carry more than 30 passengers, for which the individual certificate of airworthiness was issued on or after July 1, 1979, to be equipped with GPWS. Part I, 6.15.2, recommended that such airplanes first certified before July 1, 1979, should be equipped with GPWS. A similar recommendation, but without any reference to dates of certification for airworthiness, was contained in Annex 6, "Part II, International General Aviation Aeroplanes," 6.9.[9] The application varies from country to country, and some countries require GPWS for both domestic and international operations.

Responding to an FSF CFIT Task Force recommendation, ICAO has expanded Annex 6 to apply the requirements described above to a greater proportion of the world's aircraft fleet. The new GPWS standards, effective Dec. 31, 1998, require GPWS in all airplanes in international commercial air service with an MCTM in excess of 12,566 pounds (5,700 kilograms), or authorized to carry more than nine passengers. No exception is made currently for older airplanes. A similar Standard in Annex 6, Part II, will require GPWS in all equivalent airplanes involved in international general aviation operations. This implies raising the status of the requirement from a Recommended Practice to an ICAO Standard. A further amendment to Annex 6, Parts I and II, also specifies the minimum modes in which the GPWS is required to operate.

Since the introduction of the GPWS, the overall CFIT accident rate has decreased.[10–12] The implementation of the minimum safe altitude warning (MSAW) feature of the automated radar terminal system (ARTS III), expansion and upgrading of air traffic control (ATC) radar, enhancement of flight crew training programs, improved flight standards, approach lighting, the visual approach slope indicator system (VASIS) and superior approach procedures may have contributed directly or indirectly to reducing the CFIT risk. There have also been significant improvements in the basic GPWS design since its introduction. Nevertheless, the current accident record suggests that the problem is far from eliminated, and these accidents continue to occur today with unacceptable frequency.[1, 4–5]

Currently, various sectors of the industry are focusing on means of further reducing the accident risk. These involve both long- and short-term strategies. The short-term strategies are required to bring about an immediate reduction in the current CFIT rate using low-cost, easily implemented concepts. The most notable effort is the FSF CFIT Task Force. Since 1992, the FSF-led aviation industry task force, in counsel with the International Air Transport Association (IATA) and ICAO, has attempted to improve awareness of CFIT accidents and establish measures to further reduce the accident rate.[13–23]

Other, longer-term efforts involve the development of advanced ground-collision avoidance systems (GCASs). Advanced systems with a forward-look capability could provide crews with earlier alerts of a CFIT threat. Some of these systems are being developed with terrain displays to enhance flight crew terrain awareness. Enhanced and synthetic vision systems are also under scrutiny.

The introduction of high-integrity terrain data bases, data storage devices, global positioning system (GPS)/global navigation satellite system (GNSS), head-up displays (HUDs), high-speed data processing hardware and new sensors has accelerated the interest. Some of the concepts have had previous military applications, and it is widely accepted that further research into the feasibility of such systems for civilian cockpits is needed. New technology, by its nature, is a longer-term solution.

1.3 Study Objectives

The overall objective of this study was to identify and analyze factors associated with CFIT accidents in commercial aviation. Identifying differences among CFIT accidents of major operators, regional operators and air taxi operators (Section 3.4.2.1 [a]–[c]) was central to the research.

2.0 Previous CFIT Accident Analyses

The concept of analyzing CFIT accidents is not original, and there is no shortage of literature, for example refs. 6–7, 10–13 and 24–36. Although much credible work has been done, some of the references date back more than 20 years (e.g., refs. 6 and 24–25) and may not reflect today's operational environment and current-generation aircraft. The more recent literature (e.g., refs. 10–13) indicate that a number of measures have been introduced over the years to prevent CFIT. The data suggest that the overall rate at which these accidents occur has decreased, but the current rate remains unacceptable. When comparing the analyses from the 1960s and 1970s (e.g., refs. 6 and 24–25) with more recent literature (e.g., refs. 10–13), it is evident that despite the preventive measures taken, some factors have continued to contribute to CFIT accidents. Some of these factors are related to flight crew (e.g., use of nonstandard phraseology, noncompliance with procedures, fatigue and visual illusions), ATC (e.g., erroneous vectors), weather and organizational issues. Other factors, such as confusing aeronautical charts and nonoptimal approach procedure designs, have also been implicated. Refs. 6 and 30 stress that CFIT is related heavily to organizational failures.

Other publications (such as refs. 26, 29 and 34) concentrate on GPWS performance. Ref. 34 says that the drawback of GPWS is that it treats an outcome, namely unsafe terrain proximity or closure, rather than addressing how the crew allowed this unsafe condition to develop. It notes that the

GPWS is an attempt to break the last link in the chain of events leading to CFIT, and that a better prevention strategy might be to intervene earlier.

Most of the studies referred to above, although recognizing that multiple agents may contribute to CFIT, have not necessarily conducted a comprehensive analysis of such factors. Ref. 32 does present evidence of the development of an appropriate accident taxonomy. That study was conducted primarily for defining flight crew information requirements. Information deficits that occurred in a limited sample of incidents and accidents were identified, so that changes in cockpit equipment and procedures could be proposed. The present study attempts to expand on the ideas presented in ref. 32 so that problems external to the cockpit can also be identified.

The recent thrust of industry activities related to CFIT by organizations such as FSF, ICAO, IATA and the International Federation of Air Line Pilots' Associations (IFALPA), and that no recent, similar study of CFIT causal factors with similar objectives could be identified, makes the current study timely and appropriate. The FSF effort has produced considerable insight into CFIT accidents, which has supported this investigation.

3.0 Methodology

3.1 Study Approach

The overall approach employed in this study was to:

(a) Identify a sample of CFIT accidents appropriate to the study objectives, using statistical and narrative accident data from worldwide sources;

(b) Identify potential CFIT factors using the accident narratives and literature;

(c) Develop an appropriate taxonomy for the collation and analysis of the information; and,

(d) Analyze the gathered information to determine what factors and to what degree they were associated with CFIT accidents in the study sample.

3.2 Data Sources

Accident data were acquired for two primary purposes:

(a) To apply the criteria in Section 3.3 to establish the accident sample; and,

(b) To compile specific information on each of the accidents according to the accident taxonomy described in Section 3.4.

Searches were conducted using the following data bases and sources:

- Airclaims Ltd.;
- AlliedSignal (formerly Sundstrand) CFIT data base;
- Australian Bureau of Air Safety Investigation (BASI);
- U.K. Civil Aviation Authority (CAA) World Airline Accident Summary;[37]
- Flight International annual review of accident statistics;[38]
- FSF publications;
- FSF CFIT Task Force accident data base;
- ICAO Aviation Data Reporting Program (ADREP) data base;
- Lawrence Livermore [U.S.] National Laboratory;[39]
- NTSB;
- NLR's accident data base (Flight Safety and Flight Testing Department); and,
- Netherlands Aviation Safety Board — Accident and Incident Investigation Bureau (NASB — AIIB).

These sources provided sufficient data to compile a virtually complete listing of CFIT accidents of major operators that fulfill the criteria in Section 3.3. Compiling a complete list of CFIT accidents of regional and air taxi operators was more difficult because of data limitations. Nevertheless, the NTSB data base was comprehensive enough to allow compilation of a nearly complete list of U.S. CFIT accidents for regional and air taxi operators. Those data were included in the accident sample, at the cost of biasing the sample by overrepresenting accidents to U.S. operators, because that information was more available.

Another challenge was collecting specific data for parameters of interest for each accident. Accessing accident investigation reports for each accident in the final accident sample was very difficult. Except for a few U.S. and European complete accident reports, accident summaries/narratives provided by the sources listed above were generally applied. Even where there were multiple data sources for an accident, the quality of data obtained was inferior to that found in well-documented accident investigation reports.

3.3 Accident Inclusion Criteria

Criteria used to establish the final accident sample, analyzed in this investigation, were as follows:

(a) The accidents involved CFIT.

For this study a slightly altered definition was applied to CFIT from that given on page 166:

A CFIT accident is one in which an aircraft, under the control of the crew, is flown (unintentionally) into terrain, obstacles or water with no prior awareness on the part of the crew of the impending collision.

Therefore, this study excluded collisions with terrain or water caused by problems such as:

- Hard landings;
- Unstabilized approaches;
- Gear-up landings or failures of landing gear;
- Runway overruns;
- Emergency descents;
- Fuel exhaustion;
- Downdraft/wind shear/wake vortex;
- Icing on airframe or wings;
- Bird strikes;
- Loss of power;
- Control-system problems;
- Pilot incapacitation;
- Sabotage/hijacking;
- Military action; and,
- Intoxication or drug use.

These exclusions were adopted because it is sometimes argued that many accidents involving collision with terrain are wrongly classified as CFIT.

(b) The accidents involved:

- Fixed-wing aircraft (helicopters were not considered);
- Turbojet, turboprop and piston-engine aircraft; and,
- Aircraft in all weight categories.

(c) The accident flights included those that were:

- Engaged in public transport;
- Both scheduled and unscheduled operations;
- Freight, passenger and positioning flights; and,
- Both international and domestic operations.

There was no restriction on geographical location.

Excluded were:

- Executive/corporate operations;
- General aviation;
- Training flights;
- Experimental/test flights;
- Aerial application/survey flights; and,
- Construction-work flights.

(d) The accidents occurred during 1988 through 1994.

This period is considered large enough to provide a statistically acceptable number of accidents, and the data are applicable to present-day aviation. The FSF CFIT Task Force used the same period for its accident data base. On the assumption that most of the 1995 data are still incomplete and preliminary, data from the most recent accidents were not used.

(e) The accidents resulted in loss of life.

Details of nonfatal accidents and incidents are not widely available in some countries. Therefore, only accidents that resulted in loss of life were included in the final accident sample. A preliminary examination suggested that most CFIT accidents involved at least one fatality, so the majority of CFIT accidents are probably included.

Application of the criteria resulted in a sample of 156 accidents, listed in Appendix B.

3.4 Accident Causal Factor Taxonomy

3.4.1 Development of a taxonomy

The accident record suggests that accidents rarely have a single cause but, instead, are the result of a series of contributory factors. Reason[40] argues that accidents should not be considered as isolated, infrequent events, but as the consequences of active and latent failures, sometimes acting in combination with external environmental factors, which facilitate a failure of the system. The taxonomy applied here also attempted to account for multiple contributory factors.

In a previous CFIT study,[7] NLR developed a comprehensive taxonomy of causal factors by using accident reports and related literature. That taxonomy consists of eight main parameter groups:

- Flight (basic parameters such as date, local time, flight phase, etc.);

- Flight crew;
- Environment;
- Airport and approach;
- ATC;
- Aircraft equipment;
- Air carrier (organizational); and,
- Regulatory issues.

The original CFIT taxonomy was considered too detailed to allow collection of many of the data items, a problem also encountered in the recent FSF/NLR study into approach-and-landing accidents.[41]

Therefore, the original CFIT taxonomy was simplified. The resulting taxonomy, which contains 85 factors, is presented in Appendix C. Many of the items discarded in this simplification are not unimportant causal factors. Nevertheless, the main groups referred to above have been preserved.

3.4.2 Definitions

3.4.2.1 Flight variables

It was difficult to obtain explicit definitions of major, regional and air taxi operators that would apply worldwide. The following definitions, based on U.S. operations, were loosely applied to categorize operator type:

(a) **Major operator.** Operators that have similar characteristics to carriers currently operating under FARs, Part 121. The aircraft generally have more than 30 seats.

(b) **Regional operator.** Air carriers that generally provide scheduled and nonscheduled short-haul passenger and freight services. Typically a wide range of both turboprop and turbojet aircraft with seating capacities of 19 to 100 are used.

(c) **Air taxi operator.** Air carriers that transport persons, property and mail, generally using small aircraft (fewer than 30 seats). In the United States, these carriers operate in accordance with FARs, Part 135. Much of the operation is on-demand, as opposed to following a published flight schedule.

The following flight phase definitions, based on those used by the U.K. CAA[37] and Airclaims, were adopted for this investigation:

(a) **Takeoff (initial climb)**. From liftoff until first power reduction or 1,500 feet (458 meters);

(b) **Takeoff (climb cruise)**. From end of initial climb until first en route altitude;

(c) **En route**. From top of climb to commencement of descent. Included are changes of level en route, en route holding, etc.;

(d) **Landing (descent)**. From top of descent to 1,500 feet (458 meters);

(e) **Landing (hold)**. Holding during descent;

(f) **Landing (approach)**. From 1,500 feet (458 meters) to the runway threshold; and,

(g) **Landing (go-around)**.

3.4.2.2 Flight crew variables

The flight crew error definitions were derived from ref. 42. The main goal was to record the number of accidents in which each error type occurred. Therefore, even when a particular error occurred more than once in an accident, the error was recorded as a single event. This approach was adopted because of the limited information provided in most of the accident summaries.

Primary errors are independent of any prior error. The six primary error types are:

(a) Communication: Incorrect read-back, hear-back; failing to provide accurate information; providing incorrect information.

Examples:

- Did not read back frequency change.
- Misinformed tower of aircraft position.

(b) Navigational: Selecting the wrong frequency for the required radio navigation station; selecting the wrong radial or heading; misreading charts.

Example:

Used distance measuring equipment (DME) rather than cross-bearing for desired intersection.

(c) Procedural: Failing to make required call-outs, making inaccurate call-outs; not conducting or completing required checklists or briefs; not following prescribed checklist procedures; failing to consult charts or obtain critical information.

Examples:

- Did not request updated weather information.
- Did not call out 1,000 feet (305 meters) above field level.

(d) **Situational awareness**: Controlling aircraft to wrong parameters.

Examples:

- Descended below 3,000 feet (915 meters) prior to being established on the localizer.
- Commenced descent to minimum descent altitude (MDA) prior to reaching the final approach fix (FAF).

(e) **Systems operation**: Improper operation of engines or hydraulic, brake and fuel systems; misreading and mis-setting instruments; disabling warning systems.

Examples:

- Turned off GPWS.
- Stated incorrect reading of fuel quantity gauges.

(f) **Tactical decision**: Improper decision making; failing to revise action in response to signal to do so; failing to heed warnings or alerts that suggest a revision of action.

Examples:

- Continued to hold; accepted a vector away from the airport.
- Descended below decision height (DH) prior to sighting runway environment.

In contrast, a *secondary error* depends on another crew member previously or simultaneously making a primary error.[42]

(g) **Monitoring/challenging**: Failing to monitor and/or challenge faulty action or inaction (primary error) by another crew member.

Example:

- The primary error was made by the captain, who was the pilot flying (PF). The captain did not execute a go-around on reaching DH in instrument meteorological conditions (IMC). The monitoring/challenging error, made by the first officer, who was pilot not flying (PNF), entailed not challenging descent below DH.

3.5 Accident Data Coding Protocol

An accident was included in the sample only when it clearly satisfied the CFIT definition in Section 3.3(a). Several accidents were listed as CFIT occurrences in a particular data base, but the accident summary (or accident investigation report) did not support a CFIT classification according to the definition used in this study. Those accidents were not included, ensuring a more homogeneous sample.

The general procedure for coding the data from each accident included reviewing the appropriate accident summary or report. The accident was coded in terms of the CFIT taxonomy. Only those variables with clear information cited in the report or summary were coded. The coding protocol precluded interpretation of the report narrative by the analysts to complete the variable (especially where a subjective judgment could be applied, e.g., fatigue, improper crew pairing, etc.). Where information was not provided, or was not complete enough, the value was coded as “unknown.” Some information may have been lost, but this procedure reduced the risk of coding bias, improved coding reliability and ensured consistency of coding across all accidents.

3.6 Airport Data

For the accidents that occurred in the landing (descent) and landing (approach) phases of flight, airport-specific data were demanded by the taxonomy.

Data sources were principally the Jeppesen Airways Manual and other aeronautical information publications. In addition, navigational documentation published by major airlines was consulted.

The only common feature of these data sources is that they are used for navigation and they are periodically updated with an amendment service. Therefore, these data must be considered biased because they represent a November 1995 snapshot of available resources at the airports, and it is assumed that this snapshot describes the situation throughout the 1988–1994 time span. This assumption is plausible considering the time and investments required to significantly upgrade airport facilities; the level of facilities offered in 1995 differ significantly from the 1988–1994 situation for only a few airports.

The data items required fall into two categories: airport and runway variables. *Airport variables* describe the airport as a whole and hold true for all runway-ends at that airport; *runway variables* describe an individual runway.

Data regarding the following airport variables were collected:

(a) The presence of significant terrain features in the airport vicinity. Significant terrain is defined as “any spot elevation or obstacle more than 2,000 feet (610 meters) above the aerodrome reference point (ARP) elevation within a circle of six nautical miles (NM) (6.9 statute miles/11.1 kilometers) around the ARP or 6,000 feet (1,830 meters) within a circle of 25 NM (28.75 statute miles/46.26 kilometers) around the ARP.” A similar definition is used by Jeppesen to determine whether to include colored contours in its approach plates,[43] and was employed in the recent FSF/NLR airport safety study;[41]

(b) The availability of the latest weather observations to the pilot via automatic terminal information service (ATIS) or meteorology information for aircraft in flight (VOLMET);

(c) The presence of terminal approach radar (TAR); and,

(d) The presence of published arrival routes from the airways to the FAF of the standard terminal arrival route (STAR).

For every runway-end, information about these runway variables was collected:

(e) The presence of an approach lighting system;

(f) The presence of a visual glidepath-indicating system such as precision approach path indicator (PAPI) or VASIS;

(g) The most precise published instrument approach procedure to the runway-end; and,

(h) Whether the instrument approach has a constant descent gradient from FAF to the runway threshold that can be monitored by the crew during the approach.

3.7 Analytical Processes

One goal of this study was to estimate the risk associated with the various factors included in the accident taxonomy. To accomplish this, it is also essential to understand the underlying prevalence of those individual factors, systemwide, among commercial operators *not* involved in accidents. These data could then be used to determine rates for each of the potential risk factors. This approach has been successfully adopted elsewhere (e.g., in the FSF/NLR approach-and-landing aids study).

Nevertheless, two major difficulties were encountered during this study. First, many of the nonaccident data for many parameters in the CFIT taxonomy were unavailable. Second, when nonaccident data were available, they were often incomplete and could not be used to estimate rates. For example, worldwide movement data for scheduled flights of major operators were available, but data were impossible to obtain for nonscheduled flights and for air taxi operations within a number of ICAO regions. These difficulties meant that risk rates associated with many parameters of interest could not be calculated.

The major steps included in the analysis for this study are listed below:

(a) A digital version of the data base was accomplished, and the data were evaluated through simple single-variable analysis. This included developing frequency distributions for each variable, looking at the geographic distribution of accidents and performing other simple explanatory analyses that provided a basic understanding of the accident data. Single-population qualitative data were analyzed using chi-square (χ^2) tests; and,

(b) After the basic evaluation was completed, relationships among various parameters were evaluated. For qualitative data, the comparison of two or more populations and the analysis of the relationship between two variables were facilitated by the use of a χ^2 test of a contingency table. The tests for quantitative data involving two or more populations included the Krusskal-Wallis test for completely randomized design (i.e., independent samples).

4.0 Results and discussion

Unless otherwise stated, all percentages are based on the total sample (N = 156), presented in Appendix B. *N* denotes the number of valid cases.

The level of significance, α, is set at 0.05.

4.1 Missing Data

Analyzing parameters with a large proportion of missing data would not lead to very useful results (especially because the accident sample size was limited). Therefore, the data set was examined to identify variables with significant missing data. Those parameters are presented in Appendix D. Although most of those parameters were excluded from subsequent analysis, several were retained because they have been reported elsewhere as important contributory factors to CFIT accidents.

4.2 Flight Variables

4.2.1 Year of accident

The distribution of the absolute number of accidents per year for the period under study did not show any striking trend. Rates were difficult to estimate because of lack of aircraft movement data. Nevertheless, based on movement data of scheduled air traffic published by ICAO,[44–50] it was possible to calculate approximate CFIT accident rates per year for scheduled flights of major operators (Figure 1, page 186).

When the raw data are stratified across domestic/international flights and operator type, the resulting trends are shown in Figure 2 (page 186) and Figure 3, (page 187) respectively. An average of about four accidents per year involved international operations, in contrast to an average of 14 for domestic operations. Regional and air taxi operations together accounted for about 13 accidents per year on average, whereas major operators suffered an average of five per year.

4.2.2 Time of accident

Figure 4 (page 187) shows the distribution of the times the accidents (N = 101) occurred. About 42 percent of the accidents occurred in the morning-midday period (0600–1359 hours), 47 percent during the afternoon-evening period (1400–2159) and 12 percent in the overnight period (2200–0559). (These definitions are derived from ref. 42.) As time-of-day data for a sample of nonaccident flights were not available, rates could not be determined. The small number of accidents in the overnight period probably reflects the lower activity levels during that period.

Table 1 presents the time-of-accident data stratified across operator type. The overnight period accounted for 15.4 percent of major-operator accidents. Ref. 42 provides time-of-day data for a sample of 214,000 nonaccident flights conducted by major U.S. operators during 1988. Of those, 13 percent operated between 2200 and 0559, which is comparable to major operator accidents in this study. The regional operators also accounted for a small proportion of accidents in the overnight period. Nevertheless, 29.4 percent of air taxi accidents occurred in the overnight period. If activity levels of nonaccident flights for air taxi operators are comparable to those for major operators, this finding may suggest that an increased risk is associated with overnight air taxi operations.

4.2.3 Accident site

4.2.3.1 ICAO region

Figure 5 (page 188) presents the CFIT accident distribution among the major ICAO regions. North America accounts for 34.6 percent of the total accident sample. What appears to be a disproportionate number of accidents in North America is because of the accessibility of U.S. accident data, as well as the commercial aviation activity level. This bias is probably present only for the air taxi and regional operators; accident reporting of major air carriers is believed to be better in most areas of the world. Because of this bias and the unavailability of movement data, it was not possible to calculate accurate accident rates for air taxi and regional operators.

Based on movement data of scheduled air traffic published by ICAO,[44–50] it was possible to calculate CFIT accident rates per region for scheduled flights of major operators (Figure 6, page 188). A composite rate is presented for Europe (combining the rates for Europe and Eastern Europe ICAO regions). The rates calculated are compared with rates presented by the Boeing Commercial Airplane Group,[14] and risk multipliers presented in the FSF CFIT Checklist[20] are shown in Table 2. The magnitudes of the accident rates are not identical for a given region when comparing the data from the current study with that from ref. 14. This is probably because the rates estimated here are based on scheduled flights, whereas those in ref. 14 include nonscheduled operations as well. Nevertheless, in all three columns of Table 2, Africa appears to have the highest CFIT rate, followed by South America and Asia/Pacific. North America and the Middle East have the lowest CFIT rates.

In ref. 35, CFIT losses are presented for both major operators and regional operators in Europe and the United States, as average losses per year over the 10-year period 1984–1993. In Table 3 (page 174) those results are compared to the average annual losses established in this study. Those numbers correspond closely, except for the annual loss for regional operators in Europe — the magnitude presented in ref. 35 is almost five times higher than that of this study. Part of the discrepancy may be because of dissimilar definitions for the term “regional operator.” Ref. 35 does not provide an explicit definition.

Table 1
Time of Accident Stratified Across Operator Type, Study Data Base

Time	Major		Regional		Air Taxi	
Morning–midday (0600–1359)	15	(57.7%)	12	(44.4%)	11	(32.4%)
Afternoon–evening (1400–2159)	7	(26.9%)	12	(44.4%)	13	(38.2%)
Overnight (2200–0559)	4	(15.4%)	3	(11.1%)	10	(29.4%)
Totals	26	(100.0%)	27	(100.0%)	34	(100.0%)

N = 87

Source: Netherlands National Aerospace Laboratory (NLR)

Table 2
CFIT Rates for ICAO Regions
(Accidents per Million Flights)

ICAO Region	This Study	Ref. 14	Risk Multiplier, FSF CFIT Checklist
Africa	0.70	2.40	8.0
Asia/Pacific	0.57	1.00	3.0
Europe	0.27	0.45	1.3
South America	0.63	1.14	5.0
Middle East	0.00	0.00	1.1
North America	0.00	0.03	1.0

Source: Netherlands National Aerospace Laboratory (NLR)

4.2.3.2 Distance from the accident to the runway threshold

Figure 7 (page 189) presents the distance from the aircraft accident location to the runway threshold for accidents occurring in the landing (approach) phase (N = 80). The progressive increase in the number of accidents with decreasing distance to the runway threshold shown in Figure 7 is also reported elsewhere (for example, refs. 25 and 51). The shape of this curve is similar to that of a plot of undershoot and terrain-collision accidents published by ICAO.[25] The ICAO plot, however, shows more accidents occurring closer to the runway threshold because the ICAO data also include non-CFIT accidents. A similar trend is shown in ref. 11 for 40 CFIT accidents that occurred during the five-year period 1986–1990. All those accidents occurred within a radius of approximately 15 NM (17.25 statute miles/ 27.76 kilometers) from the runway threshold, and this is comparable to the data in Figure 7.

When the accident location data were scrutinized as a function of operator type, there were no notable trends.

4.2.4 Aircraft

4.2.4.1 Aircraft type

Appendix B lists the aircraft types involved in the accidents. Table 4, derived from those data, provides a more general picture of the aircraft categories. Business aircraft types accounted for 40 percent, commuter types for 25 percent and transport aircraft for 35 percent of the total sample.

For this study, the aircraft were also divided into three classes based on the applicability of current and future ICAO GPWS requirements (Section 1.2). The ICAO requirements are a function of aircraft weight and apply only to international operations. The following definitions were based on ICAO weight classes:

(a) Small — aircraft not required to be equipped with GPWS in accordance with current or future ICAO requirements outlined in ref. 21. MCTM: less than 12,566 pounds (5,700 kilograms).

(b) Medium — aircraft that will be required to be equipped with GPWS in the future, if engaged in international operations, but are currently not required to be GPWS-equipped. MCTM: 12,566 pounds (5,700 kilograms) – 33,069 pounds (15,000 kilograms).

(c) Large — aircraft that must be equipped with GPWS in accordance with current ICAO requirements if engaged in international operations. MCTM: greater than 33,069 pounds (15,000 kilograms).

Table 4
Accident Aircraft Categories, Study Data Base

Aircraft Category	Number	Percent
Business piston*	48	30.8
Business turboprop*	12	7.7
Business jet*	2	1.3
Commuter turboprop	37	23.7
Commuter jet	2	1.3
Transport turboprop	18	11.5
Transport jet	37	23.7

*Business aircraft types being used in commercial operations.

Source: Netherlands National Aerospace Laboratory (NLR)

Applying these definitions to the accident sample aircraft produces the data in Figure 8 (page 189). Comparing the frequencies of the various weight classes is not very useful because the sample is biased (e.g., 42 of the 61 small aircraft were U.S. registered).

More important, perhaps, is the percentage of accident aircraft that may benefit from new ICAO requirements when the weight classification described above is applied. The small-aircraft category accounted for 40 percent of the total sample and will not benefit from the new requirements. The medium- and large-aircraft categories must be stratified as a function of international/ domestic operations to reveal any additional protection offered by the new requirements. Data were missing in only 33 cases.

The data for applicability of future GPWS standards are shown in Figure 8. Twenty-five medium-category aircraft (63 percent) would not be covered, whereas 25 large-category aircraft

Table 3
CFIT Annual Losses in Europe and the United States

Average Annual CFIT Loss	Major Operator Ref. 35	Major Operator This Study	Regional Operator Ref. 35	Regional Operator This Study
Europe	1.2	1.1	2.8	0.6
United States	0.2	0.0	3.0	2.7

Source: Netherlands National Aerospace Laboratory (NLR)

(45 percent) would be excluded. In total, 71 percent of the accident aircraft would not be required to be fitted with a GPWS in the future if the weight classification system described above is strictly applied.

Some countries (e.g., the United States) have extended the basic ICAO requirements to include domestic operations, and this should be taken into account in interpreting the data. The Aircraft Equipment Committee of the FSF CFIT Task Force has made specific recommendations to require the installation of GPWS for domestic operations.[23]

4.2.4.2 Aircraft damage

Table 5 shows the distribution for aircraft damage. In 86.5 percent of the sample (or 97 percent of the cases where data were known), the aircraft was completely destroyed. This illustrates the high level of kinetic energy associated with fatal CFIT accidents.

Table 5
Accident Aircraft Damage, Study Data Base

Damage	Number	Percent
Destroyed	135	86.5
Substantial	4	2.6
Minor	0	0
None	0	0
Unknown	17	10.9

Source: Netherlands National Aerospace Laboratory (NLR)

4.2.5 Phase of flight

Figure 9 (page 190) shows the flight-phase distribution of the accidents. (In five accidents the data were unknown). Most accidents occurred in the landing (approach) phase (47.7 percent), followed by 21.9 percent in the landing (descent) phase, for a combined total of 69.6 percent. The en route phase accounted for about one-fifth of the accidents. The difference between the frequencies of occurrence was found to be statistically significant ($c^2 = 142$ and $p < 0.01$). Figure 9 shows a stratification in terms of operator type. Caution must be exercised in comparing operator types for a given flight phase because of the sample bias. In those cases for which data were known, 93 percent of the en route accidents were attributable to air taxi operators and regional operators. This is probably because the majority of aircraft types engaged in such operations cruise at significantly lower altitudes than those used by major operators.

Figure 10 (page 190) shows an alternative distribution of the flight phases for each operator type. Although major operators and air taxi operators suffered their greatest losses in the landing (approach) phase (61.1 percent and 48.9 percent, respectively, $p < 0.01$), the regional operators encountered the largest percentage of accidents in the en route phase (32.6 percent, $p < 0.01$).

4.2.6 Type of operation

Table 6 shows the distribution by type of operation. Nonscheduled flights accounted for at least 43 percent of the sample (44.9 percent were scheduled). At least 65.4 percent of the accident sample involved passenger flights, whereas 26.3 percent were cargo flights. Ten flights involved repositioning. Because movement data were unavailable, accident rates could not be calculated.

In accidents where data were known (N = 123), 20.3 percent of the flights were international, whereas almost 80 percent were domestic. Based on movement data of scheduled air traffic published by ICAO,[44–50] it was possible to calculate CFIT accident rates for scheduled international and scheduled domestic flights of major operators (Figure 11, page 191). The CFIT accident rate for international flights was 3.8 times higher than the CFIT accident rate for domestic flights. The increased CFIT danger for international flights is recognized by FSF, and the FSF CFIT Checklist[20] includes a risk multiplier of 3 for international flights, compared to 1 for domestic flights.

4.2.6.1 ICAO operator region

The ICAO operator region was based on the country in which the operator was registered. Figure 12 (page 191) presents the distribution of the ICAO operator regions. The disproportionate representation of North American operators, caused by the accessibility of U.S. data and U.S. commercial aviation activity

Table 6
Accident Aircraft Types of Operation, Study Data Base

Type of Operation	Yes	No	Unknown
Scheduled (no = nonscheduled)	67 (42.9%)	70 (44.9%)	19 (12.2%)
Passenger (no = freight)	102 (65.4%)	41 (26.3%)	3 (8.3%)
International (no = domestic)	25 (16.0%)	98 (62.8%)	33 (21.2%)

Source: Netherlands National Aerospace Laboratory (NLR)

levels, is evident. Comparing Figure 12 and Figure 5 (accident ICAO regions) suggests no significant differences in accident aircraft ICAO operator regions.

4.2.6.2 Operator type

Table 7 presents the distribution of air taxi, regional and major operations. As mentioned earlier, the accident sample is biased because U.S. regional and air taxi operator CFIT accident data are more easily accessible than those of many other areas of the world. Therefore, the true contribution of regional and air taxi operator accidents is probably even higher than that shown in Table 7. Official sources appeared to reinforce that supposition. Rates could not be estimated because movement data were unavailable.

Table 7
Accident Aircraft Operator Types, Study Data Base

Operator Type	Number	Percent
Major	36	23.1
Regional	46	29.5
Air taxi	47	30.1
Unknown	27	17.3

Source: Netherlands National Aerospace Laboratory (NLR)

Stratification across ICAO regions was inconclusive because of the biased data. Nevertheless, the U.S. data are considered reliable, and for the United States air taxi operator accidents accounted for 61 percent of the sample, regional operator accidents for 35 percent and major operator accidents for only 4 percent. Again, these are not rates.

Stratification of the operator type data as a function of domestic/international flights and scheduled/nonscheduled operations is presented in Figure 13 (page 192) and Figure 14 (page 192), respectively. By their nature, most air taxi and regional operations were domestic. Domestic flights, for which GPWS is not mandated by ICAO, accounted for 39 percent of the major operators' flights. Figure 14 indicates that a substantial proportion of flights in the major and regional operator categories were scheduled (69 percent and 70 percent, respectively).

Figure 15 (page 193) presents the operator data as a function of passenger and freight operations. Passenger flights accounted for the bulk of major operator flights (69 percent), whereas about one-half (49 percent) of air taxi operations comprised passenger flights. Eighty-seven percent of regional operations were passenger flights.

4.2.7 Fatalities

There were 3,177 fatalities in the total sample of 156 accidents. In three-fourths of the accidents the fatality rate (the percentage of the aircraft occupants who were fatally injured) was 100 percent. The mean fatality rate was 91 percent, another indication of the extreme kinetic energy associated with CFIT accidents.

4.3 Flight Crew Variables

4.3.1 Number of flight crew

Figure 16 (page 193) presents the distribution for the number of flight crew in the accident aircraft. In 48 accidents (30.8 percent), the flight was a single-pilot operation, while 44 (23.1 percent) of the flights were conducted by at least a two-person crew. Data were missing in 41.0 percent of the sample. An operator type stratification is made in Figure 17 (page 194). Where data were known, the major operator flights were piloted by at least a two-person crew and the majority of air taxi flights were single-pilot operations, but the regional operator sample was divided between those two categories.

4.3.2 Pilot flying

Figure 18 (page 194) shows the pilot flying (PF) distribution for the accident sample. For half the accident sample data were missing. Single-pilot operations flown by a captain (CAPT1) accounted for 30.8 percent of the sample. The high number associated with a single pilot reflects the large number of air taxi operations included in the accident sample.

It has been said that a large number of CFIT accidents occurred while the first officer was the PF. In this accident sample, for operations where there were at least two crew members, the captain (denoted by CAPT in Figure 18) was the PF in 11 (7.1 percent) of the cases, and the first officer (FO in Figure 18) was the PF in at least 13 (8.3 percent) of the flights. This difference is not statistically significant.

Stratification of the data as a function of operator type was inconclusive because of the small sample size (compounded by the missing data).

4.3.3 Flight crew experience

The basic statistics associated with flight crew experience are shown in Table 8 (page 177).

4.3.3.1 Total hours of flying experience

As might be expected, the means of the total hours of flying experience of the captains and first officers in the sample differed significantly (p = 0.005) where data were available. The distributions of flight experience for the captains and first officers are presented in Figure 19 (page 195) and Figure 20 (page 195), respectively. Almost 76 percent of the captains in accidents where data were known (N = 66), had less than 6,000 total hours of experience — 6,000 hours is the upper limit of the 95 percent confidence interval. Half the captains had less

Table 8
Flight Crew Experience, Study Data Base

Aspect of Experience	Captain	First Officer
Total flying experience (hours)		
Range	480–16,000	425–15,639
Mean	5,097	3,084
Standard deviation	3,707	4,220
N	66	13
Experience in accident aircraft type (hours)		
Range	4–4,500	4–1,100
Mean	1,046	182
Standard deviation	1,134	300
N	52	12
Total instrument flying experience (hours)		
Range	16–3,764	38–389
Mean	600	214
Standard deviation	839	248
N	37	2

Source: Netherlands National Aerospace Laboratory (NLR)

than 4,000 hours of experience. In the accidents where data were known (N =12), more than half the first officers had less than 2,000 total hours of experience.

Table 9 shows the data for captains when stratified across operator type. The major operator captains were the most experienced, the regional operator captains were next and the air taxi operator captains had the least total hours of flying experience. These differences were statistically significant at the 95 percent confidence level (p = 0.0018). A similar stratification was not possible for the first officer data because of the small sample size.

4.3.3.2 Hours on aircraft type

Not surprisingly, the difference between the mean hours on type for captains and first officers was significant (p = 0.0002), where data were available (Figure 21, page 196) and Figure 22, page 196). In 67 percent of these accidents, the captain had fewer than 1,000 hours of experience on type. More than 42 percent of the captains had fewer than 500 hours of flight time on type. For all but one first officer, experience on type was fewer than 500 hours (N = 12).

Table 9
Captains' Total Experience, Study Data Base

	Major	Regional	Air Taxi
Mean (hours)	10,378	5,869	3,743
Standard deviation (hours)	3,537	4,084	2,474
N	5	22	33

Source: Netherlands National Aerospace Laboratory (NLR)

Table 10 shows the data as a function of operator type for the captains. These means did not differ significantly at the 95 percent confidence level (p = 0.2319). Similar data for the first officers could not be calculated because of the small numbers.

Table 10
Captains' Experience on Aircraft Type, Study Data Base

	Major	Regional	Air Taxi
Mean (hours)	2,182	1,124	982
Standard deviation (hours)	1,654	1,216	1,036
N	3	21	23

Source: Netherlands National Aerospace Laboratory (NLR)

4.3.3.3 Instrument flight hours

Where data were available (N = 37, Figure 23, page 197), almost 73 percent of captains had fewer than 500 hours of instrument flight time. In about one-half the accidents the captains had fewer than 220 hours. Instrument flight times for major operator accidents were missing. The regional and air taxi operator captains' mean instrument times were found not to differ significantly at the 95 percent confidence level (p = 0.5090).

Data for first officers were available in only two accidents and are presented in Table 8.

4.3.4 Crew compatibility — improper crew pairing

Improper pairing of crews means inappropriate pairing of two pilots according to their relative levels of experience. Despite the large missing data set (87.0 percent of the relevant cases), this parameter is included because it has been an issue in some recent accidents. In seven accidents (6.5 percent of the relevant accidents, which are dual-pilot operations), improper crew pairing was cited as a contributing factor.

4.3.5 Fatigue

Again, a high proportion (63.4 percent) of the data were missing, but the data available are presented for reasons similar to those outlined in 4.3.4. In five accidents, (3.2 percent) fatigue was cited as a contributory factor, whereas in one-third of the total sample, fatigue was known not to have been a factor.

4.3.6 Visual and physical illusions

Visual and physical illusions refer to phenomena such as "black hole" approaches and somatogravic illusions, respectively. Data for approximately one-half the sample (54.5 percent) were missing. In nine accidents (5.8 percent), a visual or physical illusion contributed to the accident, but it is known that such illusions did not play a role in 39.7 percent of the accidents.

4.3.7 Flight crew errors

Figure 24 (page 197) presents a distribution of the number of accidents in which flight crew errors occurred. In a very high percentage of accidents the data were unknown, and therefore any comparison of the frequency of occurrence must be made with extreme caution. Nevertheless, the following observations can be made:

- At least 11 accidents included a communication error (7.1 percent);
- 18 accidents involved a navigational error (11.5 percent);
- 53 involved a procedural error (34 percent);
- 70 involved a situational-awareness error (44.9 percent);
- 13 included a systems-operation error (8.3 percent);
- 69 involved a tactical-decision error (44.2 percent); and,
- 31 involved a monitoring/challenging problem (28.7 percent of the relevant accidents — 48 accidents involved single-pilot operations where this error category is not applicable).

Although it is difficult to draw conclusions from the data about the relative frequencies of occurrence, because of the high proportion of missing data, it is evident that procedural, situational-awareness and tactical-decision errors are dominant, whereas communication errors were probably less of a problem. (Figure 24 also indicates that in 37.2 percent of the accidents, it is known that communication errors were not a factor.) Ref. 42 reported similar trends for a sample of 37 Part 121 U.S. accidents.

Despite the large percentage of missing data, an attempt was made to identify any association between the error types and the following variables:

(a) Single- vs. multiple-crew operation;

(b) Operator type (major, regional or air taxi);

(c) PF for multiple-crew operations (first officer vs. captain); and,

(d) Approach type (precision vs. nonprecision).

For (a), the only finding was that no systems-operation errors were reported in the single-pilot operations, and this association was significant at the 95 percent confidence level. Stratification (b) showed that the systems-operation errors were all made by the regional and major carriers. Virtually all monitoring/challenging errors involved major and regional operators. This result is not surprising, because most of the air taxi operations were single-pilot flights. No association was demonstrated between crew error and approach type (p = 0.094), but the contingency table for situational-awareness error is shown in Table 11. Data were available in 42 of the 66 landing (approach) phase accidents, and in virtually all those, situational-awareness error was present.

Table 11
Situational-awareness Error Stratified Across Approach Type, Study Data Base

	Yes	No
Precision	13	3
Nonprecision	26	0

Source: Netherlands National Aerospace Laboratory (NLR)

4.3.7.1 Visual meteorological conditions (VMC) flight into IMC

In 30 accidents (19.2 percent of the total sample), inadvertent flight from VMC into IMC was a factor. Data were missing in 67 cases (43 percent). When these 30 cases are stratified across single- and dual-/multiple-crew operations, it is seen that 21 accidents occurred in single-pilot operations, and this association is significant at the 95 percent confidence level. When the instrument flight time of pilots involved in VMC-into-IMC accidents is compared to those who were not involved in such accidents, the difference is not significant for the available data set (p = 0.9533). The mean instrument time for the accident pilots was 611 hours (N = 14).

Table 12 (page 179) shows the available data (N = 79) stratified across operator type.

Most of the accidents were for regional and air taxi operators (p = 0.006).

The data available are shown as a function of flight phase in Table 13 (page 179). Seventeen of the 30 VMC-into-IMC accidents occurred in the en route phase, and this association is significant at the 95 percent confidence level.

4.3.7.2 Minimum altitude not maintained

This error refers to the pilot/crew descending below an ATC clearance, the minimum sector altitude (MSA), the

Table 12
VMC-into-IMC Accidents Stratified Across Operator Type, Study Data Base

	Yes	No
Major	1	20
Regional	13	15
Air taxi	11	19

IMC = Instrument meteorological conditions
VMC = Visual meteorological conditions

Source: Netherlands National Aerospace Laboratory (NLR)

minimum off-route altitude (MORA) or a specific altitude associated with the approach procedure (e.g., stepdown on a very high frequency [VHF] omnidirectional radio range [VOR] distance measuring equipment [DME] approach). In at least 54 accidents (35 percent of the total sample) it was known that this error played a role, with data unavailable in the other cases. Stratification of the data as a function of single- and dual-/multiple-crew operations and flight phase is not significant (p = 0.257 and p = 0.059, respectively).

4.3.7.3 Response to GPWS alerts

Table 14 summarizes the crew responses to the GPWS alerts. In only 12 accidents (44.4 percent of the GPWS-equipped aircraft — 27 in all), was it known whether the crew reacted to the GPWS signal. This sample size is too small to draw any firm conclusions, but it is remarkable that in eight of those accidents (29.6 percent of the GPWS-equipped aircraft) there was no crew reaction to the GPWS.

Because of the lack of data, it is not possible to draw any conclusions about the delays associated with crew response, the correctness of the escape maneuver and possible disabling of the GPWS by the crew.

Table 13
VMC-into-IMC Accidents Stratified Across Phase of Flight, Study Data Base

	Yes	No
Takeoff (initial climb)	0	3
Takeoff (climb cruise)	1	2
En route	17	5
Landing (descent)	6	11
Landing (approach)	6	34
Landing (go-around)	0	4

IMC = Instrument meteorological conditions
VMC = Visual meteorological conditions

Source: Netherlands National Aerospace Laboratory (NLR)

Table 14
Crew Response to GPWS Alert, Study Data Base

	Yes	No	Unknown	Total
GPWS alert given	15	9	3	27
Crew initiated escape maneuver	4	8	15	27
Crew responded in time	2	2	23	27
Escape maneuver correct	0	4	23	27
GPWS disabled by crew	1	4	22	27

GPWS = Ground-proximity warning system

Source: Netherlands National Aerospace Laboratory (NLR)

4.3.7.4 Barometric altimeter setting/reading

The incorrect setting or reading of the barometric altimeter has been associated with some CFIT accidents.[52–54] The necessary data were available in only 16.0 percent of the accident reports or summaries. In five accidents (3.2 percent of the total sample), the barometric altimeter was set incorrectly. In only one accident (0.6 percent), was the barometric altimeter read incorrectly.

4.4 Environment Variables

4.4.1 Basic weather

Figure 25 (page 198) shows the basic weather data. Ninety-three accidents (87 percent of the sample for which data were available, N = 107) involved IMC, compared with 14 accidents in VMC.

4.4.2 Light/Dark conditions

Figure 26 (page 198) shows the distribution for the light/dark conditions at the accident time. Where data were known (N = 114), one-half the accidents occurred in dark conditions, whereas 46 percent involved light conditions. The light/dark condition data were stratified across basic weather (N = 86), where data were available (Table 15, page 180). Whatever the light/dark condition, IMC prevailed in a high proportion of the accidents. Nine accidents occurred, surprisingly, in the light/VMC combination. When the narratives of these accidents were closely examined, it appeared that although the basic conditions may have been reported as VMC, there was cloudiness in the vicinity of the accident sites. Seven of these nine accidents involved regional and air taxi flights.

4.4.3 Fog

Data on the presence of fog at the accident location was missing in 50 percent of the sample. Where data were available (N = 78), fog was present at the accident location in 55 accidents (71 percent).

4.4.4 Precipitation

Figure 27 (page 199) shows the distribution of the type of precipitation present at the accident location. Data were missing in 47.4 percent of the accidents. In almost one-fourth of the accident sample, rain was present.

4.4.5 Cloud base

Where the cloud base data were known (N = 49), the cloud base was at or below 1,000 feet (305 meters) in 31 accidents (63.3 percent).

4.4.6 Visibility

Where the visibility was known (N = 54), the visibility was less than 0.5 NM (0.58 miles/0.92 kilometers) in 27.8 percent of the accidents.

4.5 Airport and Approach Variables

Table 16 shows the distribution of the airport and approach variables. Only accidents that occurred during the landing (descent) and landing (approach) phases of flight (N = 116) are considered here.

Table 15
Light/Dark Conditions as a Function of Basic Weather, Study Data Base

	Dark		Light		Dusk	
IMC	33	(87%)	37	(80%)	2	(100%)
VMC	5	(13%)	9	(20%)	0	
Totals	38	(100%)	46	(100%)	2	(100%)

IMC = Instrument meteorological conditions
VMC = Visual meteorological conditions

Source: Netherlands National Aerospace Laboratory (NLR)

In just over one-fourth of the sample, significant terrain features were present in the vicinity of the airfield, but in almost 40 percent there was no high terrain. This indicates that CFIT accidents do occur in areas without high terrain. In about one-fourth of the cases approach lights and visual approach guidance (VASIS/PAPI) were not present, and there was no TAR for 37.0 percent of the accidents. In the recent FSF/NLR study of approach-and-landing safety[41], it was found that lack of TAR was associated with a three-fold increase in risk of accidents compared to approaches conducted with TAR present.

In about one-fifth of the sample herein, the approach procedure design to the applicable runway was not stabilized. In 35 percent of the landing (descent) and landing (approach) accidents, weather update information from automatic terminal information service (ATIS) or meteorology information for aircraft in flight (VOLMET) was not available. Ref. 41 concluded that lack of ATIS/VOLMET was associated with a four-fold increase in risk compared to approaches conducted with ATIS/VOLMET available.

In Figures 28–32 (pages 199–201), the airport and approach data are presented as a function of ICAO region. The higher frequencies associated with the presence of VASIS/PAPI, TAR, etc. for North America and Europe are presumably because airports in those regions are better equipped generally than their counterparts in South America, Africa and Asia. Lack of nonaccident data made it impossible to draw conclusions about the effectiveness of ATIS, approach lights, visual approach guidance and approach radar for the reduction of CFIT accidents.

Further stratification of the airport parameters across variables such as crew error, light/dark conditions, basic weather conditions, etc., proved to be inconclusive because of small numbers.

Figure 33 (page 202) presents the data for instrument approach aid type (N = 66, data unknown in 50 accidents). Rates could

Table 16
Airport and Approach Variables, Study Data Base

Variable	Yes		No		Unknown	
Terrain	31	(26.7%)	44	(37.9%)	41	(35.3%)
ATIS/VOLMET	43	(37.1%)	41	(35.3%)	32	(27.6%)
Approach Lights	38	(32.7%)	30	(25.9%)	48	(41.4%)
VASIS/PAPI	42	(36.2%)	26	(22.4%)	48	(41.4%)
Stabilized approach procedure design	42	(36.2%)	23	(19.8%)	51	(44.0%)
TAR	36	(31.0%)	43	(37.0%)	37	(31.9%)

ATIS = Automatic terminal information service VOLMET = Meteorology information for aircraft in flight TAR = Terminal approach radar
VASIS = Visual approach slope indicator system PAPI = Precision approach path indicator

Source: Netherlands National Aerospace Laboratory (NLR)

not be estimated because movement data were unavailable. Almost 60 percent of the approaches were nonprecision. Twenty-five percent (17 accidents) of the total sample were VOR/DME approaches. Ref. 41 concluded that precision approaches confer a risk advantage of about five over nonprecision approaches worldwide, with other factors constant.

4.6 Aircraft Equipment Variables

4.6.1 Ground-proximity warning system

Where data were available (N = 108), in only 27 accidents was a GPWS fitted aboard the accident aircraft, i.e., 75 percent of the aircraft were not fitted with a GPWS. Twenty-two of these GPWSs were aboard major operator aircraft, one was on a regional aircraft and none were on air taxi aircraft. Table 17 shows that 21 (78 percent) were early — Mark I and Mark II — systems. The latest — Mark V — systems were both aboard major operator aircraft.

Table 17
GPWS Equipment Type, Study Data Base

Ground-proximity Warning Systems Mark	Number
I	12
II	9
III	2
V	2
Unknown	2

Source: Netherlands National Aerospace Laboratory (NLR)

Of the total sample of GPWS-equipped aircraft (N = 27), 55.6 percent (15 accidents) of the GPWSs sounded valid alerts prior to the accident, whereas in one-third of the sample the GPWSs did not sound any alert (see also Table 14, page 14). Six of the accidents without GPWS alerts occurred on nonprecision approaches.

4.6.2 Flight management system (FMS)/ Autoflight

FMS/autopilot problems are often said to be one of the most important causal factors in CFIT accidents.[34] In four accidents (2.6 percent of the total sample), FMS/autoflight-related problems were described as contributing factors to the accidents. FMS-related problems were not present in 25.0 percent of the accidents, and in 72.4 percent of the accidents it was not known whether FMS-related problems were causal factors in the accidents. These findings should be treated with caution because many of the accident aircraft, especially in air taxi operations, were probably not equipped with an FMS.

4.7 Organizational Issues

4.7.1 Management issues

Management factors have been considered central causal factors in CFIT accidents.[19, 30] Management issues were identified as factors in 25 accidents (16.0 percent of the total sample). Management issues did not contribute in seven accidents (4.5 percent), and in the majority of accidents (79.5 percent) the relevant data were missing.

4.7.2 Flight crew training

Flight crew training was reported as inadequate in 23 accidents (14.7 percent), and in 4.5 percent of the sample, training was reported as adequate. For 80.8 percent of the sample, training data were unavailable.

5.0 Conclusions

(a) Seventy-five percent of 108 accident aircraft, for which data were available, were not fitted with a GPWS. Virtually all the 27 aircraft fitted with a GPWS belonged to the major operator category, and just over three-fourths of these GPWSs were early (Mark I and Mark II) types. In at least nine accidents (33 percent) an alert was not generated by the GPWS;

(b) Seventy-one percent of the accident aircraft were in one of two groups:

  (i) An MCTM category below 5,700 kilograms, involved in either international or domestic operations; or,

  (ii) Heavier aircraft involved in domestic operations.

Most of the aircraft above (i) are not authorized to carry more than nine passengers. This suggests that a very large proportion of the accident sample (nearly 70 percent) would not be required to be fitted with a GPWS in the future, if the new ICAO requirements are strictly applied;

(c) Procedural errors, situational awareness errors and tactical decision errors were the dominant crew-error types, whereas those related to communication appear to be less of a problem. In the special case of landing (approach) phase accidents, virtually all the accidents involved a situational awareness error;

(d) The landing (descent) phase and landing (approach) phase accidents together accounted for almost 70 percent of all accidents, whereas the en route phase accounted for about 20 percent. Where data were known, 93 percent of the en route accidents were attributable to air taxi and regional operators;

(e) Major and air taxi operators suffered their greatest losses in the landing (approach) phase, and the regional operators encountered the largest percentage of accidents in the en route phase;

(f) Almost 60 percent of the 66 landing (approach) phase accidents where data were known involved aircraft flying nonprecision approaches. Twenty-five percent (17 cases) of all approaches were of the VOR/DME type;

(g) Almost all landing (approach) phase accidents (90 percent) occurred within a radius of approximately 15 NM (17.25 statute miles/27.76 kilometers) from the runway threshold;

(h) In almost 40 percent of the landing (descent) phase and landing (approach) phase accidents, significant terrain features were absent in the vicinity of the airfield. This indicates that CFIT accidents do occur in areas without high terrain;

(i) In 30 accidents (one-fifth of the total sample), inadvertent VMC flight into IMC was a factor. Most of these accidents occurred in single-pilot operation flights, involving regional and air taxi operators. Seventeen of the 30 VMC-into-IMC accidents (56.7 percent) occurred in the en route phase;

(j) When the data for scheduled flights of major operators are considered, Africa appears to be the ICAO region with the highest CFIT rate, followed by South America and Asia/Pacific. North America and the Middle East have the lowest CFIT rates;

(k) For major operators, the CFIT accident rate for scheduled international flights was 3.8 times higher than that for scheduled domestic flights;

(l) For international operations, there were an average of four accidents per year, in contrast to 14 per year for domestic operations. Regional and air taxi operations together accounted for an average of 13 accidents per year, whereas major operators suffered an average of five per year;

(m) In 97 percent of the 139 accidents where data were known, the aircraft was completely destroyed. Total fatalities amounted to 3,177. The mean fatality rate (the percentage of the aircraft occupants who were fatally injured) was 91 percent;

(n) Eighty-seven percent of 107 accidents involved IMC where weather status was known. About one-half of the accidents occurred in conditions of darkness; and,

(o) The level of analytical detail was limited by the scarcity of data for factors that are significant in accident causation.

6.0 Recommendations

(a) All operators should comply with current and future ICAO requirements pertaining to the installation of GPWSs. Furthermore, the use of GPWSs for domestic operations, as recommended by the FSF CFIT Task Force, should be observed;

(b) International support should be given to reducing the CFIT risk variances among the different ICAO regions;

(c) CFIT risk-reduction efforts must include not only the major air carriers, but also regional and air taxi operations;

(d) Any means of reducing flight crew procedural and tactical decision-making errors should be encouraged. Whether this involves training and/or improved cockpit discipline, or other measures such as error-tolerant design of checklists and procedures, is for further study;

(e) Improving terrain situational awareness is encouraged. In this respect, the FSF CFIT Task Force recommends:

- The use of colored contours to present either terrain or minimum flight altitudes on instrument approach charts;
- Technological developments that give the flight crew a visual display of the terrain; and,
- A radio altitude call-out facility to improve crew awareness of proximity to terrain. Where altitude call-out is not available, or where a GPWS is not fitted, radio altimeter raw data can be used to enhance terrain awareness; and,

(f) The international sharing of accident and incident data should be encouraged to quickly and effectively address safety problems. The difficulty of obtaining complete and accurate information about accidents was a major problem in this study and is an ongoing problem for safety analysts.

7.0 Acknowledgments

This study was conducted under a contract awarded by the Netherlands Directorate-General of Civil Aviation (RLD). The constructive input from Flight Safety Foundation (FSF) and members of the FSF CFIT Task Force is greatly appreciated, especially from Capt. Paul Woodburn (British Airways), Capt. Richard Slatter (ICAO), Don Bateman (AlliedSignal) and Brian Perry (International Federation of Airworthiness).

The following organizations readily provided CFIT data and deserve a special vote of thanks: U.K. CAA Safety Data and Analysis Unit, the FSF CFIT Task Force, ICAO (Capt. Dan Maurino and Capt. Richard Slatter), U.S. NTSB, AlliedSignal (Don Bateman), Australia's Bureau of Air Safety Investigation, the Netherlands Aviation Safety Board and NLR's Flight Safety and Flight Testing Department. Finally, we offer our thanks to Ir. Arun Karwal for his valuable input, especially for developing the airport data base used in this investigation.♦

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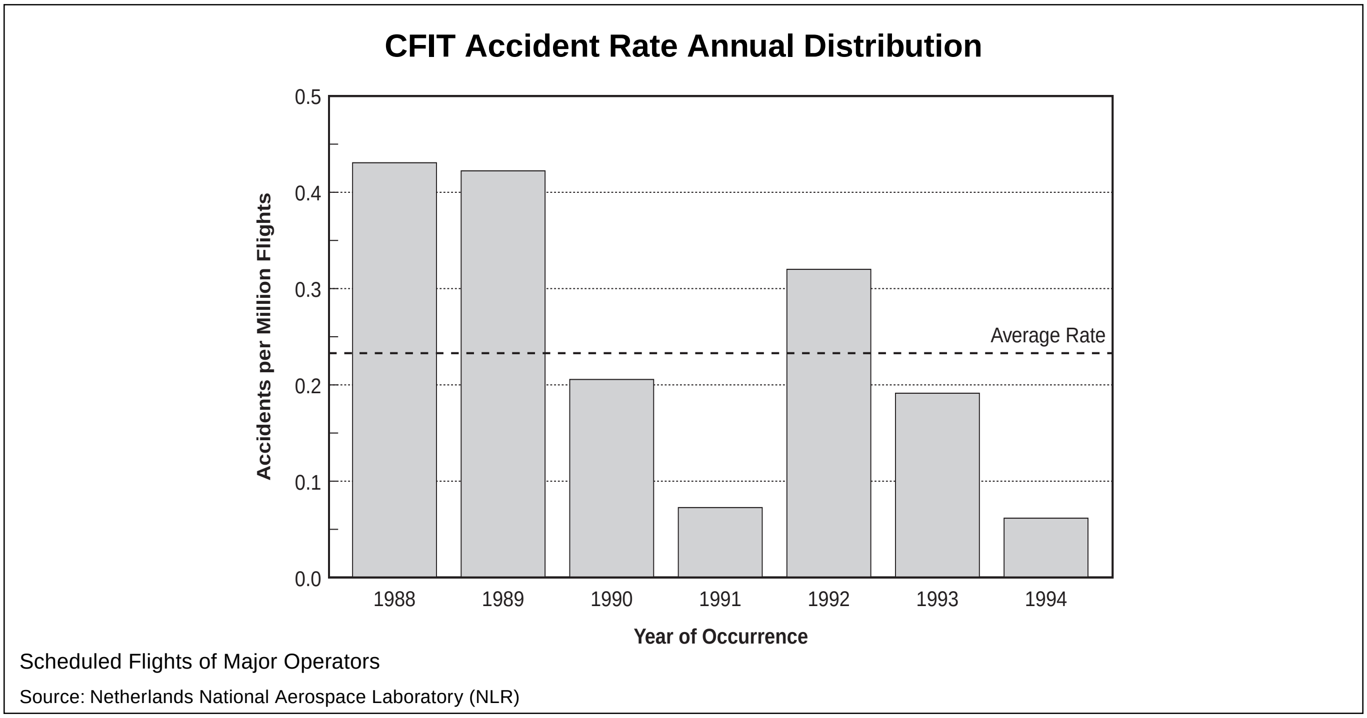
Appendix A
Figures

Appendix A
Figures

Figures are reproduced directly from the original report. For an explanation of abbreviations used in the figures, see Abbreviations and Acronyms, page 212.

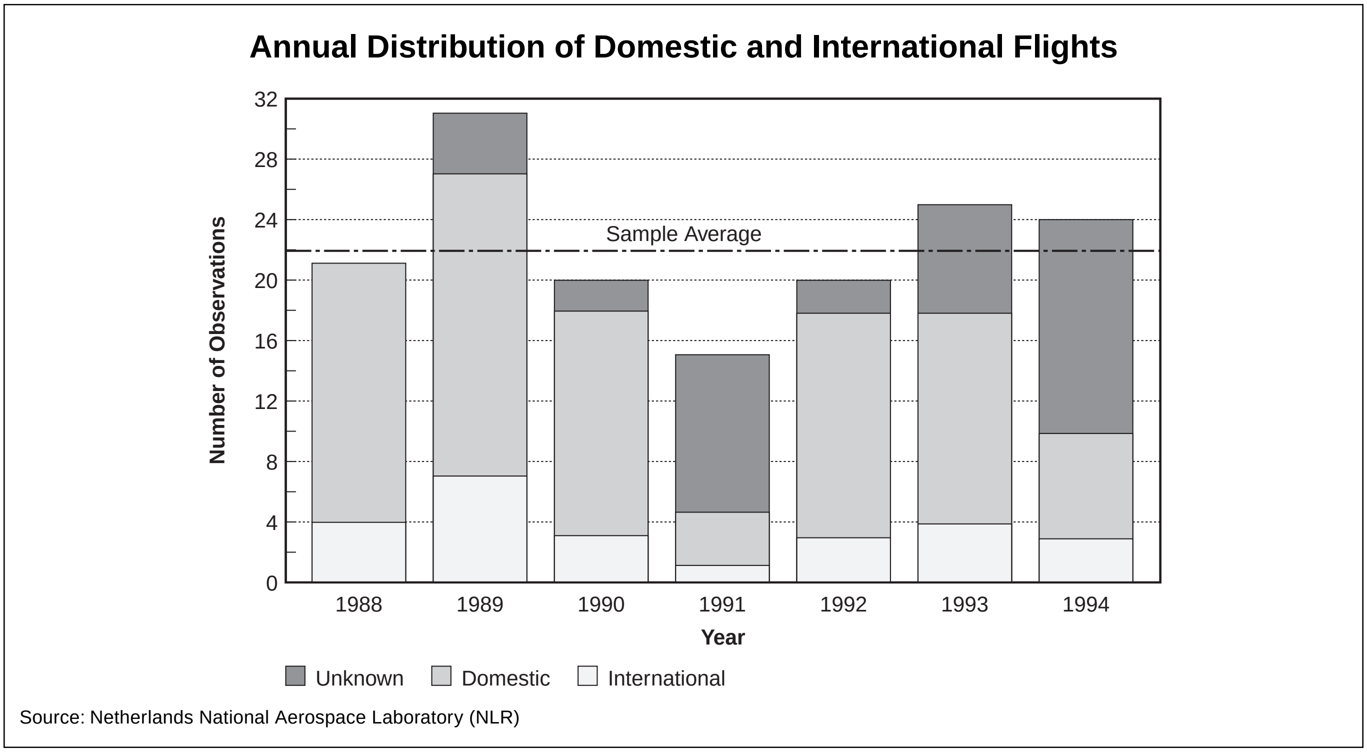


CFIT Accident Rate Annual Distribution

Scheduled Flights of Major Operators

Source: Netherlands National Aerospace Laboratory (NLR)

Figure 1

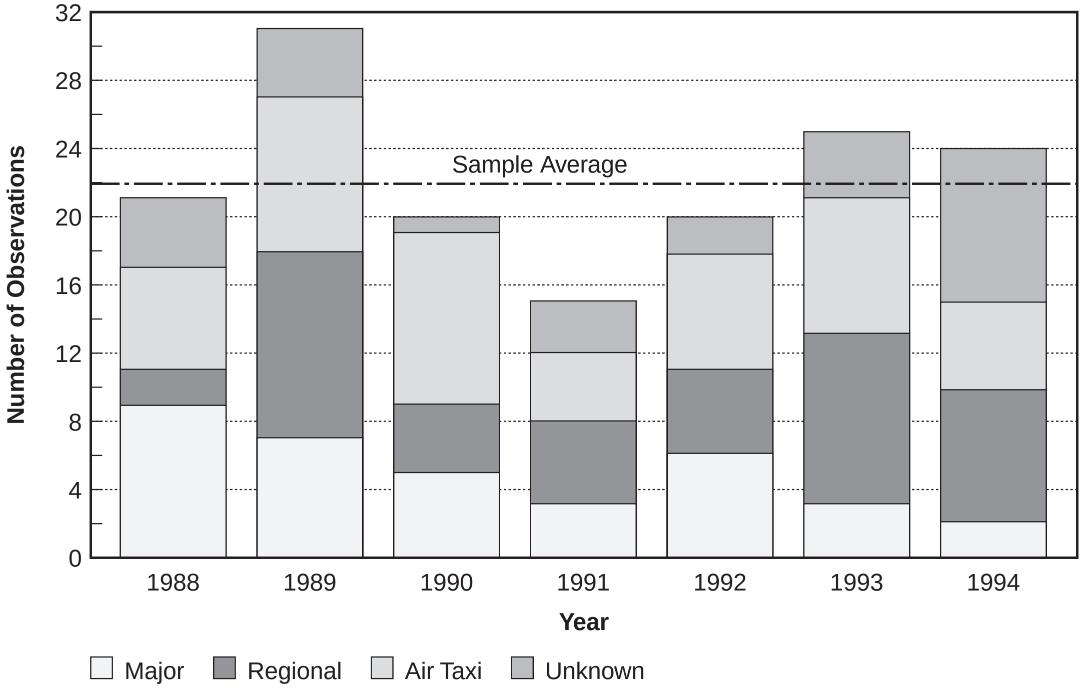


Annual Distribution of Domestic and International Flights

Source: Netherlands National Aerospace Laboratory (NLR)

Figure 2

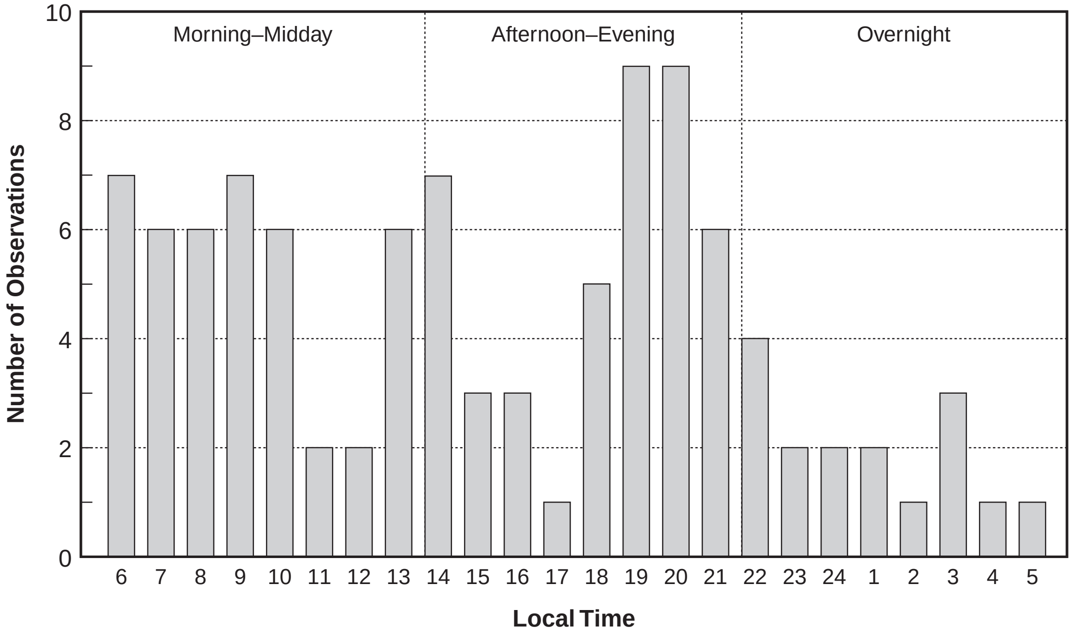
Annual Distribution of Operator Type



Source: Netherlands National Aerospace Laboratory (NLR)

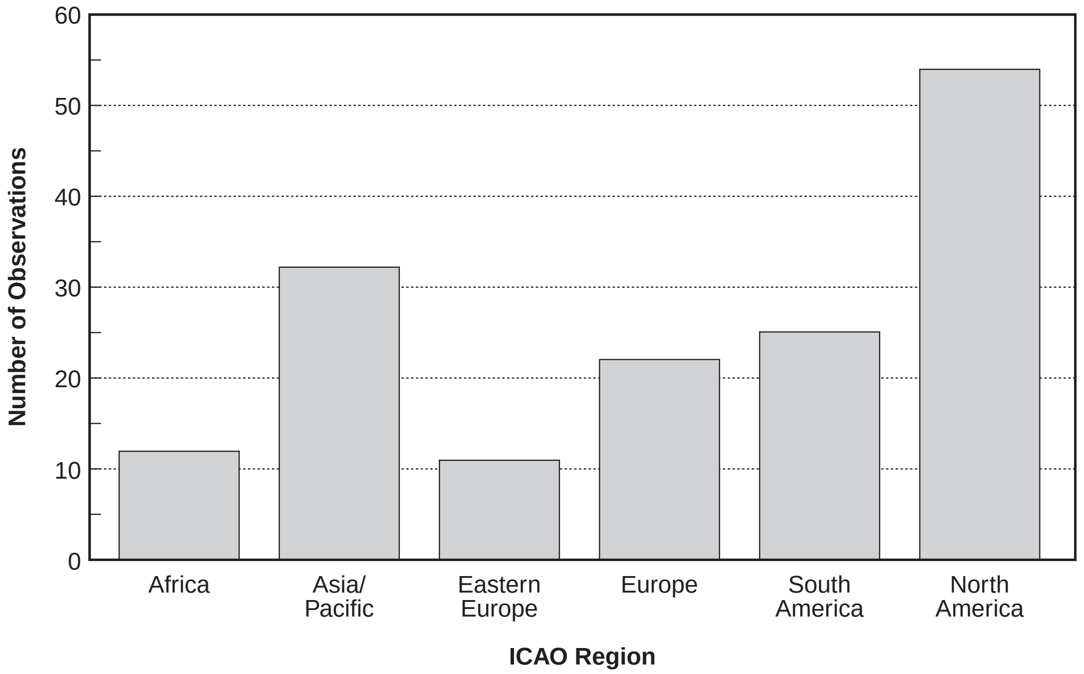
Figure 3

Time of Occurrence Distribution



Source: Netherlands National Aerospace Laboratory (NLR)

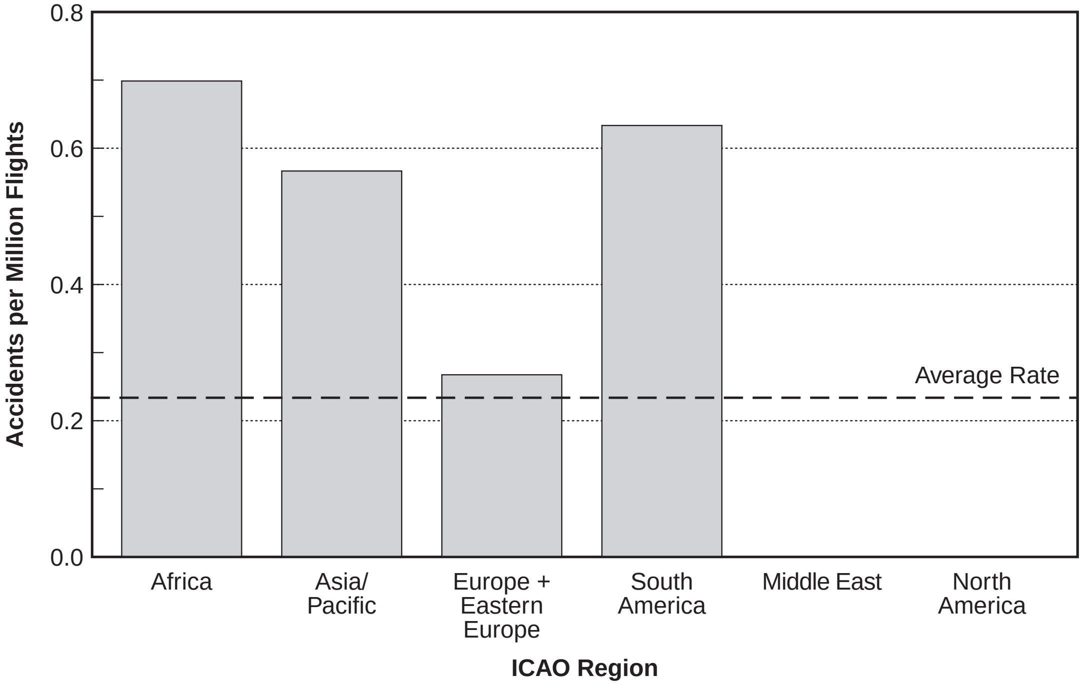
Figure 4



Accidents among ICAO Regions

Source: Netherlands National Aerospace Laboratory (NLR)

Figure 5

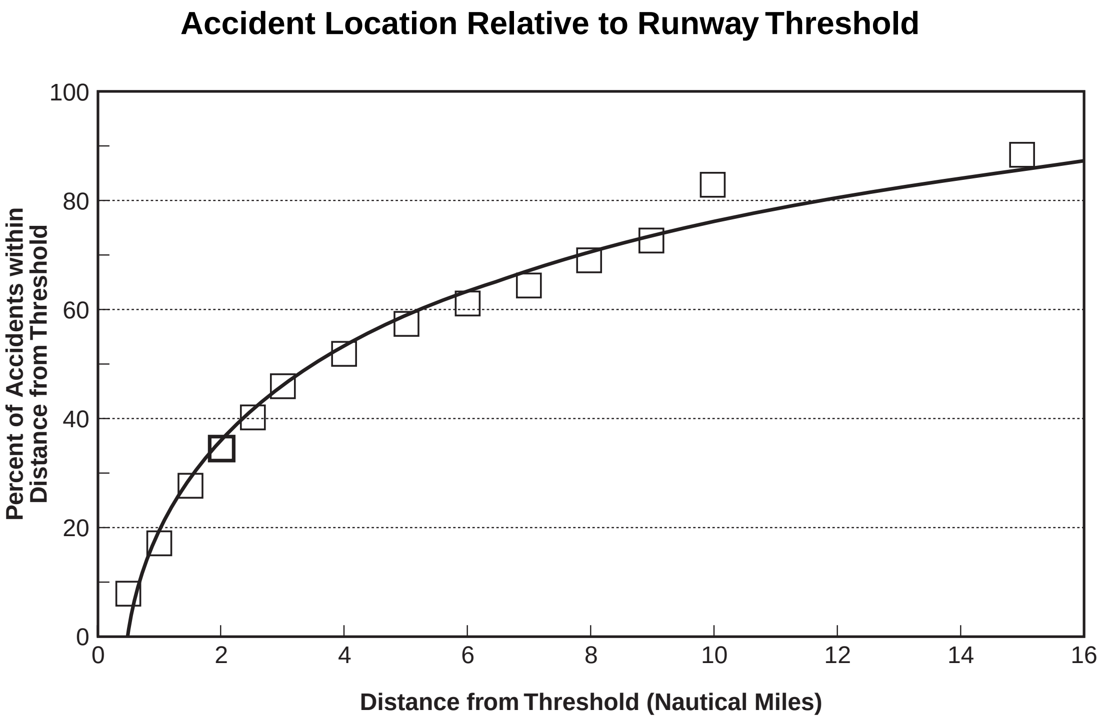


Accident Rate among ICAO Regions

Scheduled Flights of Major Operators

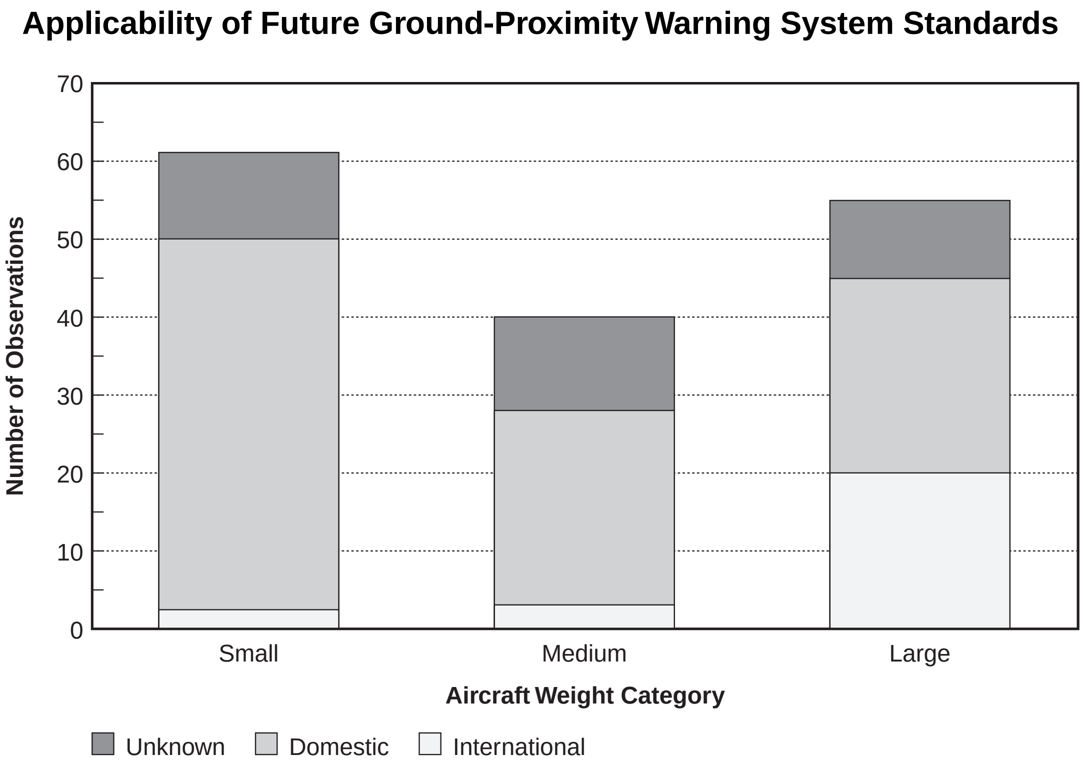
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 6



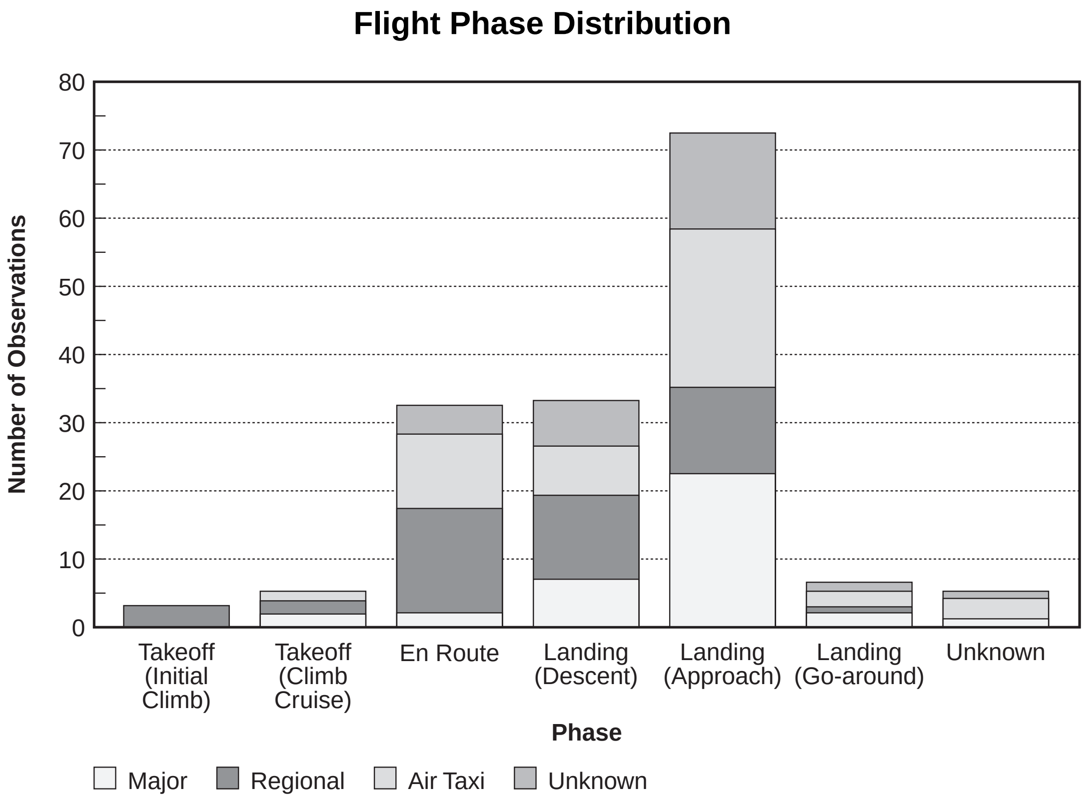
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 7



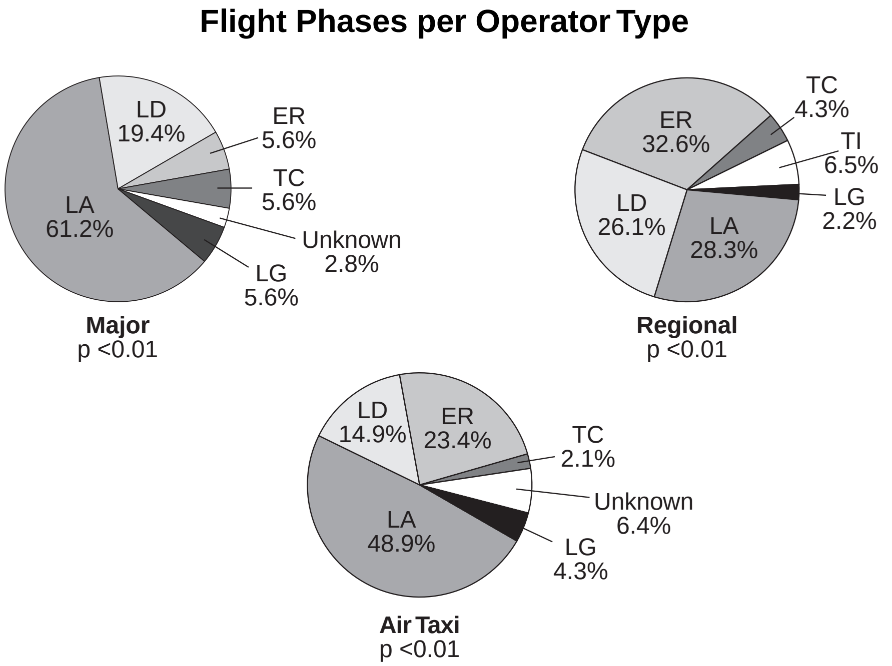
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 8



Source: Netherlands National Aerospace Laboratory (NLR)

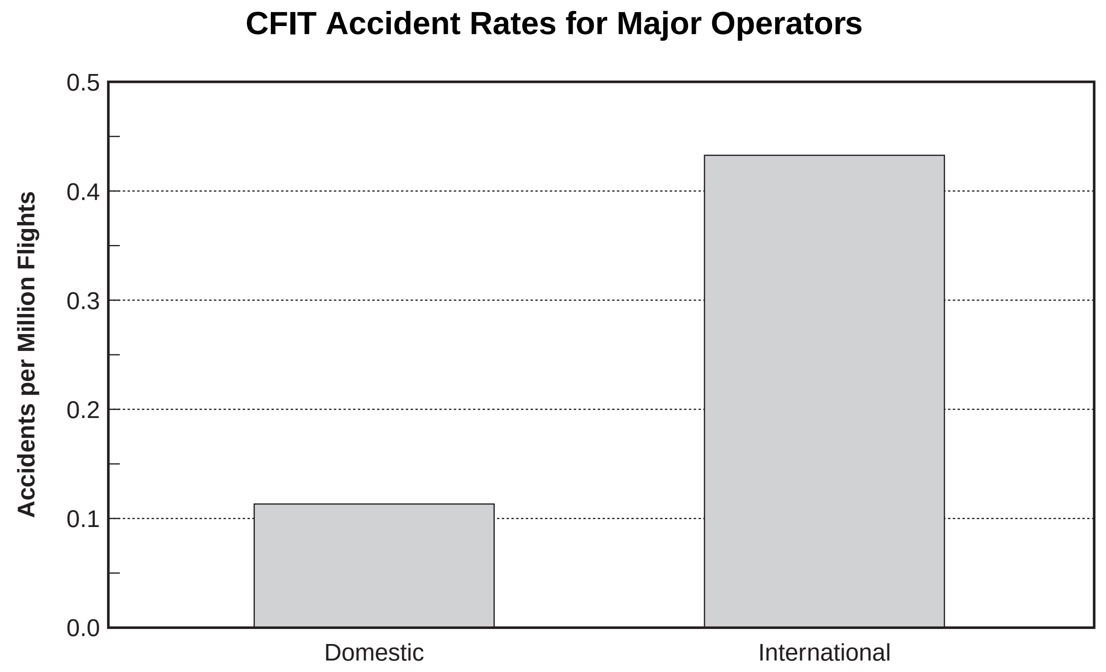
Figure 9



ER = En route LA = Landing (approach) LD = Landing (descent) LG = Landing (go-around) TC = Takeoff (climb cruise)
TI = Takeoff (initial climb))

Source: Netherlands National Aerospace Laboratory (NLR)

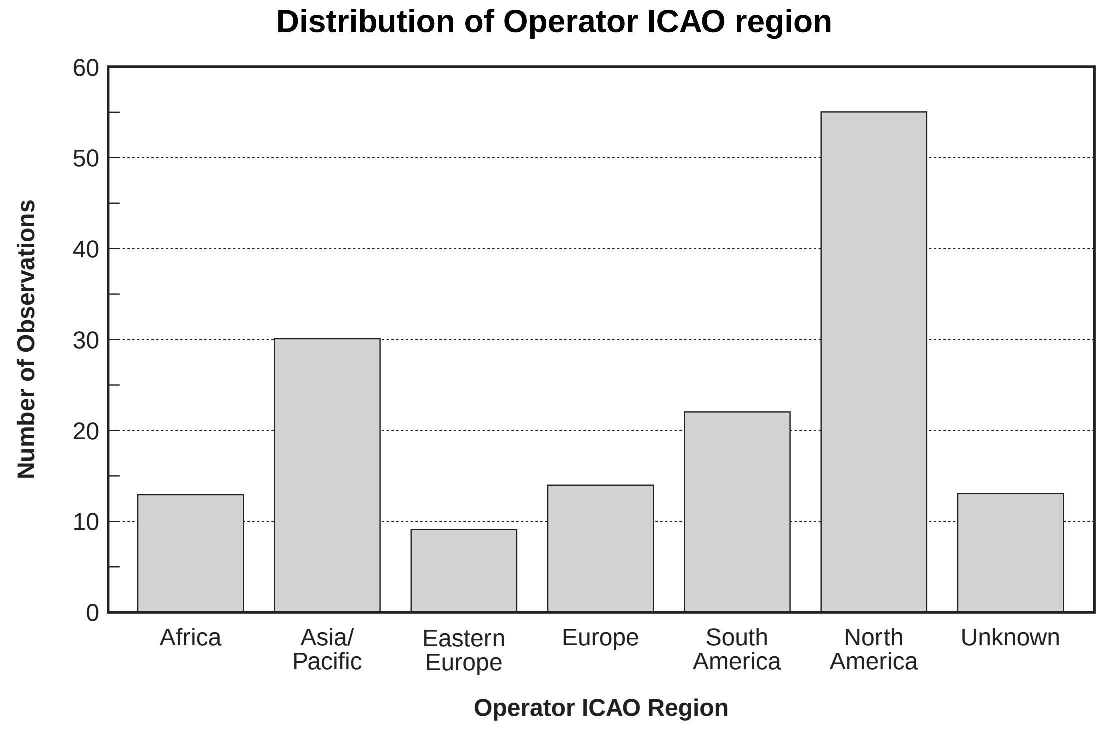
Figure 10



International vs. domestic

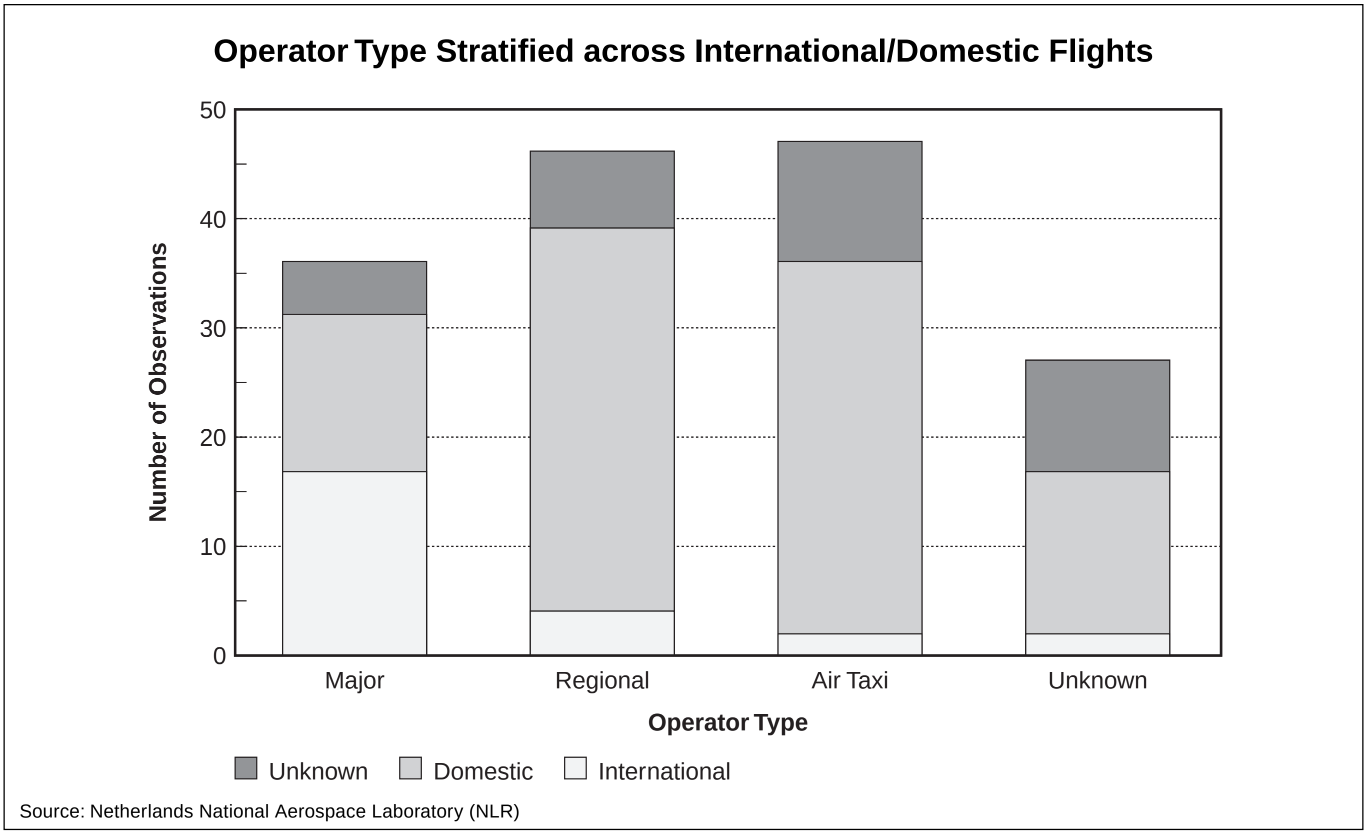
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 11



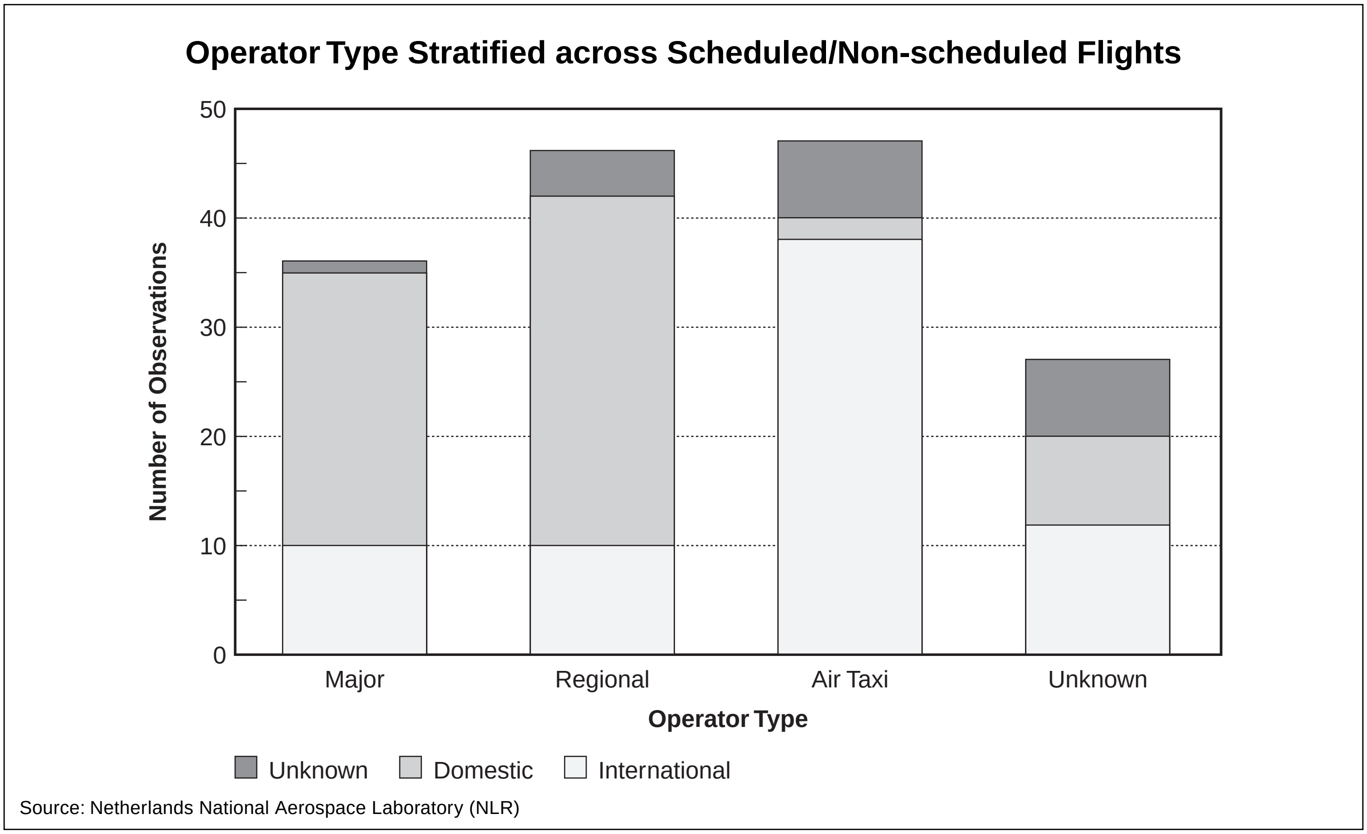
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 12



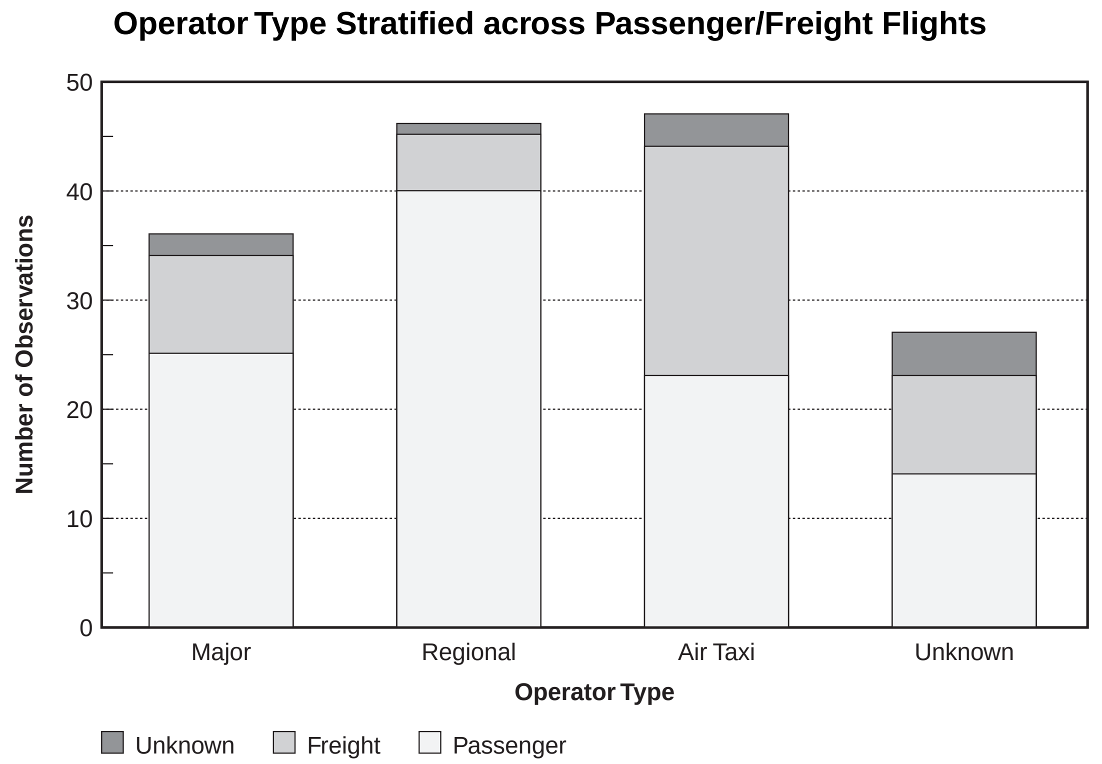
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 13



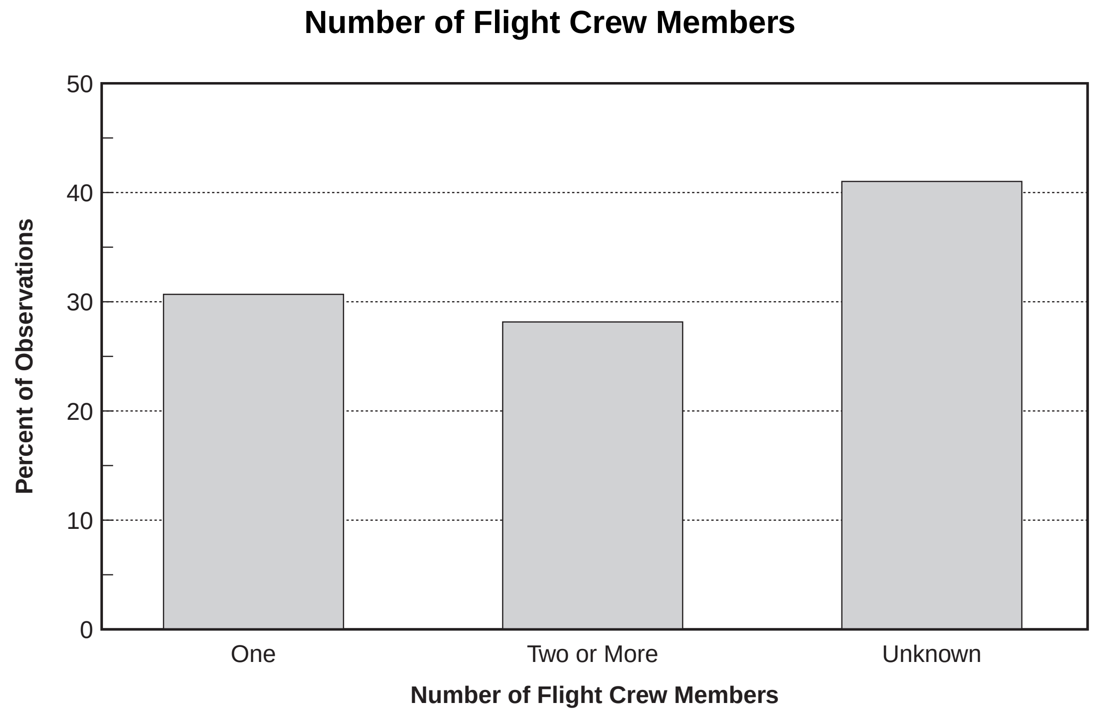
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 14



Source: Netherlands National Aerospace Laboratory (NLR)

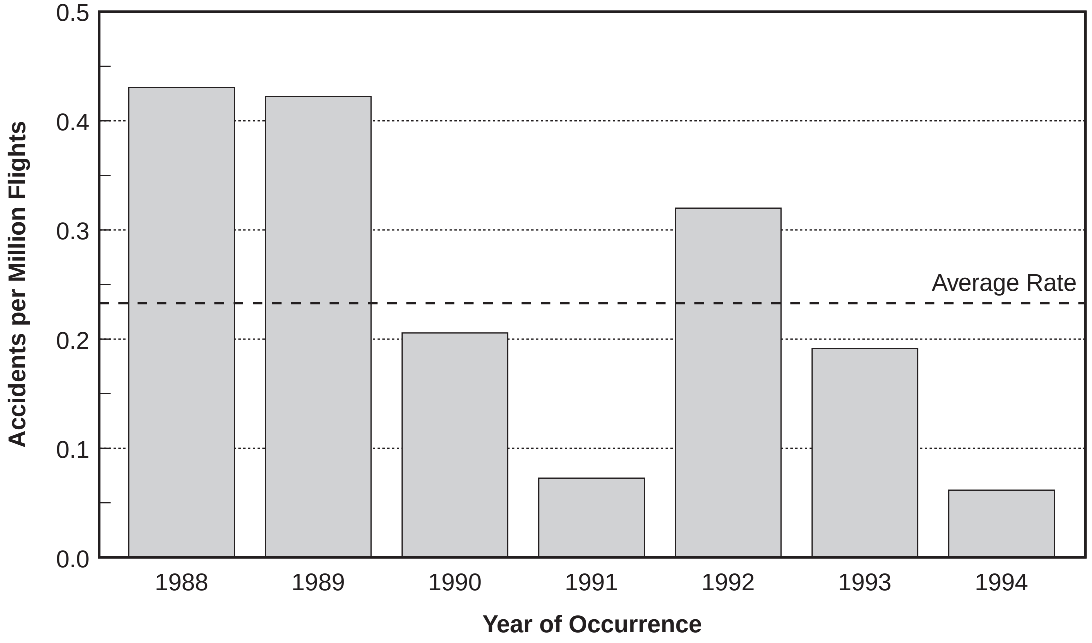
Figure 15



Source: Netherlands National Aerospace Laboratory (NLR)

Figure 16

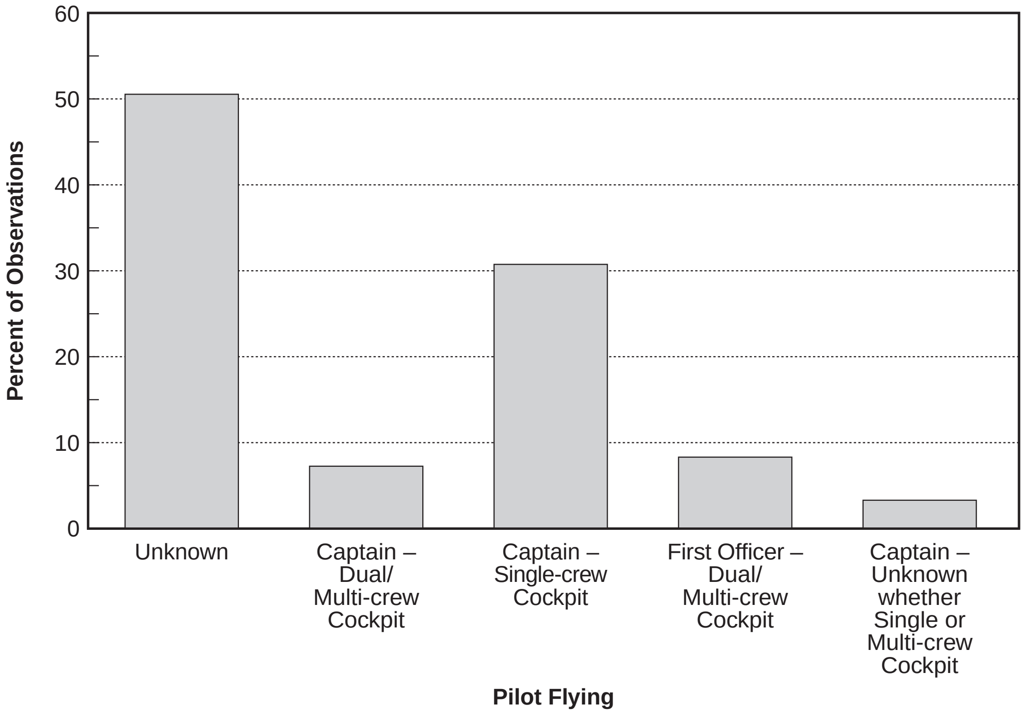
Flight Crew Composition



Source: Netherlands National Aerospace Laboratory (NLR)

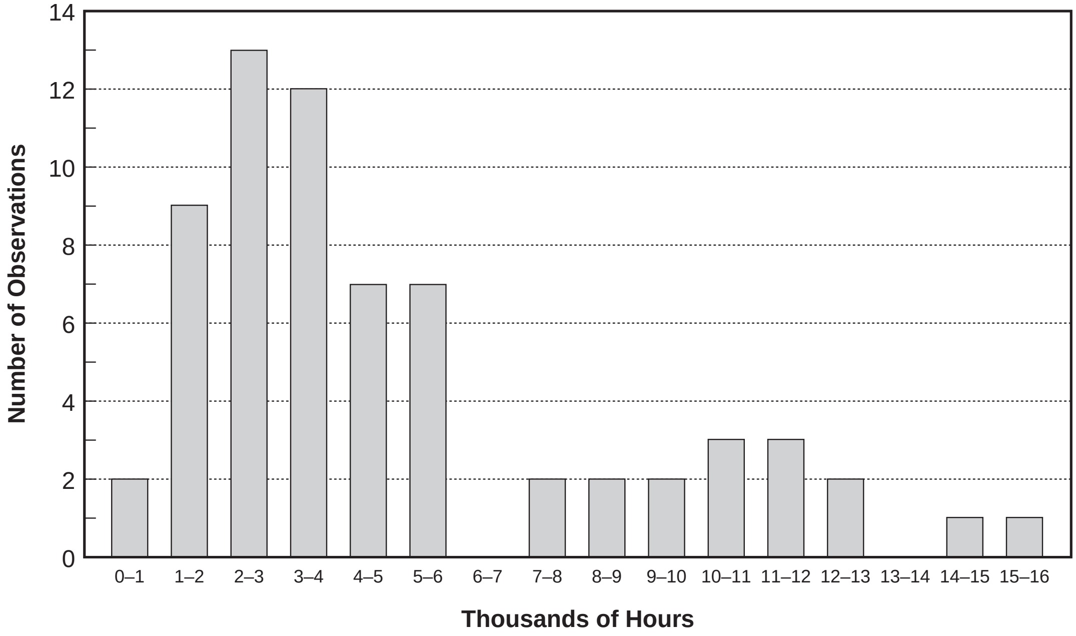
Figure 17

Pilot Flying Distribution



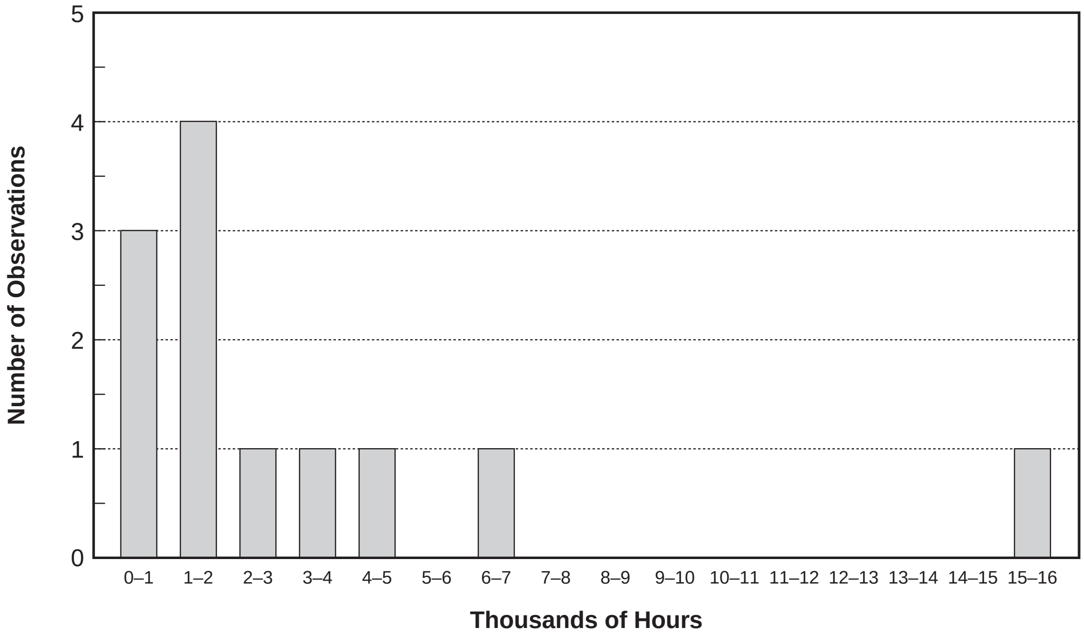
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 18



Source: Netherlands National Aerospace Laboratory (NLR)

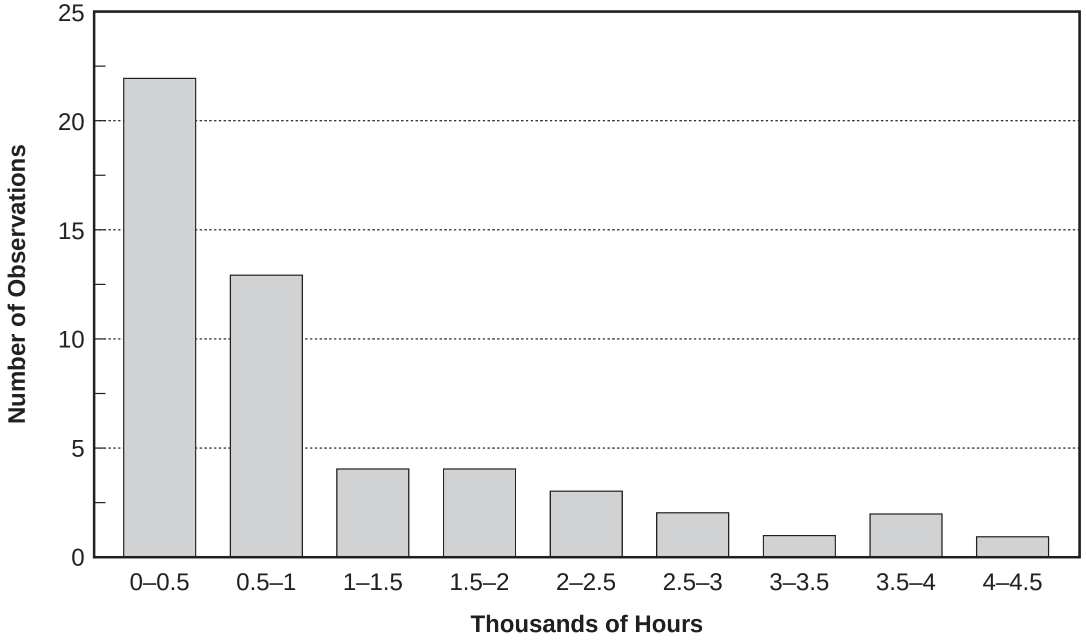
Figure 19



Source: Netherlands National Aerospace Laboratory (NLR)

Figure 20

Hours on Aircraft Type, Captain



Source: Netherlands National Aerospace Laboratory (NLR)

Figure 21

Hours on Aircraft Type, First Officer

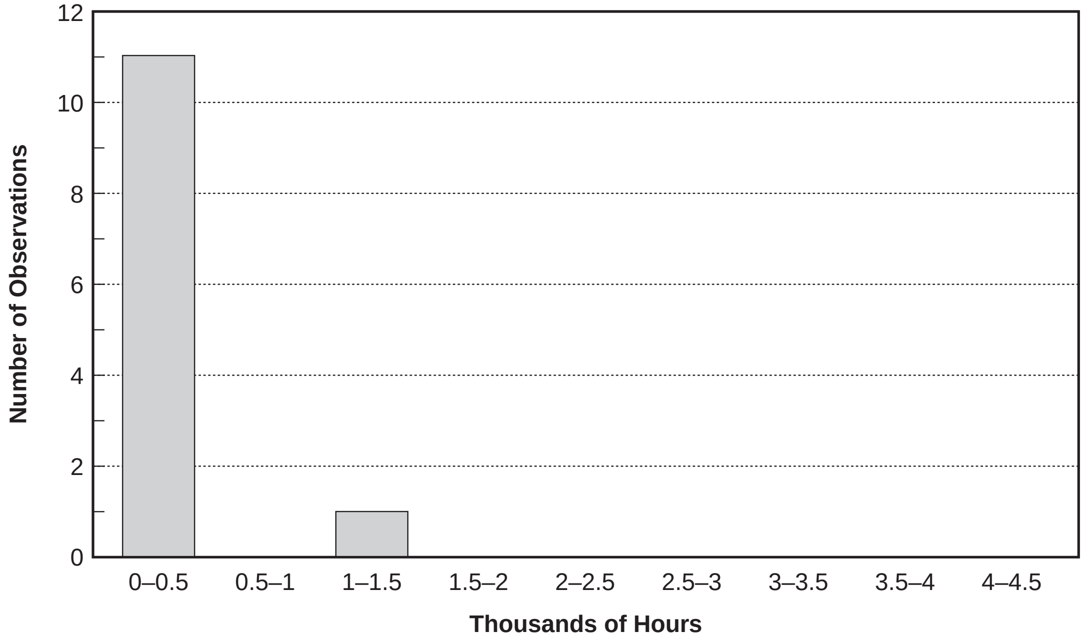


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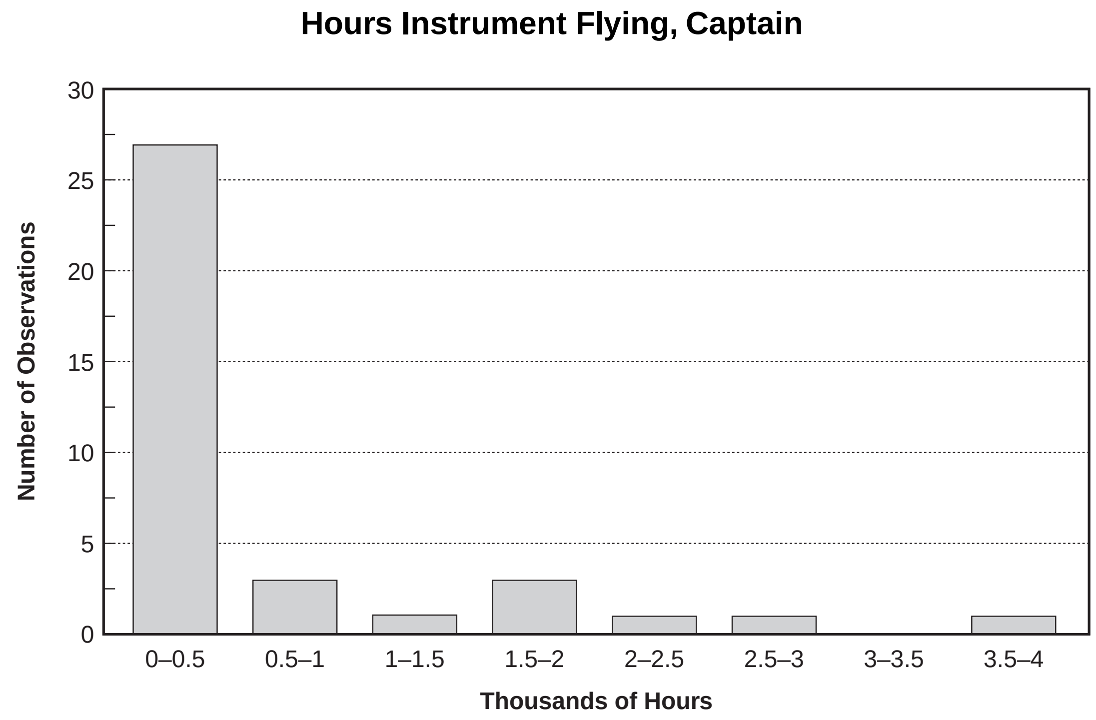
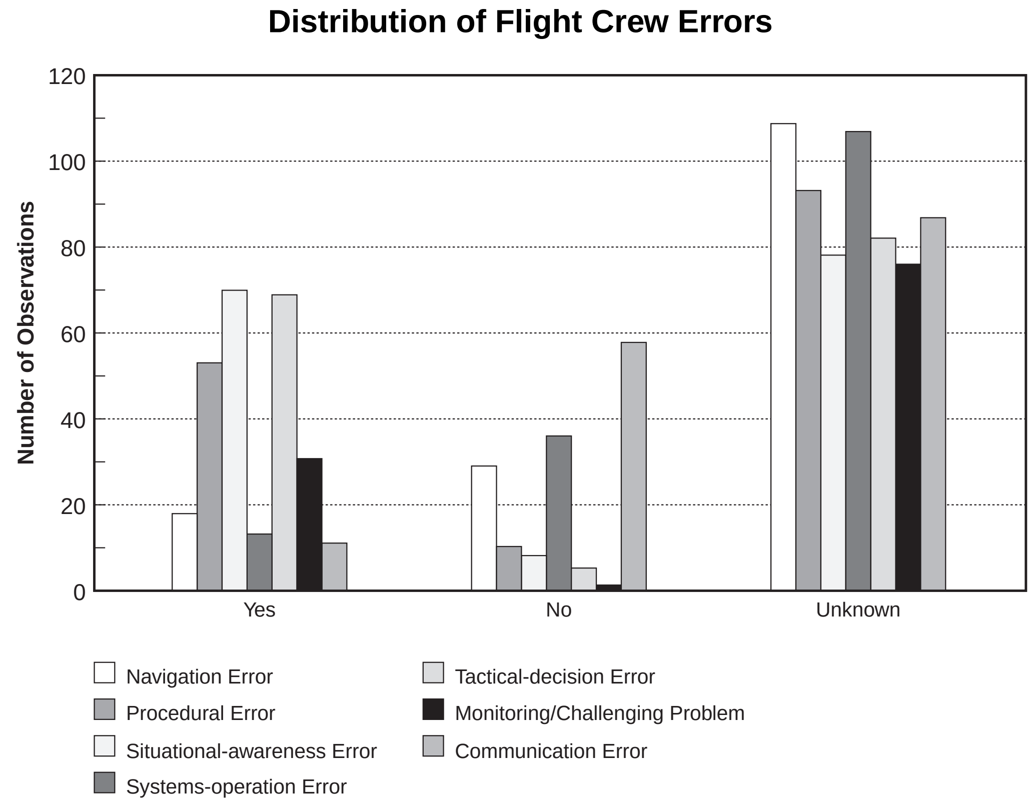
Figure 22



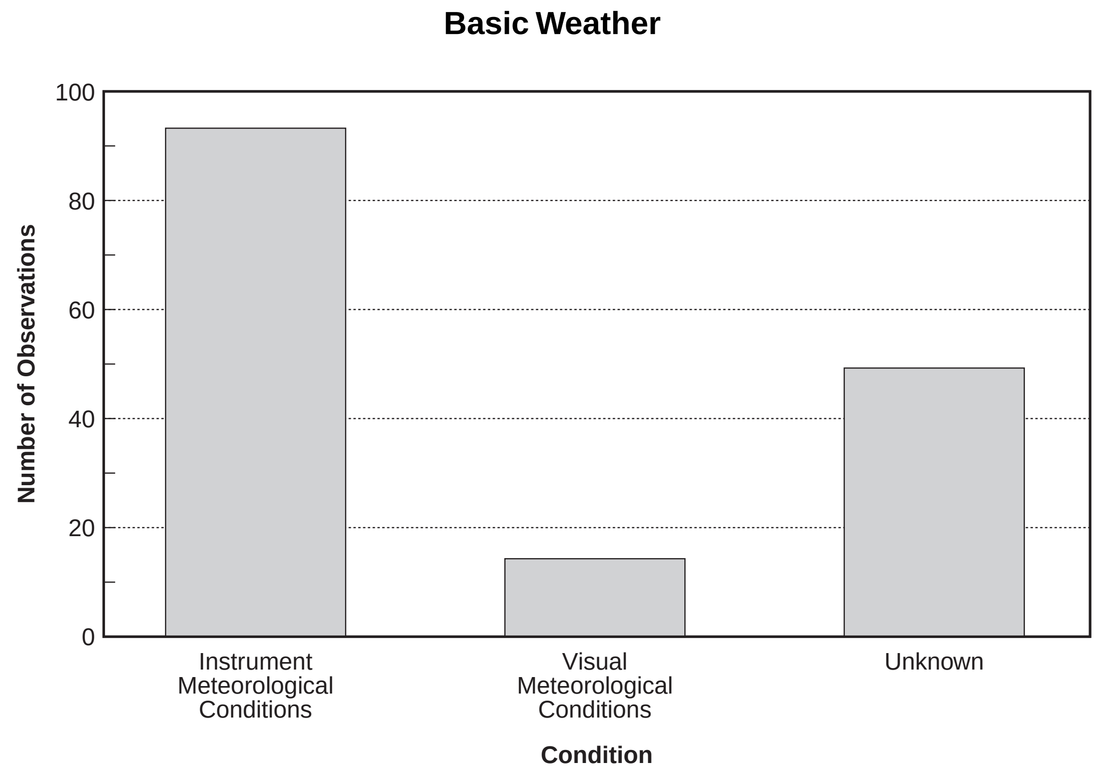
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 23



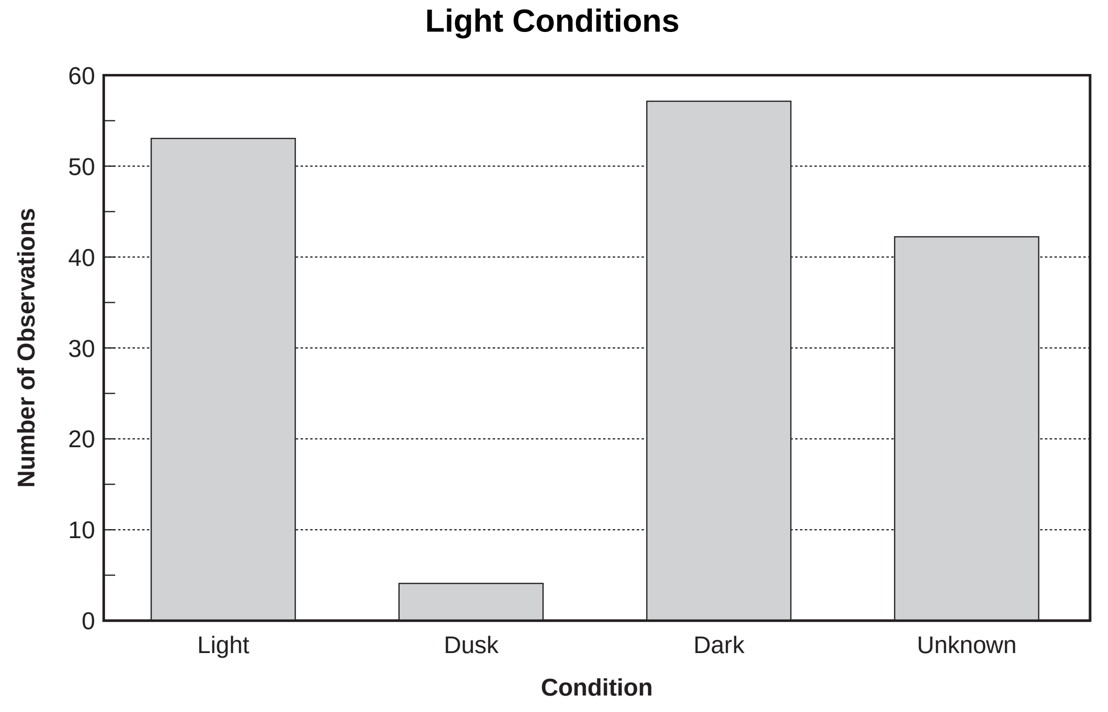
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 24



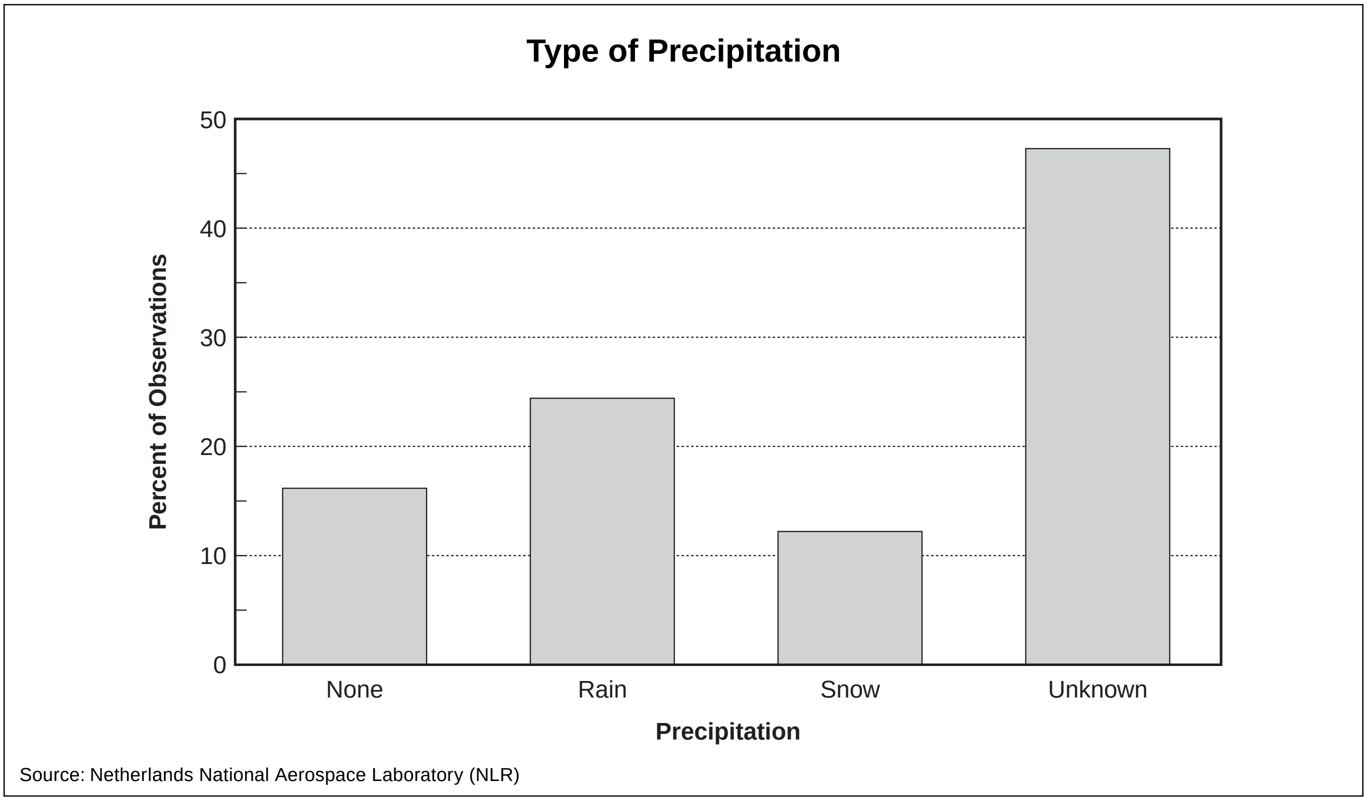
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 25



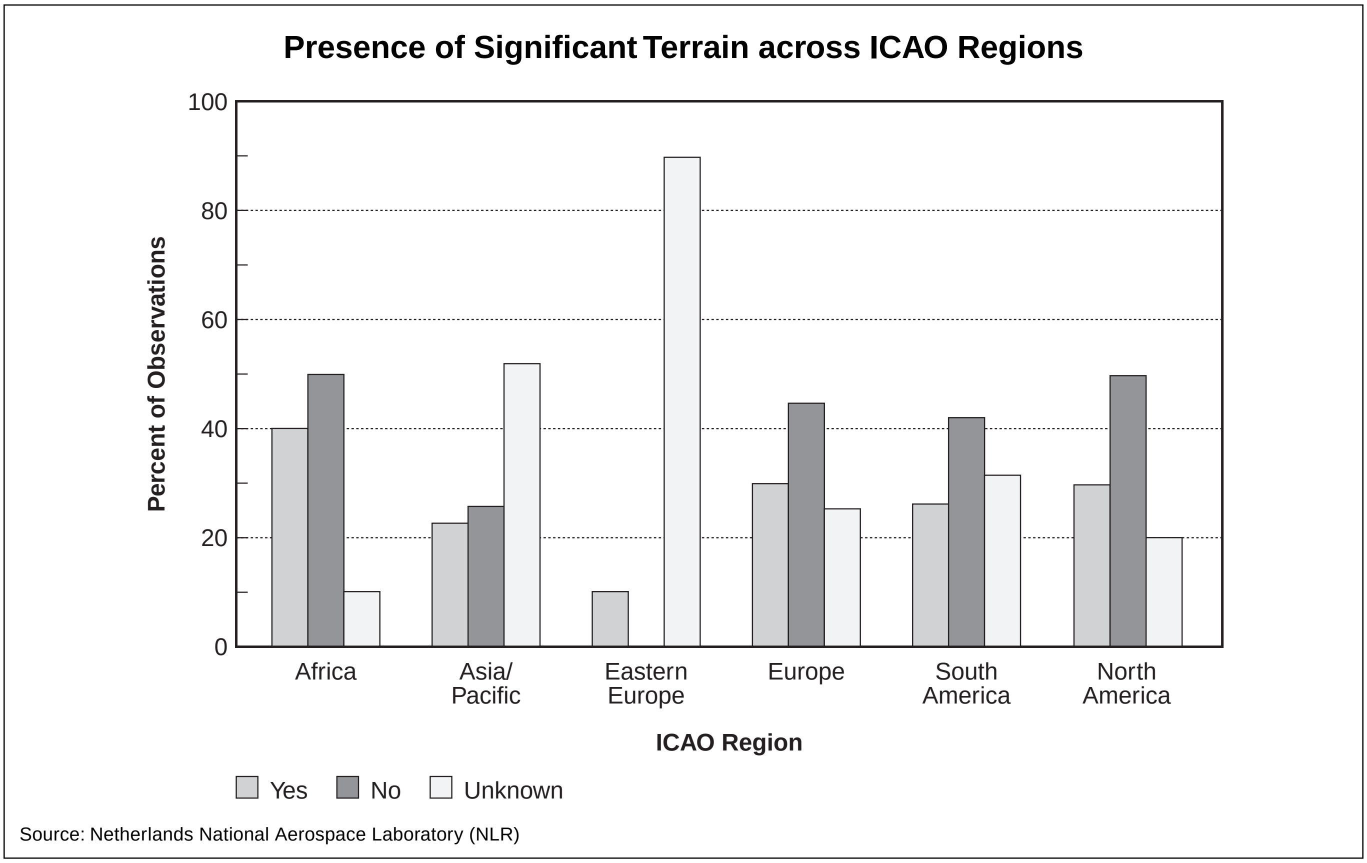
Source: Netherlands National Aerospace Laboratory (NLR)

Figure 26



Source: Netherlands National Aerospace Laboratory (NLR)

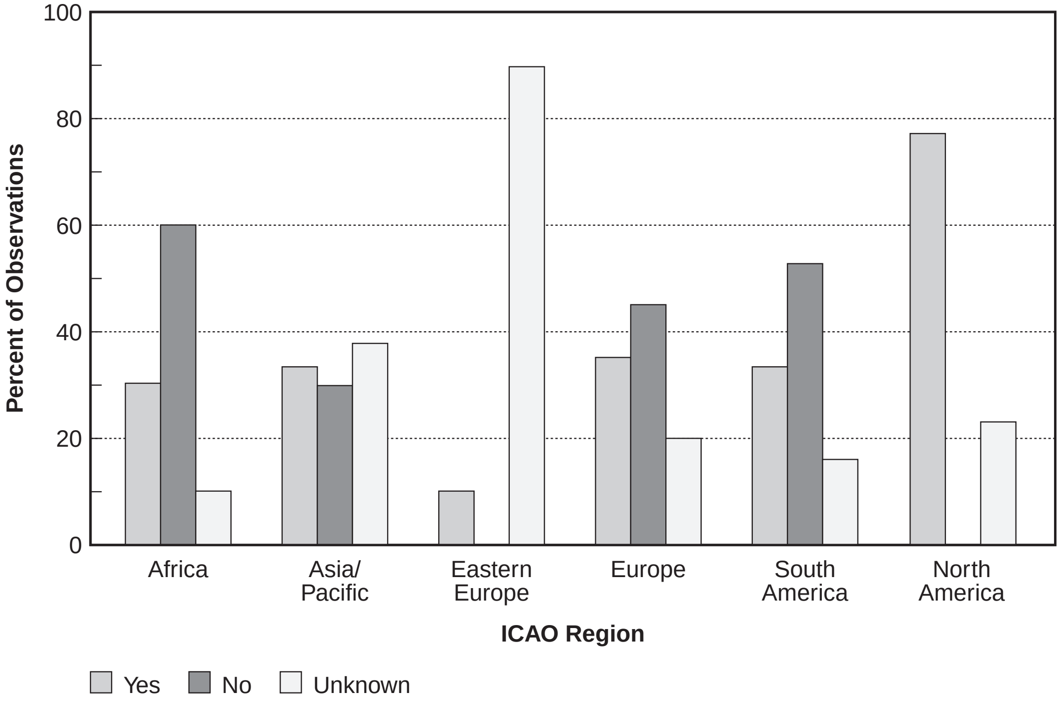
Figure 27



Source: Netherlands National Aerospace Laboratory (NLR)

Figure 28

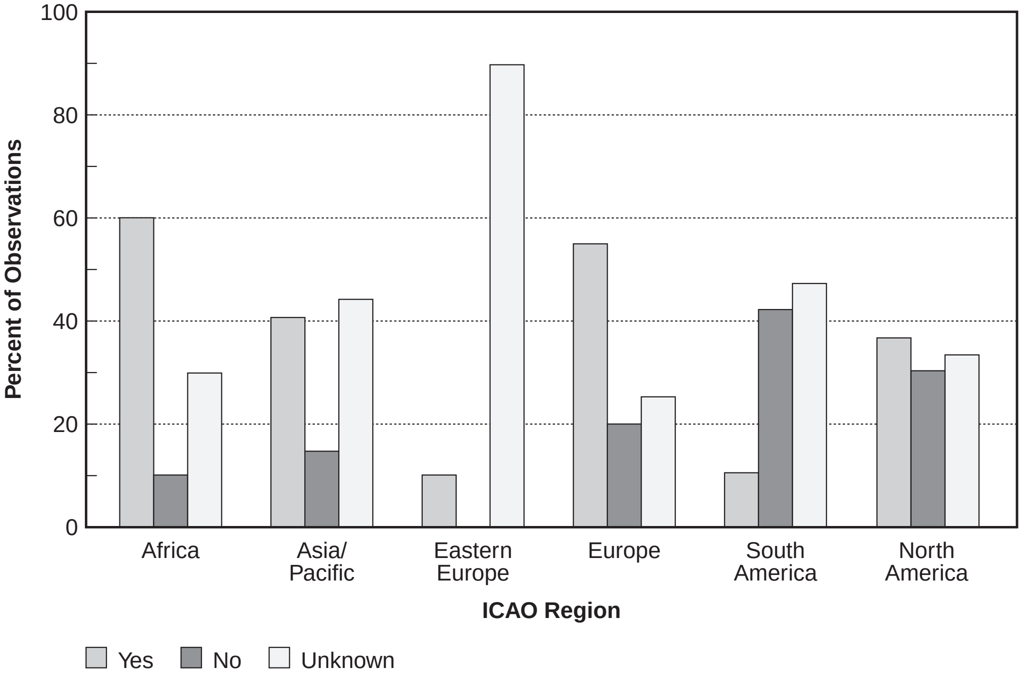
Availability of Automatic Terminal Information Service across ICAO Regions



Source: Netherlands National Aerospace Laboratory (NLR)

Figure 29

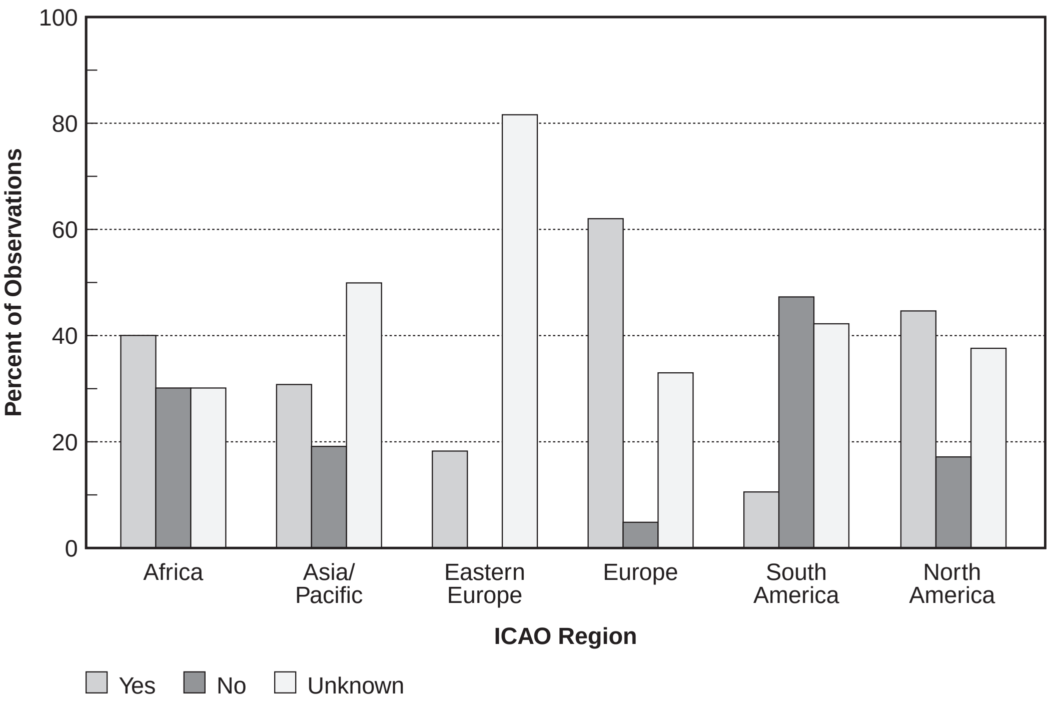
Availability of Visual Approach Slope Indicator System/Precision Approach Path Indicator across ICAO Regions



Source: Netherlands National Aerospace Laboratory (NLR)

Figure 30

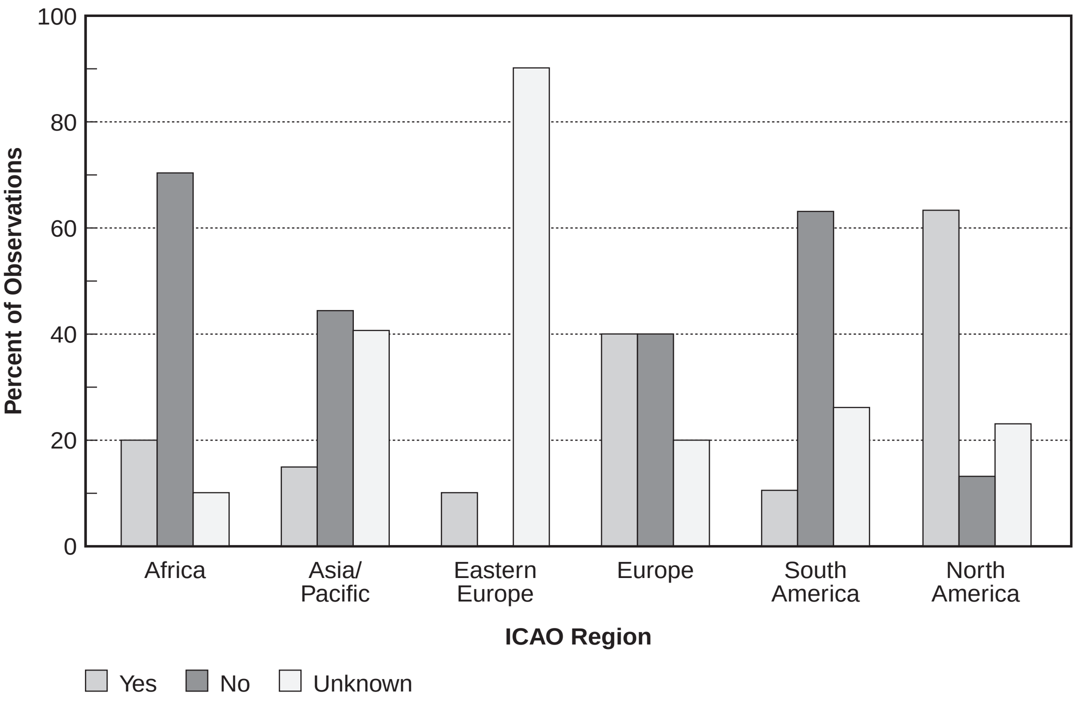
Stabilized Approach Procedure Design across ICAO Regions



Source: Netherlands National Aerospace Laboratory (NLR)

Figure 31

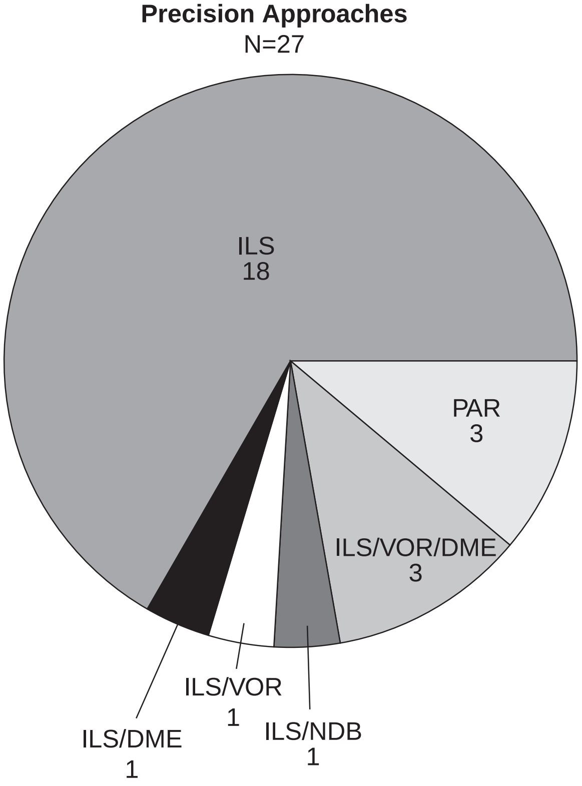
Availability of Terminal-approach Radar across ICAO Regions

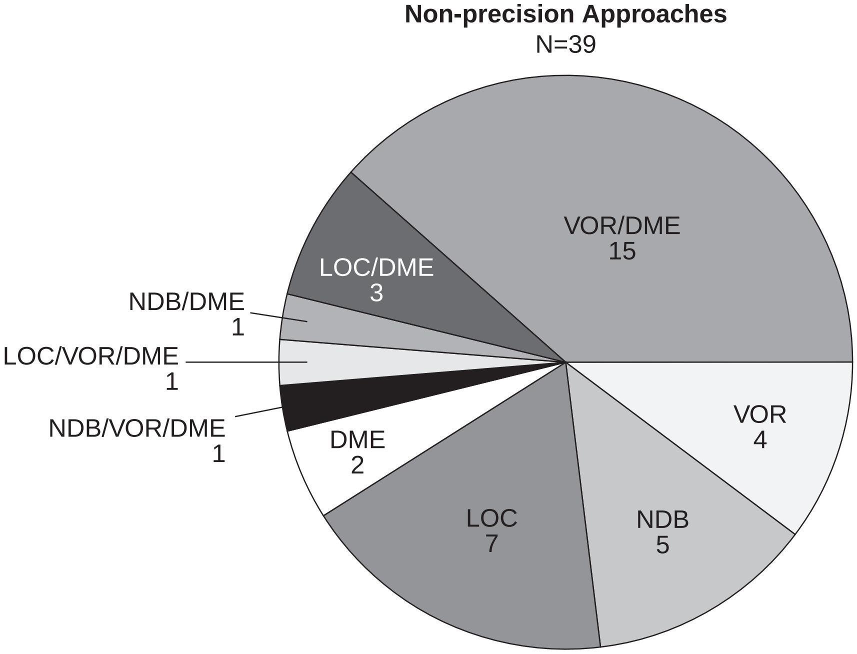


Source: Netherlands National Aerospace Laboratory (NLR)

Figure 32

Approach Aid Types





DME = Distance measuring equipment ILS = Instrument landing system LOC = Localizer NDB = Nondirectional beacon
PAR = Precision approach radar VOR = Very-high-frequency omnidirectional radio range

Source: Netherlands National Aerospace Laboratory (NLR)

Figure 33

Appendix B
Accident Sample

Date (dmy)	Location	Country	Aircraft
02/01/88	Izmir	Turkey	Boeing 737-200
08/01/88	Monroe, Louisiana	United States	Learjet 36
03/02/88	Helena, Montana	United States	Cessna 421
10/02/88	Stratford, Connecticut	United States	Piper PA-34 Seneca
27/02/88	Ercan	Cyprus	Boeing 727-200
17/03/88	Cucuta	Colombia	Boeing 727-100
07/04/88	Coffs Harbour, New South Wales	Australia	Piper PA-31
19/04/88	Bagdarin	USSR	Let 410
06/05/88	Broennoeysund	Norway	DHC-7 Dash 7
18/05/88	Skenton, Alaska	United States	Piper PA-32
09/06/88	Maralinga	Australia	Cessna 310
12/06/88	Posadas	Argentina	MD-81
21/07/88	Lagos	Nigeria	Boeing 707-320
17/08/88	Mount Torbet, Alaska	United States	Cessna 402
26/08/88	Irkutsk	USSR	Let 410
04/10/88	Batagai	USSR	Antonov An-12
17/10/88	Rome	Italy	Boeing 707-300
19/10/88	Gauhati	India	Fokker F27
19/10/88	Ahmedabad	India	Boeing 737-200
02/11/88	Houston, Texas	United States	Piper PA-601 Aerostar
14/11/88	Seinajoki	Finland	EMB 110 Bandeirante
12/01/89	Dayton, Ohio	United States	HS 748
12/01/89	Caracas	Venezuela	Beech King Air 200
08/02/89	Santa Maria, Azores	Portugal	Boeing 707-300
19/02/89	Orange County, California	United States	Cessna 402
19/02/89	(near) Kuala Lumpur	Malaysia	Boeing 747-200
23/02/89	Altenrhein	Switzerland	Commander 690
24/02/89	Helsinki	Finland	Fairchild Merlin III
25/02/89	Tegucigalpa	Honduras	DHC-7 Dash 7
22/03/89	Jacksonville, Florida	United States	Piper PA-600 Aerostar
10/04/89	Valence	France	Fairchild FH227B
19/04/89	Pelican, Alaska	United States	DHC-2 Beaver
10/05/89	Azusa, California	United States	Beech King Air 200
07/06/89	Paramaribo	Surinam	Douglas DC-8
11/06/89	Waipio Valley, Hawaii	United States	Beech 18
11/06/89	Vereda El Salitre	Colombia	DHC-6 Twin Otter
27/07/89	Tripoli	Libya	Douglas DC-10
30/07/89	Haines, Alaska	United States	Piper PA-31
31/07/89	Auckland	New Zealand	Convair 580
03/08/89	Samos	Greece	Shorts 330
07/08/89	Nome, Alaska	United States	Cessna 402
07/08/89	Gambella	Ethiopia	DHC-6 Twin Otter
28/08/89	Lynchburg, Virginia	United States	Piper PA-31
26/09/89	Terrace	Canada	Fairchild Metro III
28/09/89	Roma	Australia	Beech 95

Appendix B
Accident Sample *(continued)*

Date (dmy)	Location	Country	Aircraft
20/10/89	Leninakan	USSR	Ilyushin Il-76
21/10/89	(near) Tegucigalpa	Honduras	Boeing 727
26/10/89	Hualien	Taiwan	Boeing 737-200
28/10/89	Molokai, Hawaii	United States	DHC-6 Twin Otter
01/11/89	Fort Myers, Florida	United States	Piper PA-60 Aerostar
02/11/89	Apopka, Florida	United States	Piper PA-60 Aerostar
22/12/89	Beluga River, Alaska	United States	Piper PA-31
16/01/90	San Jose	Costa Rica	CASA 212
05/02/90	Baker, Oregon	United States	Cessna 402
14/02/90	Bangalore	India	Airbus A320
17/02/90	Cold Bay, Alaska	United States	Piper PA-31
21/03/90	(near) Tegucigalpa	Honduras	Lockheed L-188 Electra
28/04/90	Tamanrasset	Algeria	Beech King Air 90
30/04/90	Moosonee	Canada	Beech 99
04/05/90	Wilmington, North Carolina	United States	GAF Nomad
11/05/90	(near) Cairns	Australia	Cessna Citation 500
06/06/90	Altamira	Brazil	Fairchild FH227
25/06/90	Aialak Bay, Alaska	United States	Cessna 207
02/07/90	Asford, Washington	United States	Cessna 210
01/08/90	Stepanakert	USSR	Yakovlev Yak-40
13/08/90	Cozumel	Mexico	Rockwell Jet Commander
21/09/90	Flagstaff, Arizona	United States	Piper PA-31
14/11/90	Zürich	Switzerland	Douglas DC-9-32
21/11/90	Koh Samui Island	Thailand	DHC-8 Dash 8
04/12/90	Nairobi	Kenya	Boeing 707
18/12/90	Evanston, Wyoming	United States	Piper PA-31
18/12/90	Thompson, Utah	United States	Cessna 182
07/02/91	Munford, Alabama	United States	Piper PA-31
08/02/91	Mirecourt	France	Beech King Air 200
08/02/91	Stansted	United Kingdom	Beech King Air 200
05/03/91	Santa Barbara	Venezuela	Douglas DC-9-30
29/03/91	Homer, Alaska	United States	Cessna 206
04/07/91	El Yopal	Colombia	DHC-6 Twin Otter
14/08/91	Uricani	Romania	Ilyushin Il-18
14/08/91	Gustavus, Alaska	United States	Piper PA-32
16/08/91	Imphal	India	Boeing 737-200
20/08/91	Ketchikan, Alaska	United States	Britten Norman Islander
17/09/91	Djibouti	Djibouti	Lockheed L-100
27/09/91	Guadalcanal	Solomon Islands	DHC-6 Twin Otter
16/11/91	Destin, Florida	United States	Cessna 208
10/12/91	Temple Bar, Arizona	United States	Piper PA-31
18/12/91	Albuquerque, New Mexico	United States	Cessna 210
20/01/92	(near) Strasbourg	France	Airbus A320
03/02/92	Serra Do Taquari	Brazil	EMB 110 Bandeirante
09/02/92	Kafountine	Senegal	Convair 640

Appendix B
Accident Sample *(continued)*

Date (dmy)	Location	Country	Aircraft
21/02/92	Castle Rock Peak	Australia	Cessna 310
24/02/92	Unionville, Pennsylvania	United States	Cessna 310
26/02/92	Morganton, North Carolina	United States	Beech 18
24/03/92	Athens	Greece	Boeing 707-20C
17/04/92	Hamburg, Pennsylvania	United States	Piper PA-23
22/04/92	Maui, Hawaii	United States	Beech 18
08/06/92	Anniston, Alabama	United States	Beech 99
22/06/92	Cruzeiro do Sul	Brazil	Boeing 737-200
24/07/92	Ambon Island	Indonesia	Vickers Viscount
31/07/92	Kathmandu	Nepal	Airbus A310-300
27/08/92	Ivanovo	Russia	Tupolev Tu-134
28/09/92	Kathmandu	Nepal	Airbus A300
31/10/92	Grand Junction, Colorado	United States	Piper PA-42 Cheyenne
09/11/92	Boise, Idaho	United States	Cessna 210
19/11/92	Elk City, Idaho	United States	Cessna 207
19/11/92	Tehachapi, California	United States	Cessna 172
13/12/92	Goma	Zaire	Fokker F27
06/01/93	Paris	France	DHC-8 Dash 8
13/01/93	Sellafield	United Kingdom	EMB 110 Bandeirante
30/01/93	Medan	Malaysia	Shorts SC-7
07/02/93	Iquacu	Brazil	Beech King Air 90
08/02/93	Lima	Peru	Piper PA-42 Cheyenne
23/02/93	Lemont, Pennsylvania	United States	Beech 18
02/03/93	Oakley, Utah	United States	Cessna 402
18/03/93	Trijillo	Peru	Beech King Air 90
19/03/93	Dagali	Norway	Beech King Air 200
23/03/93	Cuiabo	Brazil	EMB 110 Bandeirante
19/05/93	Medellin	Colombia	Boeing 727-100
06/06/93	El Yopal	Colombia	DHC-6 Twin Otter
11/06/93	Young	Australia	Piper PA-31
25/06/93	Atinues	Namibia	Beech King Air 200
01/07/93	Sorong	Indonesia	Fokker F28
26/07/93	Mokpo	Korea	Boeing 737-500
31/07/93	Bharatpur	Nepal	Dornier 228
27/09/93	Lansing, Michigan	United States	Beech King Air 300
25/10/93	Franz Josef Glacier	New Zealand	GAF Nomad
27/10/93	Namsos	Norway	DHC-6 Twin Otter
10/11/93	Sandy Lake	Canada	HS 748
13/11/93	Urumqi	China	MD-82
20/11/93	Ohrid	Macedonia	Yakovlev Yak-42
01/12/93	Hibbing, Minnesota	United States	BAe Jetstream 31
30/12/93	Dijon	France	Beech King Air 90
14/01/94	Sydney	Australia	Commander 690
18/01/94	(near) Kinshasa	Zaire	Learjet 24
24/01/94	Altenrhein	Switzerland	Cessna 425 Conquest

Appendix B
Accident Sample *(continued)*

Date (dmy)	Location	Country	Aircraft
23/02/94	Tingo Maria	Peru	Yakovlev Yak-40
09/03/94	Tamworth	Australia	Fairchild Merlin IV
06/04/94	Latacunga	Ecuador	DHC-6 Twin Otter
25/04/94	Nangapinoh	Indonesia	Britten Norman Islander
13/06/94	Uruapan	Mexico	Fairchild Metro III
18/06/94	(near) Palu	Indonesia	Fokker F27
18/06/94	Washington, D.C.	United States	Learjet 25
22/06/94	Juneau, Alaska	United States	DHC-3 Otter
26/06/94	Abidjan	Ivory Coast	Fokker F27
17/07/94	Fort-de-France	Martinique	Britten Norman Islander
07/08/94	Kodiak, Alaska	United States	DHC-2 Beaver
13/09/94	(near) Abuja	Nigeria	DHC-6 Twin Otter
18/09/94	Tamanrasset	Algeria	BAC 111
29/10/94	Ust-Ilimsk	Russia	Antonov An-12
04/11/94	Nabire	Indonesia	DHC-6 Twin Otter
19/11/94	Saumur	France	Beech King Air 90
22/11/94	Bolvovig	Papua New Guinea	Britten Norman Islander
10/12/94	Koyut, Alaska	United States	Cessna 402
17/12/94	Tabubil	Papua New Guinea	DHC-6 Twin Otter
21/12/94	Willenhall	United Kingdom	Boeing 737-200
29/12/94	Van	Turkey	Boeing 737-400

BAC = British Aircraft Corp.   BAe = British Aerospace   CASA = Construcciones Aeronauticas SA
DHC = de Havilland Canada   EMB = Empresa Braileira de Aeronautica SA (Embraer)   GAF = Government Aircraft Factory
HS = Hawker Siddeley   IAI = Israel Aircraft Industries   MD = McDonnell Douglas   USSR = Union of Soviet Socialist Republics

Source: Netherlands National Aerospace Laboratory (NLR)

Appendix C
Accident Data Coding Protocol

Codes:
n = no
na = not applicable
u = unknown
y = yes

1 Flight Variables

Date of accident

Local time

Crash site – geographical location (city, state)
– ICAO region AFR/APA/EEU/EUR/LAM/MID/NAM
– location relative to airport/runway in nm

Aircraft – type
– operator and country of origin
– damage: destroyed/substantial/minor/none/u

Flight phase – TI/TC/ER/LD/LH/LA/LG/u

Type of operation – air taxi/regional/major operator
– scheduled/nonscheduled/u
– passenger/freight/u
– domestic/international flight/u
– repositioning/u

Total number of crew and passengers onboard

Total number fatalities (crew and passengers)

2 Flight Crew Variables

No. of flight crew

Pilot Flying – FO/CAPT/u

Experience	FO	CAPT	Other
Total hours			
Hours on type			
Total instrument time			

Crew compatibility – improper pairing of crews – y/n/u

Fatigue-related – yes/no

Illusions – Visual (e.g. black hole approaches) – y/n/u
– Physical (e.g. somatogravic illusion) – y/n/u

Crew Errors:

(1) Communications issues (CO)
– pilot-pilot – y/n/u
– pilot-controller – y/n/u
(2) Navigation error (NE) – y/n/u
(3) Procedural errors (PE) – y/n/u
(4) Situational awareness (SA) – y/n/u
(5) Systems operation (SO) – y/n/u
(6) Tactical decision (TD) – y/n/u
(7) Monitoring/Challenging (MC) – y/n/u

Specific crew errors:

Navigational aid programmed correctly/incorrectly/u

Attempting visual flight in instrument conditions – y/n/u

Descended below minimums prior to acquiring visuals – y/n/u

Minimum altitude not maintained (e.g. ATC clearance, MSA, MORA, IFR procedure, stepdown altitude on VOR/DME approach) – y/n/u

Response to GPWS

– crew initiated escape maneuver – y/n/u/na

If “yes” – crew response on time (i.e. no delay) – y/n/u/na
– escape maneuver correct – y/n/u/na
(Incorrect would include turns, inadequate pitch rate, failure to level wings)

If “no” – no crew action – y/n/u
– disabled GPWS – y/n/
– other – y/n/u

Barometric altimeter
– set incorrectly – y/n/u
– read incorrectly – y/n/u

3 Environment Variables

Light/dark conditions – Dark/twilight/light/u

Weather data – basic weather: IMC/VMC/u
– ATIS/VOLMET available – y/n/u
– fog – y/n/u
– winds/gusts – y/n/u
Precipitation – none/u/snow/rain/hail-ice
– cloud base (feet)
– visibility (statute miles)

4 Airport and Approach Variables

High terrain around airport – y/n/u/na

Lighting
- runway lights – y/n/u/na
- approach lights – y/n/u/na
- VASIS/PAPI-equipped – y/n/u/na

Runway used for approach

VFR approach/landing: – None/y/u/na
(“Yes” includes traffic pattern/straight-in/valley-terrain following/go-around)

Type instrument approach flown (multiple entry):
- None/u/na
- ADF/NDB
- LOC type aid: SDF/LDA/ILS-LOC
- VOR
- DME
- ILS full/ILS backcourse
- ASR/PAR
- visual/circling/sidestep
- other (specify)

Navaid (ground facility)-related problems – y/n/u/na

Approach
- Procedure design:
  stabilized approach – y/n/u
- If nonprecision, average approach slope:

5 ATC Variables

Airport and approach control capabilities
- Terminal approach radar – y/n/u

Clearance instructions
- Radar vectoring to final approach – y/n/u
- Vectoring error – y/n/u

Controller communication issues – y/n/u
Controller experience issues – y/n/u
Controller fatigue issues – y/n/u

6 Aircraft Equipment Variables

GPWS
- was it required to be equipped ? – y/n/u
- was it equipped ? – y/n/u

GPWS characteristics (if equipped):
- mark
- inoperative due to mechanical problem

GPWS warning characteristics (if equipped):
- sounded warning – y/n/u/na
- GPWS alarm – false/nuisance/valid/u

Radio altimeter – y/n/u

Autoflight/FMS/flight director-related – y/n/u/na
(e.g. mode confusion, FD attentional tunnelling)

7 Air Carrier Variables

Company management/organizational issues – y/n/u

Crew training – adequate/inadequate

Maintenance issues – y/n/u

8 Regulatory Issues

Operator surveillance inadequate – y/n/u

Appendix D
Variables Excluded From Analysis

It was not always possible to obtain all of the information that would have been optimal for the current investigation. Variables that have not been analyzed because of the large proportion of missing data are listed below:

- Navigation aid (ground facility) problems;
- Controller communication issues;
- Controller experience;
- Controller fatigue;
- Navigation aid programmed incorrectly;
- Radio altitude read incorrectly;
- Radio altimeter set incorrectly;
- Descending below minimums prior to acquiring visual contact;
- Presence of strong winds/gusts;
- Management issues;
- Maintenance issues; and,
- Inadequate regulatory authority surveillance.

Nevertheless, some of these factors are referred to in the body of the text for comparison with other sources.

Appendix E
Data and Study Limitations

Results of the study should be interpreted in the light of methodological limitations.

Sample size

One limitation was the accident sample size. The sample of 156 accidents represents the majority of CFIT accidents involving commercial aircraft during the study period, but the small number of events limited the analysis to single- and two-factor analysis. Application of this simplistic analytical model to what is acknowledged to be a complex event (i.e., factors involved in aviation accidents) was the only method by which these data could be evaluated. The greater insight that might have been gained from multivariable analysis (i.e., where all factors are held constant while the factor of interest is evaluated) was not possible.

Sample bias

The accident sample is biased because North American accidents accounted for 34.6 percent of the total sample. This is probably because of the ease with which U.S. accident data can be accessed, as well as the level of commercial aviation activity in that area of the world. This bias is probably present only for the air taxi and regional operator samples because accident reporting of major air carriers is believed to be better than that for air taxi and regional air carriers in most of the world. This bias limited the number of two-factor analyses, especially stratifications by ICAO region.

Missing data

Information on many factors of interest was not available, so many accidents had factors coded as “unknown.” This problem also limited some of the two-factor analyses that could be conducted because of problems associated with small numbers. Missing data may represent a serious problem because their influence on the study results is unknown.

Inadequate crew training, misreading instruments, organizational weaknesses, improper crew pairing, fatigue and visual illusions are among the factors that have been strongly associated with CFIT accidents. To the extent that such data were obtained for the accident sample, they have been mentioned. But because those data were missing for such a large proportion of the accidents, no conclusions could be drawn about those factors.

One original goal of this study was to estimate the risk associated with the various factors included in the accident taxonomy. For each factor of interest the corresponding distribution, systemwide, among commercial operators not involved in accidents must also be known. Those data can then be used to determine rates for each of the potential risk factors (Section 3.7). Most of the nonaccident data required were not available (within the limited time frame of the study), so the risk rates associated with many of the parameters of interest could not be calculated.

Appendix F
Tables

Appendix G
Abbreviations and Acronyms

ADF	Automatic direction finder
ADREP	Aviation Data Reporting Program (ICAO)
AFR	African Region of ICAO
AIP	Aeronautical information publication
ALPA	U.S. Air Line Pilots Association
APA	Asia/Pacific Region of ICAO
ARP	Aerodrome reference point
ARTS	Automated radar terminal system
ATC	Air traffic control
ATIS	Automatic terminal information service
BASI	Bureau of Air Safety Investigation (Australia)
CAA	U.K. Civil Aviation Authority
CDU	Control display unit
CFIT	Controlled flight into terrain
CO	Communication
DH	Decision height
DME	Distance measuring equipment
EEU	Eastern European Region of ICAO
ER	En route
EUR	European Region of ICAO
FAA	U.S. Federal Aviation Administration
FAF	Final approach fix
FD	Flight director
FMS	Flight management system
FO	First officer
FSF	Flight Safety Foundation
GCAS	Ground-collision avoidance system
GNSS	Global navigation satellite system
GPWS	Ground-proximity warning system
GPS	Global positioning system
HUD	Head-up display
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFALPA	International Federation of Air Line Pilots' Associations
IMC	Instrument meteorological conditions
ILS	Instrument landing system
JAA	Joint Airworthiness Authorities
LA	Landing (approach)
LAM	Latin American Region of ICAO
LD	Landing (descent)
LDA	Localizer-type directional aid
LG	Landing (go-around)
LH	Landing (hold)
LOC	Localizer
MC	Monitoring/Challenging
MCTM	Maximum certified takeoff mass
MDA	Minimum descent altitude
MID	Middle East Region of ICAO
MORA	Minimum off-route altitude
MSA	Minimum sector altitude
MSAW	Minimum safe altitude warning
NAM	North American Region of ICAO
NDB	Nondirectional beacon
NE	Navigation error
NLR	National Aerospace Laboratory, Netherlands
NTSB	U.S. National Transportation Safety Board
PAPI	Precision approach path indicator
PAR	Precision approach radar
PE	Procedural error
PF	Pilot flying
PNF	Pilot not flying
RAeS	U.K. Royal Aeronautical Society
RLD	Netherlands Directorate-General of Civil Aviation
SA	Situational awareness
SDF	Simplified directional facility
SO	Systems operation
STAR	Standard terminal arrival route
TAR	Terminal approach radar
TC	Takeoff (climb cruise)
TD	Tactical decision
TI	Takeoff (initial climb)
VASIS	Visual approach slope indicator system
VFR	Visual flight rules
VMC	Visual meteorological conditions
VOLMET	Meteorology information for aircraft in flight
VOR	Very-high-frequency omnidirectional radio range

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Airport Safety: A Study of Accidents and Available Approach-and-landing Aids

Many factors influence the overall risk of approach-and-landing accidents, including airport landing aids, air traffic control and operator standards and practices. But data indicate that airports can significantly minimize risk with precision approach-and-landing guidance facilities.

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Properly executed precision approaches resulted in a five-fold risk advantage over nonprecision approaches on a worldwide basis, according to a study of factors that influence approach-and-landing safety at airports.

The study, conducted under the auspices of Flight Safety Foundation (FSF) for the Netherlands Directorate-General of Civil Aviation (RLD), focused on the influence of fully functioning precision terminal approach and guidance equipment on risk. It concluded that, when stratified according to International Civil Aviation Organization (ICAO) region, the risk increase associated with flying nonprecision approaches compared with flying precision approaches varied from three-fold to nearly eight-fold. Some of the relationships between terminal approach radar (TAR) and precision guidance equipment (ILS) are shown in the data analysis, and it was concluded that the lack of TAR increased risk among the study population by a factor of three, compared to approaches using TAR.

But other factors, beyond the direct control of the airport authority, can decisively affect the overall risk of approach-and-landing performance. Among these factors are air traffic control (ATC), operators' operating standards and practices, and surrounding terrain and other obstacles. Many factors can affect risk. The study's conclusions, for example, do not imply that a positive association between a risk factor and approach accidents represents causation, but do show that a demonstrated association exists. Thus, airport authorities can significantly minimize risk for approach-and-landing safety with precision approach-and-landing guidance facilities.

Safe operating procedures vary among operators, even though all may meet or exceed required operating standards. Different aircraft and equipment capabilities, and how they are used by the operator and the crew, introduce further variations. Professional discipline and high-quality crew performance in making critical decisions on whether or not to proceed with a given approach, or recognizing aircraft and crew limitations under particular circumstances, will also affect risk. Therefore, operator data were solicited to develop an international operator profile. More than 50 percent of survey questionnaires were returned. This profile provided insight into operators' practices and how they used landing-and-approach aids of varying capability.

A literature survey revealed much speculation about the safety value of flying a precision approach, but this study appears to be the first effort to attempt some quantification of the benefits.

Important worldwide sources of accident data were reviewed. Airports and operators using Schiphol Airport, Amsterdam, Netherlands, and “Schiphol-like” airports throughout the world were surveyed to determine airport characteristic ranges and to illustrate the range and variability of aircraft, equipment and crew training factors that exist today.

The sample of 557 “representative airports” comprises airports around the world for which both movement data and airport and runway variables were available. Movement data for the principal airports were taken from National Aerospace Laboratory, Netherlands (NLR) data bases, which assimilate data from the Airports Council International (ACI), the U.S. Federal Aviation Administration (FAA) and ICAO.

For the period 1984–1993 (the most recent 10-year period for which official accident data were available), a sample of 132 accidents meeting certain criteria was selected as the study data set. Within this data set, aircraft operating during a 10-year period varied considerably from one another in equipment and crew practices. Some changes in airport and ATC facilities also occurred within the period; the analysis attempted to take into account these differences, which were nevertheless deemed insufficient to substantially affect the study’s conclusions.

In addition, information critical to the study was missing in many accident reports and summaries. Although a larger set of data could strengthen confidence in a broader array of conclusions, the diminished data set was deemed adequate for the basic purposes of the study.

1.0 Introduction

1.1 Operational Context

The continued success of commercial air travel and cargo shipment will depend on sustaining efforts to prevent accidents and serious incidents that erode the public’s confidence in the air transport system.

From a safety standpoint, the air transport system’s three main operating components are: The aircraft, its equipment and its operations (including maintenance and ground servicing); the airport terminal guidance facilities (e.g., runway, taxiway and lighting systems, overall layout with respect to surrounding terrain and other obstacles, approach-and-landing guidance systems, takeoff and climb paths); and the supporting infrastructure (e.g., ATC, communications and weather information systems, other hazard warning systems). The environment (e.g., weather, terrain) also influences risk, which is mitigated by technological tools and precise knowledge of the environment (e.g., well-designed approach charts) and the flight crew’s skills at overcoming hazards. Within all these components, the role of human decision making and action substantially determines the success or failure of the operation.

Attention to safety on and around airports increased substantially following the El Al Airlines Boeing 747 accident near Schiphol Airport in October 1992. [While attempting to return to the airport after the no. 3 pylon and engine separated from the aircraft, the crew lost control of the aircraft, which crashed into an apartment building in an Amsterdam suburb. The four persons aboard the B-747 and 43 persons on the ground were killed. For an account based on the Netherlands Aviation Safety Board report, see *Accident Prevention*, January 1996.] What constitutes a safe airport has never been clearly defined, but the majority of aviation accidents occur on or in the vicinity of airports, and as public awareness of the risk potential from aircraft operations grows, public interest is sure to increase. Recent studies of third-party risk associated with Schiphol’s present and contemplated future operations have shed some light on determining risk to people on the ground near the airport (refs. 19, 27 and 28). This study pursued the “safe airport” concept by examining the interaction between airport and nonairport factors that affect aviation safety.

1.2 Background

Safety data from many studies show that approach-and-landing accidents and controlled-flight-into-terrain (CFIT) accidents account for the majority of fatal air transport accidents worldwide. FSF, in collaboration with ICAO, the International Air Transport Association (IATA), the International Federation of Air Line Pilots’ Associations (IFALPA) and others, has led an international CFIT Accident Reduction Task Force that has developed much insight about CFIT accidents.

The establishment of a stabilized approach to landing is regarded by operations experts as a fundamental requirement for lowest-risk terminal operation. Data examined by the FSF CFIT Task Force suggest that the absence of ground-proximity warning system (GPWS) equipment or improper use of installed GPWS equipment, and the employment of “stepdown” approach paths (particularly in nonprecision approaches), are associated with many CFIT accidents. Stepdown approaches may inhibit establishing a stabilized final approach. Although this factor is often cited in safety discussions, its importance relative to other factors has not been thoroughly examined.

Other factors that affect safety on and near the airport include: Organizational factors; ATC training, procedures and practices; flight crew training, procedures and practices; effective communication on the flight deck and between flight deck and ATC personnel; condition of runways and configuration of high-speed turnoffs; weather and other operational conditions (e.g., darkness, visibility); and the extent to which meeting or exceeding international standards is accomplished by all parties.

To reduce terminal area accidents, the approach and landing must also be conducted with precision and integrity, by automated equipment or by well-trained and experienced crews operating properly equipped and maintained aircraft. These factors are not directly controllable by the airport, because they are "owned" by the user (i.e., the operators), who control the equipment inventory and its condition, as well as the quality and thoroughness of the selection, training and supervision of experienced flight crews in appropriate procedures. The integrity of terminal area navigation and guidance must also be ensured, and this is often a function of a separate, nonairport authority.

Thus, approach-and-landing accidents can and do happen at airports having correctly functioning precision approach equipment. This study addresses the premise, suggested by existing data and current industry debate, that the operational risk is nevertheless considerably lower at such airports than at those lacking precision approach equipment.

The importance of this aspect of risk management is clear. Elimination of approach-and-landing accidents could prevent about 80 percent of the civil air transport fatalities that occur at present accident rates.[2] Although these accidents are statistically rare and numerically few, they attract a disproportionate share of public attention and their prevention is important from both moral and economic standpoints.

1.3 Literature Survey

A literature survey of similar previous investigations was conducted, with the assistance of the NLR library. Several well-known sources were employed for the literature search (e.g., European Space Agency [ESA] and DIALOG). These sources also incorporated data from the U.S. National Aeronautics and Space Administration (NASA), NLR, U.S. National Technical Information Service (NTIS) and the INSPEC data base.

The review confirmed that much credible work has been conducted by several organizations (e.g., refs. 1–11, 15–22, 30–32). Many references date back to the 1960–1970 period and might not fully reflect today's operational environment and the present generation of aircraft. In addition, a large proportion of the studies addressed very specific problems within the approach-and-landing phase accidents; for example, weather influences (e.g., refs. 2 and 17), visual problems (ref. 1), geographic disorientation (ref. 7), CFIT (e.g., refs. 5, 6, 10 and 22), third-party risk evaluation (e.g., refs. 19, 27–28), general aviation-related accidents (e.g., refs. 11 and 25).

The Aircraft Owners and Pilots Association (AOPA) (ref. 25) and ICAO (ref. 20) have conducted special studies on approach-and-landing accident prevention. In particular, the ICAO study conducted in 1967 considered the merits of precision, nonprecision and visual approaches. It postulated that precision approaches undoubtedly offer superior levels of safety compared to nonprecision approaches.

Much recent discussion within the FSF CFIT Task Force has also centered around improved safety levels offered by ILS-type approaches. The most recent data from the Task Force suggests that about 50 percent of CFIT accidents for jet aircraft, for a five-year period to July 1994, involved nonprecision approaches. Furthermore, ref. 3 suggests that approximately 50 percent of all accidents occur during the approach and landing. Such statistics, and that this survey failed to find any recent study aimed at specifically identifying the relative merits of precision and nonprecision approaches, makes the current study especially timely and appropriate.

2.0 Methodology

2.1 Approach

The study collected statistical and narrative accident data and airport movement data from sources worldwide; identified approach-and-landing accident factors; developed a taxonomy for the collation and analysis of the information; devised and distributed an operator profile questionnaire and analyzed the information gathered from these tasks in the context of the central research question.

2.2 Accident Data Sources

Accident data were acquired for two primary purposes:

(a) To apply the criteria described in Section 2.3 to establish the accident sample used for this investigation; and,

(b) To compile specific data on each of these accidents in accordance with the coding protocol described in Section 2.5 and the accident taxonomy presented in Appendix B.

Searches were conducted on the following data bases/sources by NLR, in some cases with the assistance of the organization concerned:

- Airclaims;
- AlliedSignal (formerly Sundstrand) CFIT data base [ref.10];
- Australian Bureau of Air Safety Investigation (BASI) — partial listing of CFIT accidents;
- U.K. Civil Aviation Authority (CAA) World Airline Accident Summary [ref.14];
- *Flight International* annual review of accident statistics [ref. 24];
- FSF CFIT Task Force data base;
- Fokker Aircraft B.V.;

- ICAO Aviation Data Reporting Program (ADREP) data base;
- Lawrence Livermore [U.S.] National Laboratory [ref. 23];
- NLR accident data base (Flight Safety and Flight Testing Department);
- U. S. National Transportation Safety Board (NTSB);
- Netherlands Aviation Safety Board;
- Robert E. Breiling Associates Inc. [refs. 12 and 13]; and,
- Skandia International.

These sources provided data for virtually all reported accidents that occurred on the principal airports that fulfill the criteria presented in Section 2.3. Nevertheless, collection of specific data for each individual accident (i.e., task (b) above) proved to be more challenging. Access to well-documented accident reports was very difficult in many countries. Without well documented accident reports, even where there were other multiple data sources for an accident, the quality of data was inferior.

2.3 Accident Sample and Inclusion Criteria

Several criteria were used to establish the final accident sample:

1) The accidents involved aircraft operated by commercial operators.

   [This included air taxi operators, freight operators and large air carriers involved in public transport; both scheduled and nonscheduled flights; freight, passenger and positioning flights; international and domestic flights; fixed-wing aircraft (helicopters are excluded); turbojet, turboprop and piston-engine aircraft; and aircraft in all weight categories. Excluded were training flights, experimental/test flights, aerial application/survey flights and construction work flights.[3]]

2) The accidents occurred during 1984 through 1993.

   [This time frame was considered large enough to provide an acceptable number of accidents, and the data were applicable to present day aviation. Most of the 1994–1995 data were still incomplete and preliminary.]

3) The accidents occurred during initial and final approach, landing, flare, rollout after touchdown and go-around at a principal airport (Section 2.6.a).

   [Only accidents occurring within 25 nautical miles (NM) from the destination airport were considered. This was deemed adequate to encompass all phases referred to above. Accidents in which the aircraft returned immediately to the departure airport (e.g., because of an engine malfunction) were included if the aircraft subsequently reached the approach stage. Because movement data were usually scarce, it was decided to consider accidents occurring on principal airports only. Principal airports usually contain a mixture of traffic, e.g., commuter, international, air taxi and regional, and appear, to a first order, to be comparable to Schiphol Airport.]

4) The accident resulted in loss of the aircraft hull.

   [Details of accidents resulting in “substantial” or “minor” damage and information on incidents are still not widely available in some countries. Therefore, only accidents that resulted in hull loss, in which the aircraft was destroyed or was a total loss, were included. A preliminary examination of many accident data sources suggested that most approach-and-landing phase fatal accidents resulted in a hull loss, and therefore the majority of fatal accidents were included.]

5) Accidents caused by sabotage, terrorism and military actions were excluded.

2.4 Development of the Accident Causal-factor Taxonomy

The accident record suggests that accidents do not have a single cause; instead, a series of contributory factors is nearly always involved. The hypothesis that various elements of the aviation system can contribute to the cause of accidents is not new. For example, Reason (ref. 29) argues that accidents should not be considered as isolated and infrequent events, but should be regarded as the consequences of particular sets of circumstances in which active and latent factors, sometimes acting in combination with external environmental factors, facilitate a failure of the system.

The NLR is analyzing CFIT accidents (ref. 22), under contract to the RLD. A comprehensive taxonomy of CFIT causal factors was developed by using accident reports and other related literature. The taxonomy consists of eight main categories:

- Flight;
- Flight crew;
- Environment;
- Airport and approach;
- ATC;
- Aircraft;

- Air carrier (organizational); and,
- Regulatory issues.

The flight category contains basic parameters such as aircraft type, geographical location and number of fatalities.

It was felt that a similar method was suitable for this study, because the taxonomy appeared to be applicable to approach-and-landing accidents. Nevertheless, the CFIT taxonomy in its present form was considered too detailed for this study (it contains approximately 130 items), and the accident narratives available would not allow collection of most of the items. Although the occurrence of many factors could be established from the accident summaries, estimating the rate of occurrence would be very difficult, if not impossible, because of the unavailability of the appropriate nonaccident data distributions.

Therefore, the CFIT taxonomy was greatly simplified (Appendix B). The main groups referred to above have been preserved, indicating that factors other than airport and approach variables were considered in the final taxonomy, which contains a total of 55 factors. Each accident was classified according to one of the 18 options presented in paragraph 9 of the taxonomy. A single entry was allowed for any given accident, with the final choice based on the primary causal factor. Particular care was taken not to classify just any accident involving collision with terrain as CFIT. The following definition was used:

CFIT accidents are those in which an otherwise serviceable aircraft, under the control of the crew, is flown into terrain, obstacles or water with no prior awareness on the part of the crew of the impending disaster.

2.5 Accident Data Coding Protocol

Most data items required a simple "yes/no" or "unknown" response. It was anticipated that this approach would enable easier analysis of the data. Because of the limitations of many accident summaries, it was also anticipated that some fields in the taxonomy would contain very little data.

The general procedure for coding the data from each accident included one of the study team members reviewing the appropriate accident summary or report. The accident was coded using the values included in the accident taxonomy (Appendix B). Only clear information cited in the report or summary was coded, with interpretation of the report by the analysts precluded. Where information was not provided, or was not complete enough to make an accurate assessment, the value was coded as unknown. This process may have resulted in some information being lost, but it reduced the risk of introducing bias, improved coding reliability and ensured consistency.

2.6 Airport Data

Because a certain contributing factor occurred in a significant proportion of the accident sample, it could not necessarily be concluded that the factor was an important cause of accidents. The equivalent proportion for all nonaccident flights had to be determined, to assess the significance of the fraction found in the accident sample. Ideally, the available data on nonaccident flights would have enabled a full comparison between the accident data and the movement data. This would have involved establishing, in nonaccident flights, the occurrences of all the factors that were included in the accident taxonomy. Nevertheless, much of this data was not available, and therefore a more pragmatic approach was chosen in which the data gathering primarily focused on airport and approach data. This included both movement data (i.e., number of landings) and available approach aids for each individual runway. The subsections below describe the collection of the data sets concerning generation of the principal airports list, airport movement data and airport facilities data.

2.6.a Principal Airports List

A sample group of airports for which accident, airport-specific and movement data could be collected was required. Movement data were available at NLR for a group of airports referred to as principal airports. This sample has previously been used for a number of airport safety-related studies, including third-party risk analysis (refs. 27–28). Closer inspection of the characteristics of these airports suggested that these airports would provide a representative sample for this study.

The final list comprised 557 airports, consisting of the world's most important domestic and international airports. It was based on the "Principal International Airports of ICAO States" as listed in the ICAO *Statistical Yearbooks*. International principal airports of ICAO states are defined by ICAO as those airports having a combined total of at least 90 percent of the international commercial traffic (scheduled or nonscheduled) of all the airports of that country.

In its annual statistics, ICAO lists only 15 of the 25 busiest airports in the United States. Therefore, the "Principal International Airports of ICAO States" was extended to include the 120 busiest U.S. airports, using FAA movement data. (See also ref. 28.)

In recent years, domestic air traffic movements have vastly expanded in areas such as India, Eastern Europe and China. Domestic airports in those regions may not appear in the principal airports list. The required data, both for movements and accidents, were not easily accessible. Despite these limitations, the principal airport list was believed to provide a representative sample that included most of the world's most important domestic and international airports.

2.6.b Principal Airport Movement Data

Movement data provided the necessary control group for the accident data. These data for the principal airports were collected from three main sources: ICAO, ACI and the FAA.

It was not possible to achieve a complete overview of movements on principal airports for the time frame under consideration in this study. Missing entries had to be supplemented. This was accomplished by interpolation and extrapolation of the appropriate data. Where intermediate entries were missing from a string of data, linear interpolation was applied to estimate missing data. Trend-corrected extrapolation was used where linear interpolation could not be used. For extrapolation, the general trend of all available movement data was established. The missing data could then be estimated, using the trend and the known data closest to the missing entry for that airport. [See ref. 28 for a more elaborate description of this method].

2.6.c Airport-specific Data

2.6.c.1 Airport Data Sources and Limitations

Airport and runway variables for each of the airports in the principal airports list were included in the airport data base.

Referenced data sources were principally the Jeppesen Airways Manual and the national aeronautical information publications. In addition, navigational documentation published by some of the major airlines was consulted.

The only common feature of all these data sources is that they are used for navigation and are periodically updated. Therefore, these data have to be considered biased because they represent a July 1995 snapshot of available resources at the principal airports, and it is assumed that this snapshot adequately describes the situation throughout the 1984–93 period. This assumption is plausible considering the time and investments required to significantly upgrade airport facilities. Only for a very few airports in the principal airports list is the level of facilities offered in 1995 likely to differ significantly from 1984 and later.

In addition, the possible unserviceability of technical facilities during 1984–1993 was not accounted for. By checking NOTAMS for the principal airports, it was discovered that less than 2 percent of the approaches were compromised by the unserviceability of approach aids on an average day. There appeared to be no bias in discounting the possibility of unserviceable technical facilities, and what variations might have occurred would not affect the study's conclusions.

The final, and perhaps most important, limitation of the airport data is that they are incomplete. For example, weather at or below operating minima for the approach is a contributing factor in some accidents. Correlating observed weather conditions at an airport to its movement data, however, is difficult because forecasted or actual weather reports below operating minima will result in delayed approaches until weather has improved or diversion to alternate airports. For this reason, weather conditions, although possibly one of the most frequently stated contributing factors in accident reports, were not included in airport-related data.

2.6.c.2 Airport and Runway Variables

The data items collected fell into two categories: airport variables and runway variables. Airport variables described the airport as a whole and all runway ends at that particular airport, while runway variables described the (approach to the) individual runway end.

Airport variables collected were:

- The presence of significant terrain features in the vicinity of the airport. Significant terrain was defined as any spot elevation or obstacle more than 2,000 feet (610 meters) above the airport reference point (ARP) elevation within a circle of six NM around the ARP or 6,000 feet (1,830 meters) within a circle of 25 NM around the ARP. This definition is also used by Jeppesen to determine whether or not to include colored contours in its approach plates;

- The availability of the latest weather observations to the pilot via automatic terminal information system (ATIS) or meteorological information for aircraft in flight (VOLMET);

- The presence of TAR;

- The presence of published arrival routes from the airways to the FAFs of the instrument approaches at the airfield; and,

- Number of movements per year, averaged over the 1984–1993 period.

For every runway end, variables collected were:

- Runway length;

- The presence of an approach lighting system;

- The presence of any visual glidepath-indicating system such as precision approach path indicator (PAPI) or visual approach slope indicator (VASI);

- The most precise published instrument approach procedure to the runway end;

- Whether or not the instrument approach has a constant descent gradient from the FAF to the runway threshold that can be monitored during the approach;

- The gradient of the designed stabilized approach path; and,
- The absolute number of landings on the runway end. This number is derived from the number of movements to the airfield, distributed over the runway ends at that airfield where actual operational experience, prevailing winds, published preferential runway usage and runway-end approach facilities are used to determine this distribution.

Although the list is limited, some of these variables are considered pivotal factors in some previous accidents. While the study is not limited to CFIT accidents, the data gathered can also be compared to the "Destination Risk Factors" of the FSF CFIT Checklist that determines the level of CFIT risk associated with each flight. Of the five risk factor groups in the FSF CFIT Checklist, only "controller/pilot language skills" was not included in the movement data, because the information was unavailable.

2.7 Development of the Operator Profile

2.7.a Survey Goals

Because the primary purpose of this study was to determine the relationship between accident risk and type of approach procedure, and to develop a risk ratio (RR) for various factors, the study team explored causal factors in approach-and-landing accidents. Details from the accident data suggested factors associated with aircraft equipment and cockpit procedures, but quantifying the risk associated with a factor required having some idea of how often it was present in aviation operations.

A survey was developed to gain perspective on the relationship between approach accidents and airline-related factors. The responses would comprise an operational profile of international and regional air carriers. The operator profile survey was designed to gather information describing the equipment, general policies and cockpit procedures, especially as they related to flying precision and nonprecision approaches. To ensure that the survey remained manageable and to elicit the maximum response, it was limited to five pages of questions that, for the most part, required "check box" responses. It was designed to be completed within 15 minutes.

The survey was distributed to international and regional air carrier operations directors (or their equivalents). FSF provided a representative contact data base of 156 operators for this purpose. The survey form was accompanied by a cover letter from FSF that explained the purpose and background of the study. Respondents were assured that the survey was confidential and the results would be presented in a nonattributable form.

2.7.b Survey Structure

Survey questions were divided into eight broad areas (Sections A–H on the form). Although the study team initially wanted to elicit more background information, the need for brevity reduced Sections A and B to a minimal description of the respondent's role, the age of the company and services offered.

Section C addressed flight crew training issues. Multiple-response questions allowed the respondent to indicate the topics covered by the formal training. These topics roughly comprised modern cockpit training regimens such as line-oriented flight training (LOFT) and crew resource management (CRM), specific instrument-approach skills, nonoptimum environmental factors and aircraft/equipment operation. Additional queries dealt with company policies regarding crew response to alerting devices (e.g., traffic-alert and proximity warning systems [TCAS], GPWS, etc). Because the survey focused on international practices, some questions addressed communication issues such as language and phraseology. A characterization of the training aids employed was also requested.

Many items detailed in Section C were motivated by issues addressed by the FSF CFIT Task Force. Specifically, questions 1 and 3 addressed the use of GPWS and terrain awareness training. These questions were motivated by concerns that some airlines do not train their flight crews in how specifically to respond to GPWS alerts, and provided limited guidance on developing a mental model of terrain using all available information sources. Similarly, questions 5 and 6 addressed the FSF CFIT Task Force recommendations that are incorporated in the FSF CFIT Checklist.

Other items addressed in section C were also motivated by factors discovered in air carrier accidents. These included the use of ICAO standard phraseology, night operations and wind-shear avoidance/recovery. Questions about English language training were included because airlines increasingly hire culturally diverse pilots, especially outside the United States. English language skills may become critical not only for flight crew–ATC communication, but also for intracockpit communication.

Question 3, although seemingly redundant to items in question 1, attempted to distinguish whether or not training curricula and company policies/procedures were consistent with one another.

Section D asked respondents to describe types of aircraft, automation features and approach category capabilities for their fleet. The goal was to learn how often certain equipment-related differences existed in the international fleet, especially as these equipment differences related to approach-and-landing accident factors. For example, the study team was strongly interested in how often ground-proximity warning systems (GPWS) and radar altimeters are available, because previous research suggested that operators differ about the importance of such devices. Aircraft involved in CFIT accidents have sometimes not had these features installed or functioning, even though they were required equipment. Conversely, some operators install this equipment even when it is not required.

Older-technology equipment, such as first generation GPWS and three-pointer altimeters, has also been cited as a contributor to accidents, and the study team was interested in gauging the extent to which such equipment is still used.

Questions in Section E addressed topics relevant to recent air carrier accidents. Questions 2 and 3 dealt with flight crew qualification and related closely with information elicited in Section C. Respondents were asked to indicate company policies on instrument approach currency and experience of paired flight crew members. Company policies on flight and duty time were also surveyed.

Section F concerned the written procedures that each company provided, including content of the flight operations manual, availability and format of instrument approach charts and a specific question about the written company policy for missed approaches and go-arounds. These questions were included to provide a sense of what procedures companies find most necessary to prescribe. It was presumed that procedures not specifically documented are ambiguous to flight crews.

Questions regarding the content and depictions of approach charts were again motivated by factors addressed in recent studies on CFIT accidents — particularly how the information provided on charts lends itself to terrain awareness and promotes a stabilized approach.

In Section G, questions 1–4 sought to determine a company's emphasis on checklist use and the preferred roles between cockpit crew members during approach. Question 3 related directly to the issues addressed in Section D, question 2, which tried to gauge airline emphasis on terrain awareness through use of a radar altimeter.

Questions 5–14 addressed configuring the airplane for approach and landing. The study team perceived that the stabilized approach concept has been a particularly important factor in approach-and-landing accidents. Thus, many of the 15 questions in Section G were aimed at characterizing a company's emphasis on flying stabilized approaches. Because cockpit procedures were of particular interest, Section G sought considerably more detail than the other topical areas.

Finally, Section H asked about the character and source of the flight crew support services, such as dispatch and weather information. The presumption was that the availability of these services unburdens the flight crew and, therefore, is correlated with a higher level of safety in a business environment that emphasizes high aircraft utilization and the resulting quick turn-around times.

2.8 Analytical Processes Employed in This Study

Factors other than approach type can influence the risk of an accident occurring during an approach to a runway. These might include flight crew variables (fatigue, pilot flying, total time of the pilots, crew training, crew communication, etc.), operator variables (operating standards and adherence thereto, corporate safety culture, etc.), airport variables (high terrain surrounding the airport, runway length, ATC services available, etc.) and much more. But the lack of reliable information made inclusion of these factors difficult.

Central to all the evaluations was the desire to estimate the risk associated with the various approach and operator factors. To do this, it was essential to understand the prevalence of these individual factors, systemwide, among commercial operators *not* involved in accidents. This information was used to determine rates and RRs for each of the risk factors. The major steps included in the analysis for this study are listed below.

1) After the accidents were coded, and the airport data collected, the data were verified. New categorical variables were developed, which collapsed certain variables with a large number of values into larger, and fewer, categories. This was done because the analysis of variables with many category values, combined with the small number of accidents (132), would limit the value of the resulting analysis because of the problem of small numbers. This was most notable with two variables dealing with the make and model of the aircraft involved and with the accident factor category. The resulting collapsed values are present in Tables 3.2 and 3.12, and discussed in more detail in Section 3.0, Findings.

2) After the data bases were in the final form, the data were evaluated through simple single-variable analyses. These included developing frequency distributions for each variable, looking at the geographic distribution of accidents and other simple exploratory analyses that provided a solid baseline understanding of the accident data and their characteristics.

3) After the basic evaluation was completed, relationships between variables were evaluated. An estimate of the risk of crashing with a particular factor present was accomplished by developing an RR, according to the following formula:

$$\mathbf{RR = \{a/A\} / \{f/N\}}$$

where:

RR = risk ratio
a = numbers of occurrences of a factor in accidents
A = total number of accidents
f = number of occurrences of the factor in nonaccident flights
N = total number of movements

The resulting risk ratio value provided some insight on the association of a particular factor on the risk of an accident. A value of 1 indicated that there was no significant difference in the association between the factor and accidents. A value >1 indicated an increased level of risk and, conversely, a value <1 indicated that the factor had a possible protective effect against an accident. These relationships were tested for statistical significance and 95 percent confidence intervals calculated for the risk estimates.

The calculation of the RR could only be accomplished for variables where data existed for the prevalence of the factor among all airports in the study sample. This was limited primarily to airport factors such as approach type (precision and nonprecision), surrounding terrain, approach radar services, standard terminal arrival routes (STARs) and visual approach path guidance (VASI/PAPI). Denominator information (f/N) for operator factors such as pilot experience, GPWS and pilot-to-pilot communication was not available for the entire commercial aircraft fleet. Therefore, appropriate rates and risk ratios could not be calculated for these elements.

3.0 Findings

3.1 Findings, Univariate Analysis

Table 3.1 presents the distribution of the approach accidents among the major ICAO regions. (All geographic references in subsequent text — e.g., Middle East, North America — refer to ICAO regions.) Latin America, Europe and North America together account for 66 percent of the accidents in this sample. This is most likely a function of the high level of commercial air carrier activity in these regions. The rate of landing accidents per million movements is also presented. The estimated average rate for the study period was slightly more than 10 accidents per million movements. The lowest rate was for North America, at four accidents per million movements. The highest rate was for Latin America, at 32 accidents per million movements.

Table 3.1
Aircraft Accident Distribution by ICAO Region, Study Data Base

ICAO Region	Number of Accidents	Movements	Rate/Million Movements
Africa	17	562,734	30.21
Asia-Pacific	19	1,039,380	18.28
Eastern Europe	5	243,300	20.55
Europe	26	2,732,780	9.51
Latin America	34	1,050,632	32.36
Middle East	3	263,183	11.40
North America	28	6,860,700	4.08
Total	**132**	**12,752,709**	**10.35**

ICAO = International Civil Aviation Organization

Source: John H. Enders, Robert Dodd et al.

Table 3.2 (page 222) shows the distribution of aircraft type (by broad category) involved in the approach accidents.

Table 3.3 (page 222) shows the categories of aircraft involved in the accidents reviewed. The categories are derived from Table 3.2 and are designed to provide more insight into the flight characteristics of the aircraft involved in the accidents. Seventy-six percent of the accident aircraft were transport or commuter airplanes.

Table 3.4 (page 223) provides the distribution of the type of operation of the accident aircraft. For each category, the operational status of a significant number of the accidents is unknown.

Table 3.5 (page 213) displays the distribution of the type of approach flown by the accident aircraft. The approach type for a significant number of the cases is unknown. Among those where approach status is known, however, the distribution of precision and nonprecision is roughly equal. (These values represent raw numbers that have not yet been adjusted to account for the differences in number for precision and nonprecision approaches flown.)

Table 3.6 (page 213) shows the light conditions at the time of the accident among the study population. Where light status was known, 55 out of 84 (65 percent) occurred at night or twilight, while 29 of the 84 (35 percent) occurred during the day.

Table 3.7 (page 223) shows the average flight experience of the captain and first officer in accidents, where the information was available. This Table also provides the range of these values (highest and lowest value for each category). In only 36 out of 132 accidents (27 percent) was the captain's flight experience given in the records.

Table 3.8 (page 223) displays the distribution of the presence or absence of important airport-related factors. Approach lights were present for 58 of the 81 accidents (72 percent), while 61 of the 93 accidents (66 percent) occurred while approaching runways with visual approach guidance systems. The presence of approach lights could not be determined for 51 of the accidents (39 percent), and the presence of VASI/PAPI could not be determined for 39 of the accidents (30 percent).

Table 3.9 (page 224) shows weather at the time of the accident. The most common occurrence was instrument meteorological conditions (IMC), present in 47 of 72 (65 percent) of the accidents where weather was known to the researchers. Fog was present in 30 out of 72 (42 percent) of the cases where weather was known, while rain was present in 31 out of 72 (43 percent) of the cases.

Table 3.2
Types of Aircraft Involved in Approach Accidents, Study Data Base

Aircraft	Number of Accidents	Percent*	Aircraft	Number of Accidents	Percent*
A-300	1	1	IL-18	2	2
A-310	1	1	IL-76	1	1
A-320	2	2	Jet Commander	1	1
B-707	14	11	Jetstream	1	1
B-727	4	3	King Air	2	2
B-737	11	8	L-1011	1	1
B-747	4	3	L-188	3	2
BAC 1-11	2	2	Lear 23	2	2
Beech 18	2	2	Lear 24	1	1
C-46	1	1	Lear 25	2	2
CASA-212	5	4	Lear 31	1	1
CL-44	1	1	Lear 35	1	1
CL-600	1	1	MU-2B	2	2
CV-440	1	1	Metro	7	5
Citation I	1	1	Nomad	1	1
DC-10	4	3	PA-31T	2	2
DC-6	2	2	PA-32	1	1
DC-8	4	3	SD-360	1	1
DC-9	6	5	Saberliner	1	1
DHC-6	3	2	Saber Jet	1	1
DHC-8	2	2	Skyvan	1	1
EMB-120	1	1	TC-690	1	1
F-27	6	5	TU-134	2	2
Falcon 20	1	1	TU-154	3	2
Gulfstream II	2	2	Trident	1	1
HS-125	4	3	Trislander	1	1
Herald	1	1	Viscount	2	2

*Rounded to the nearest whole number

Source: John H. Enders, Robert Dodd et al.

Table 3.3
Accident Aircraft Categories, Study Data Base

Aircraft Category	Number of Accident Aircraft	Percent
Business Jet	20	15.2
Business Piston	4	3.0
Business Turboprop	7	5.3
Commuter Piston	1	0.8
Commuter Turboprop	21	15.9
Transport Jet	61	46.2
Transport Piston	4	3.0
Transport Turboprop	14	10.6

Source: John H. Enders, Robert Dodd et al.

Table 3.10 (page 224) shows the mean value of the cloud ceiling and visibility for accidents where the information was provided. As with the pilots' flight experience, only a small percentage (34 percent) of the accident reports or summaries recorded this information.

Table 3.11 (page 224) shows the distribution of accident categories coded by the analysts in this study. These categories were mutually exclusive and only one was selected for each accident. Accidents where no category could be determined were categorized as unknown.

Table 3.12 (page 225) lists factors associated with the accident, with coding based on accident reports and summaries. Many accident reports and summaries did not provide insight into whether procedural errors occurred. Consequently, many of the values in Table 3.12 were coded as unknown.

Table 3.4
Type of Operation, Study Data Base

Type of Operation	Yes	Percent Yes	No	Percent No	Unknown	Percent Unknown
Scheduled (no = nonscheduled)	70	53.3	41	31.1	21	15.9
Passenger (no = freight)	85	64.4	31	23.5	16	12.1
International (no = domestic)	40	30.3	51	38.6	41	31.2

Source: John H. Enders, Robert Dodd et al.

Table 3.5
Type of Approach Flown, Study Data Base

Type Approach	Number of Accidents	Percent
Nonprecision	27	20.5
Precision	35	26.5
Unknown	57	43.2
Visual	13	9.8

Source: John H. Enders, Robert Dodd et al.

Table 3.6
Light Conditions at Time of Accident, Study Data Base

Light Condition	Number of Accidents	Percent
Dark	48	36.4
Twilight	7	5.3
Light	29	22.0
Unknown	48	36.4

Source: John H. Enders, Robert Dodd et al.

Table 3.7
Pilot and First Officer Flight Experience (Flight Hours), Study Data Base

Pilot	Mean	Range	Standard Deviation	Valid Cases
Captain, Total Time	10,729	1,824–29,967	7,127	36
Captain, Time in Type	2,256	10–9,500	2,358	33
First Officer, Total Time	4,908	1,463–15,639	3,429	15
First Officer, Time in Type	878	61–2,634	728	14

Source: John H. Enders, Robert Dodd et al.

Table 3.8
Airport-related Factors, Study Data Base

Airport-related Factor	Yes	Percent Yes	No	Percent No	Unknown	Percent Unknown
Approach Lights	58	43.9	23	17.4	51	38.6
STAR*	97	73.5	34	25.8	1	0.8
Approach Radar*	89	67.4	42	31.8	1	0.8
High Terrain*	37	28.0	94	71.2	1	0.8
VASI/PAPI*	61	46.2	32	24.2	39	29.5
ATIS/VOLMET*	103	81.4	28	21.2	1	0.8

* These values were derived from the airport activity data base. Cases from the accident data base, and the information from the airport data base, were matched on the runway identification (ID) and ICAO airport ID for the runway the accident aircraft was approaching.

STAR = Standard Terminal Arrival Route
PAPI = Precision Approach Path Indicator
VOLMET = Meteorology Information for Aircraft in Flight
VASI = Visual Approach Slope Indicator
ATIS = Automatic Terminal Information System

Source: John H. Enders, Robert Dodd et al.

Table 3.9
Weather Conditions, Study Data Base

Weather Condition	Yes	Percent Yes	No	Percent No	Unknown	Percent Unknown
Instrument Meteorological Conditions	47	35.6	25	18.9	60	45.5
Fog	30	22.7	42	32.0	60	45.0
Rain	31	23.5	41	31.1	60	45.5
Ice	3	2.3	65	49.2	64	49.0
Thunderstorm	4	3.0	65	49.2	63	47.7
Winds	11	8.3	56	42.4	65	49.2
Wind Shear	7	5.3	60	44.7	65	49.2
Snow	4	3.0	65	49.2	63	47.7

Source: John H. Enders, Robert Dodd et al.

Table 3.10
Cloud and Ceiling Values Among a Subset of Accidents, Study Data Base

Weather Factor	Mean	Range	Standard Deviation	Valid Cases
Visibility	7.2 statute miles (11.6 kilometers)	0.1–100 statute miles (0.2–161 kilometers)	15.6 statute miles (25.1 kilometers)	45
Cloud Ceiling	8,178 feet (2,494 meters)	0–30,000 feet (9,150 meters)	11,879 feet (3,623 meters)	44

Source: John H. Enders, Robert Dodd et al.

Table 3.13 (page 225) shows the relation between the presence of TAR and the presence of an ILS. The TAR/ILS dependency ratio is the number of approaches made with the assistance of approach radar divided by the number of ILS approaches, and the results are stratified by region.

From Table 3.13 it can be concluded that in North America, virtually no ILS approach was made without the presence of a TAR. On the other hand, Africa and Latin America show that a significant number of airports offered a precision approach facility but did not have a TAR. In developed regions of the world (Europe and North America), an ILS installation is usually associated with a TAR.

3.2 Findings, Bivariate Analysis

Table 3.14 (page 14) presents the association of airport-related risk factors and approach accidents, adjusted for the number of movements involving each risk factor. As mentioned earlier, a risk ratio of 1 (RR=1) means there is no significant difference in risk whether the risk factor is present or absent. A value greater than 1 indicates a greater risk. The larger the value of the RR, the stronger the association between the risk factor and the accident risk. The value itself indicates the magnitude of that risk. The 95 percent confidence interval provides insight on what the range of that risk might be; the RR is not absolute, because its estimation is based on a sample. If the 95 percent confidence interval does not include the value of 1, then the risk ratio is deemed to be statistically significant at the 0.05 level.[5]

Table 3.11
Detailed Accident Categories, Study Data Base

Accident Category	Number	Percent
CFIT, Unknown	1	0.8
CFIT, Land. Short	24	18.2
CFIT, Collision. High Terrain	22	16.7
CFIT, Collision. Object	4	3.0
CFIT, Water	2	1.5
Aircraft Collision on Ground	1	0.8
Landing Overrun	14	10.6
Runway Excursion	2	1.5
Landing Gear Problem	7	5.3
Wheel-up Landing	1	0.8
Unstable Approach	10	7.6
Loss of Control, Crew-caused	12	9.1
Wind Shear	3	2.3
Airframe Ice	1	0.8
Midair Collision	4	3.0
Loss of Power	7	5.3
Aircraft Structure	1	0.8
System Malfunction	6	4.5
Fuel Exhaustion	1	0.8
Unknown	9	6.8

CFIT = Controlled flight into terrain

Source: John H. Enders, Robert Dodd et al.

Table 3.12
Associated Factors, Study Data Base

Associated Factor	Yes	Percent Yes	No	Percent No	Unknown	Percent Unknown
Poor Pilot-to-pilot Communication	10	7.6	19	14.4	103	78.0
Poor Pilot-to-center Communication	7	5.5	24	18.2	101	76.5
GPWS Installed	21	15.9	31	23.5	80	60.6
Poor Aircraft Handling	29	22.0	23	17.4	80	60.6
Poor Maintenance	5	3.8	37	28.0	90	68.2
Poor Company Management	9	6.8	28	21.2	95	72.0
Navigation Error	18	13.6	59	44.7	55	41.7
Poor System Operations	14	10.6	37	28.0	81	61.4
Engine Problems	12	9.1	72	54.5	48	36.4
Radar Altimeter Installed	23	17.4	3	2.3	106	80.3
Structural Failure	3	2.3	80	60.6	49	37.1
Oversight/Surveillance Poor	8	6.1	27	20.5	97	73.5
System Failure	12	9.1	69	52.3	51	38.6
Crew Training Adequate	23	17.4	14	10.6	95	72
Vector Error	4	3.0	46	34.8	82	62.1
VMC into IMC	3	2.3	62	47.0	67	50.8

GPWS = Ground-proximity Warning System VMC = Visual Meteorological Conditions IMC = Instrument Meteorological Conditions

Source: John H. Enders, Robert Dodd et al.

The movement ratio (number of nonrisk movements divided by risk-factor movements) provides some insight into the ratio of movements with the risk factor present to those without the risk factor present. A high value denotes a large difference, while a lower value denotes that the number of movements with and without the risk factor present are more similar.

Table 3.13
TAR/ILS Dependency Ratio,*
Study Data Base

ICAO Region	Ratio
Europe	0.82
Eastern Europe	0.91
North America	0.97
Africa	0.36
Middle East	0.78
Latin America	0.53
Asia-Pacific	0.82

* Number of approaches made with the assistance of TAR divided by the number of ILS approaches

ILS = Instrument Landing System
TAR = Terminal Approach Radar
ICAO = International Civil Aviation Organization

Source: John H. Enders, Robert Dodd et al.

The results presented in Table 3.14 (page 226) treat the TAR, approach status and ATIS/VOLMET variables as independent factors. It is likely, however, that these factors are closely related, since most large air carrier airports provide all these services. These limitations should be kept in mind when reviewing the results of Table 3.14.

The accident risk while flying a nonprecision approach was five times greater than that associated with flying a precision approach. If TAR was not available, the accident risk was three times greater than when it was available. If there was no standardized approach routing, the accident risk was about one and a half times that when STARs were available. If there was no ATIS or VOLMET, the accident risk was almost four times greater than if current airport weather information was available. The presence of high terrain, the lack of VASI or PAPI, and the lack of approach lights were not associated with a greater accident risk within this population. The values in Table 3.14 were calculated for all accidents in all the ICAO regions combined.

Table 3.15 (page 226) looks at the risk associated with nonprecision approaches, stratified by ICAO regions. All regions had a greater association between nonprecision approaches and the accident risk while on approach than between precision approaches and the accident risk. The movement ratio gives some indication of the frequency of nonprecision approaches compared to precision approaches. Europe had the highest

Table 3.14

Risk Ratio for Airport-related Risk Factors, All ICAO Regions, Study Data Base

Airport-related Risk Factor	Risk Ratio	95 Percent Confidence Range	Risk-factor Accidents	Risk-factor Absent Accidents	Risk-factor Movements	Risk-factor Absent Movements	Movement Ratio
Nonprecision Approach	5.2	3.9–6.9	27	35	1,037,947	11,403,061	11.0
No TAR	3.1	2.4–4.0	42	89	1,322,944	11,429,765	8.6
High Terrain	1.2*	0.9–1.6	37	94	2,852,450	9,588,652	3.4
No STAR	1.6	1.2–2.1	34	97	2,122,025	10,630,685	5.0
No ATIS/VOLMET	3.9	2.8–5.5	28	103	693,875	12,058,835	17.4
No Approach Lights	1.4	1.0–2.0	23	58	2,559,278	10,191,932	4.0
No VASI/PAPI	0.8*	0.6–1.1	32	61	5,294,677	7,458,033	1.4

* Denotes that the risk ratio (RR) value was not statistically significant at the 5 percent level.

ICAO = International Civil Aviation Organization
TAR = Terminal Approach Radar
ATIS = Automatic Terminal Information System
VASI = Visual Approach Slope Indicator
STAR = Standard Terminal Arrival Route
VOLMET = Meteorology Information for Aircraft in Flight
PAPI = Precision Approach Path Indicator

Source: John H. Enders, Robert Dodd et al.

Table 3.15

Risk Ratio for Nonprecision Approaches, Stratified by ICAO Region, Study Data Base

ICAO Region	Nonprecision Approach Risk Ratio	95 Percent Confidence Range	Precision Approach Accidents	Nonprecision Approach Accidents	Precision Approach Movements	Nonprecision Approach Movements	Movement Ratio
All Regions	5.2	3.9–6.9	35	27	11,403,061	1,037,947	11.0
Africa	3.6	2.1–41.7	3	5	438,193	92,031	4.8
Eastern Europe	n/a	n/a	2	0	222,743	20,080	11.1
Asia-Pacific	7.7	4.5–13.1	3	5	938,480	83,062	11.3
Europe	4.1	1.8–9.8	13	4	2,552,976	153,408	16.6
Middle East	n/a	n/a	1	0	235,666	22,730	10.4
Latin America	3.0	2.0–4.4	3	7	765,238	236,313	3.2
North America	5.8	3.0–11.0	10	6	6,249,763	430,321	14.5

ICAO = International Civil Aviation Organization

Risk ratio (RR) values for Eastern Europe and Middle East were not included in this listing because they did not have any nonprecision approach accidents that were identified in this study. They were included in the aggregate calculation for all regions.

Source: John H. Enders, Robert Dodd et al.

movement ratio of 16.6, while Latin America had the lowest, with a ratio of 3.2.

Table 3.16 (page 227) provides the RR of the association between TAR and accidents. The risk was three times greater with no TAR when all ICAO regions were considered. When the regions were considered individually, the picture became less clear. Where Europe and Asia-Pacific showed a statistically significant no-TAR RR of three, in these regions the presence of a TAR is often combined with the presence of an ILS (see Table 3.13, page 225), while in the regions with low correlation between ILS and TAR, namely Africa and Latin America, the TAR RR is considerably lower. It seems likely that the RR for no TAR was correlated to some extent with the RR associated with a nonprecision approach.

The movement ratio for TAR shows, not surprisingly, that in Europe and, especially, North America, the vast majority of the arrivals and approaches were TAR-assisted, while in Africa and Latin America, the number of TAR-assisted arrivals just about equaled the number of arrivals without radar (procedural guidance only).

Table 3.16
Risk Ratio for Absence of Terminal Approach Radar, Stratified by ICAO Region, Study Data Base

ICAO Region	Absence of TAR Risk Ratio	95 Percent Confidence Range	TAR-absent Accidents	TAR-present Accidents	TAR-absent Movements	TAR-present Movements	Movement Ratio
All Regions	3.1	2.4–4.0	42	89	1,322,944	11,429,765	8.6
Africa	1.2*	0.8–1.7	11	6	298,844	263,890	1.1
Eastern Europe	n/a	n/a	0	5	28,100	215,200	7.6
Asia Pacific	3.0	1.7–5.5	7	12	126,400	912,980	7.2
Europe	3.5	1.4–8.5	4	21	144,700	2,988,080	17.9
Middle East	1.3*	0.3–6.5	1	2	66,400	196,783	3.0
Latin America	1.2*	0.9–1.6	19	14	505,680	544,982	1.1
North America	n/a	n/a	0	28	152,850	6,707,850	43.9

* Denotes that the RR value was not statistically significant at the 5 percent level.

ICAO = International Civil Aviation Organization TAR = Terminal Approach Radar

Risk ratio (RR) values for Eastern Europe and North America were not included in this listing because they did not have any accidents that were identified in this study in which TAR was absent. They were included in the aggregate calculation for all regions.

Source: John H. Enders, Robert Dodd et al.

Both Africa and Latin America had no demonstrated increase of risk when TAR was not present. Both of these regions had TAR movement ratios that indicated an equal number of TAR and non-TAR movements during the study period. The North American region had a very high TAR movement ratio of 44, which indicated that the vast majority of approaches in the North American region were flown with TAR guidance.

Table 3.17 shows the RRs associated with high terrain around the airports. Only Asia-Pacific had a significant RR associated

Table 3.17
Risk Ratio for High Terrain Around Accident Airport, Stratified by ICAO Region, Study Data Base

ICAO Region	High-terrain Risk Ratio	95 Percent Confidence Range	High-terrain Accidents	High-terrain Absent Accidents	High-terrain Movements	High-terrain Absent Movements	Movement Ratio
All Regions	1.2*	0.9–1.6	37	94	2,852,450	9,588,652	3.4
Africa	0.4*	0.1–1.5	2	15	165,570	397,164	2.4
Eastern Europe	n/a	n/a	1	4	21,050	222,250	10.6
Asia Pacific	1.0*	0.6–1.9	7	12	367,300	672,080	1.8
Europe	0.9*	0.4–2.1	5	20	581,300	2,151,480	3.7
Middle East	n/a	n/a	1	2	58,650	204,533	3.5
Latin America	0.8*	0.5–1.3	10	23	415,500	635,132	1.5
North America	1.1*	0.5–2.1	6	22	1,387,850	5,472,850	3.9

* Denotes that the RR value was not statistically significant at the 5 percent level.

ICAO = International Civil Aviation Organization

Risk ratio (RR) values for Eastern Europe and Middle East were not included in this listing, because the number of accidents in one or more categories was too small to calculate. They were included in the aggregate calculation for all regions.

Source: John H. Enders, Robert Dodd et al.

with high terrain and accident risk. Eastern Europe had a movement ratio of 10.6, the highest by a factor of two among all the ICAO regions.

Table 3.18 lists the RRs associated with the absence of STARs at airports where the approach accidents occurred. Only Africa and North America had RRs that were significantly greater than one for the absence of STARs.

Table 3.19 shows the association of visual approach guidance (VASI and PAPI) and accident risk, stratified by ICAO region. As can be seen, there were no significant risk increases associated

Table 3.18
Risk Ratio for Absence of STAR, Stratified by ICAO Region, Study Data Base

ICAO Region	Absence of STAR Risk Ratio	95 Percent Confidence Range	STAR-absent Accidents	STAR-present Accidents	STAR-absent Movements	STAR-present Movements	Movement Ratio
All Regions	1.6	1.2–2.1	34	97	2,122,025	10,630,685	5.0
Africa	1.6	1.1–2.3	11	6	224,775	337,959	1.5
Eastern Europe	n/a	n/a	0	5	20,950	222,350	10.6
Asia-Pacific	1.8*	0.5–6.8	2	17	60,050	979,330	16.3
Europe	1.8*	0.3–4.5	2	23	184,700	2,548,080	13.8
Middle East	n/a	n/a	0	3	110,600	152,583	1.4
Latin America	0.9*	0.5–1.5	10	23	361,400	689,232	1.9
North America	1.9	1.1–3.3	9	19	1,159,550	5,701,150	4.9

* Denotes that the RR value was not statistically significant at the 5 percent level.

ICAO = International Civil Aviation Organization STAR = Standard Terminal Arrival Route

Risk ratio (RR) values for Eastern Europe and Middle East were not included in this listing, because the number of accidents in one or more categories was too small to calculate. They were included in the aggregate calculation for all regions.

Source: John H. Enders, Robert Dodd et al.

Table 3.19
Risk Ratio for Absence of VASI or PAPI, Stratified by ICAO Region, Study Data Base

ICAO Region	Absence of VASI/PAPI Risk Ratio	95 Percent Confidence Range	VASI/PAPI-absent Accidents	VASI/PAPI-present Accidents	VASI/PAPI-absent Movements	VASI/PAPI-present Movements	Movement Ratio
All Regions	0.8*	0.6–1.1	32	61	5,294,677	7,458,033	1.4
Africa	1.5*	0.6–3.7	3	6	125,954	436,780	3.5
Eastern Europe	n/a	n/a	3	0	125,919	117,381	0.9
Asia-Pacific	1.0*	0.2–6.9	1	12	75,906	963,473	12.7
Europe	1.6*	0.9–2.7	8	13	660,190	2,072,589	3.1
Middle East	n/a	n/a	0	3	26,371	236,811	9.0
Latin America	1.3*	0.6–2.7	5	17	189,273	861,359	4.6
North America	0.9*	0.6–1.3	12	10	4,091,062	2,769,637	0.7

* Denotes that the RR value was not statistically significant at the 5 percent level.

ICAO = International Civil Aviation Organization
VASI = Visual Approach Slope Indicator PAPI = Precision Approach Path Indicator

Risk ratio (RR) values for Eastern Europe and Middle East were not included in this listing, because the number of accidents in one or more categories was too small to calculate. They were included in the aggregate calculation for all regions.

Source: John H. Enders, Robert Dodd et al.

with an absence of visual approach guidance. Nevertheless, other correlations may exist, for example, if stratified across approach type (precision vs. nonprecision).

3.3 Operator Profile Analysis

3.3.a Response Rate

Although 156 airlines were identified in the sample, contacts were established with only 119. The operator profile survey was completed by 63 of 119 airlines, a return rate of 53 percent. Subsequent sampling of the nonrespondents revealed no indication that the survey design, method of distribution, organizational source or purpose was in any way objectionable to the field of potential respondents, and that reasons for the nonresponse were administrative or organizational. A composite of the questionnaire and responses is included as Appendix C.

3.3.b Univariate Tabulations

The survey form contained no overt reference to the respondent's company or name. Nevertheless, an internal tracking number was maintained for each survey, to allow identification of nonrespondents for follow-up telephone calls. These tracking numbers also allowed showing data distributions by ICAO regions.

3.3.b.1 Distribution of Respondents

The overall distribution of respondents is shown in Table 3.20. Comparison of the two percentage columns gives a sense of whether regions are over- or under-represented among respondents. Roughly, it can be seen that European and North American operators are over-represented, while African and Asian-Pacific operators are under-represented. It is not clear why these discrepancies exist or to what extent they are significant.

3.3.b.2 Respondent Information

Because approximately 80 percent (95 out of 119) of the survey addressees were company executive officers (vice-president or president), question A-1 indicates that the survey was often passed down to a lower level for completion, usually to chief pilots or managers overseeing safety or training.

3.3.b.3 Operator Background

Responses to questions in section B indicated that, on average, the surveyed airlines had a history of 34–35 years. The standard deviation was 19.4, indicating a relatively high variability in company ages. The overwhelming majority of responses came from scheduled air carriers flying international passenger operations, but it was also clear that many carriers flew domestic routes as well.

3.3.b.4 Flight Crew Training

Question C-1 explored the types of formal training endorsed by surveyed air carriers. The numbers for many items were all quite large (> 54), indicating a high degree of uniformity in these topical areas. The less-subscribed categories included human factors, terrain awareness, electronic flight instrumentation system (EFIS)/autopilot mode awareness, nonprecision approach procedures, ICAO standard phraseology, TCAS, night flying and Category II/III approach procedures. Some of these low numbers may be related to differences in the type and age of equipment. This may well be the case for EFIS/autopilot mode awareness and Category II/III approach procedures. Topics such as TCAS and ICAO standard phraseology training might suffer because of

Table 3.20
Location of Respondents/Addressees by ICAO Region, Study Data Base

ICAO Region	Number of Respondents	Percent of All Respondents	Percent of Addressees
Africa	4	6.3	12.8
Asia-Pacific	9	14.3	21.2
Eastern Europe	2	3.2	9.6
Europe	23	36.5	26.2
Latin America	4	6.3	7.1
Middle East	6	9.5	6.4
North America	15	23.8	16.7
Total	**63**	**100.0**	**100.0**

ICAO = International Civil Aviation Organization

Source: John H. Enders, Robert Dodd et al.

regulatory inconsistencies. For example, TCAS is mandated now in the United States, whereas ICAO phraseologies are underemphasized there because of U.S. FAA communication standards. Some training categories might receive less focus because they are not viewed as deserving special attention. Terrain awareness, night flying and ICAO phraseologies reflected such attitudes. The underemphasis on nonprecision approaches might be affected by a perception that they are used only rarely in air carrier operations.

Question C-2 focused on English language training. With English adopted as an international standard for communications between flight crews and air traffic controllers, there might be a need to enhance the English skills of pilots from non-English-speaking countries. More recently, however, it has been found that operators based in smaller countries tend to hire culturally diverse pilots using a variety of native languages. Thus, the importance of a common language for communication within the cockpit is increasing. The responses to question C-2 indicated that these problems have not gone unnoticed. Approximately 59 percent of all respondents stated that their companies do provide some training in English, while another 27 percent do not because all pilots are from English-speaking countries.

Question C-3 addressed three alerting devices — GPWS, TCAS and wind-shear alerts — that require similar types of flight crew actions when responding to a warning. This question distinguished itself from question C-1, because it specifically focused on formal company policies. Respondents indicated that mandated policies with respect to the use of GPWS were almost universal. Such was not the case, however, with TCAS, probably because TCAS is not universally required.

In responses to question C-4, 95 percent of all responding companies indicated that they used high-fidelity simulators for training. Such simulators would include motion bases and high-resolution visual systems.

Questions C-5 and C-6 addressed methods for familiarizing flight crews with new routes and airports. These topics appear on the FSF CFIT Checklist. Respondents indicated that route familiarization checks were conducted by 92 percent of the responding airlines. Visual aids for new airport familiarization were also gaining increased acceptance, with a 76 percent positive response regarding their use.

3.3.b.5 Aircraft and Equipment

The composition of airline fleets is well documented within the air carrier and air transport manufacturing industries. In the course of this survey, however, it was convenient to request this information from the respondents (Section D). In general, respondents indicated that advanced technology aircraft (EFIS- and Flight management system- [FMS] equipped) have become more the rule than the exception. More than 30 percent of the total fleet (for those responding) was composed of Boeing advanced-technology aircraft. Overall, advanced-technology models accounted for between 40 and 50 percent of all aircraft used by responding companies. Earlier generation medium-size aircraft were still significantly represented by Boeing 727s and 737s, as well as McDonnell Douglas DC-9s and their derivatives (e.g., MD-80). Large, wide body aircraft consisted mostly of early generation B-747s, McDonnell Douglas DC-10s and Lockheed Martin L-1011s. Collectively they made up approximately 10 percent of respondents' fleets, while advanced-technology wide-bodies made up approximately 5 percent.

Respondents were also asked to indicate the level of automation present in their fleets, as well as the approach capabilities of their aircraft. To a large extent, these capabilities are directly linked to the make and model of aircraft. In some respects, however, their presence might be discretionary. Advanced-technology equipment (EFIS and FMS) was found in nearly 58 percent of respondents' aircraft. These aircraft almost always have autoland capability, as do some of the early generation wide-bodies. GPWS, weather radar and radar altimeters existed in nearly all aircraft, while TCAS was present in over three-quarters of respondents' aircraft. Almost half the total aircraft were indicated as having Category III approach capability, while an additional 36 percent had Category II.

3.3.b.6 Flight Crew Scheduling and Qualifications

Questions E-1 through E-3 addressed operational practices which have come to the fore as a result of previous air transport accident investigations. Questions E-1 and E-2 indicated virtually universal adoption of flight and duty time limits, as well as instrument currency policies. To a large extent, companies may be mandated by regulation to follow duty time and instrument currency guidelines. Thus, it is not clear that respondents' companies were using more conservative standards than regulations dictated.

Conversely, responses to question E-3 indicated that many operators have not yet recognized the importance of pairing experienced crew members with those less experienced. It is likely that this emphasis, because it is a more recent issue, has not yet been universally endorsed.

3.3.b.7 Operational Documents, Manuals and Published Procedures

The questions in Section F addressed the extent to which airlines documented their policies and procedures, and whether they made them available to flight crews. The answers to questions F-1 and F-2 indicated that using a flight operations manual has received global acceptance. In addition, the surveyed airlines routinely used the flight operations manual to disseminate information on safety-related procedures and policies. The responses to question F-2 indicated that, of all the topics listed, only sterile cockpit procedures was included by fewer than 90 percent of the responding operators. The sterile cockpit rule (as defined by U.S. Federal Aviation Regulations [FARs] Part 121.542) was introduced in the United States in the late 1970s, but it may not have received broad endorsement by non-U. S. carriers. Table 3.21 shows the distribution of carriers, by region, that did not address the sterile cockpit concept in their flight operations manual.

The responses to questions F-3 and F-4 showed that most airlines contracted with Jeppesen to provide instrument approach and navigation charts. A significant minority, however, produced their own charts or acquired them from other airlines. The study team was interested in the use of color shading to indicate terrain heights. Seventy-one percent of the respondents stated that their charts did make use of color shading.

Another interest was the use of a charted glide path on charts for nonprecision approaches. This feature promotes using a stabilized approach configuration in lieu of stepdown procedures. It is often accomplished by providing a series of altitudes and DME distances that mimic a glideslope. As seen in Table 3.22, the operators using this feature were primarily based in western Europe.

In response to question F-6, all but a few airlines reported supplying their flight crew members with approach charts. Those that did not supply charts to individual pilots placed charts in the aircraft. The concern here is that, when one set of charts travels with the aircraft, a procedure cannot be viewed by all crew members simultaneously, thereby compromising the monitoring function of the nonflying pilot. Question F-6 responses also indicated that flight engineers were given approach charts by only 20 percent of companies responding to the survey. This was misleading, though, because it did not mean that flight engineers were treated differently as much as it indicated that relatively few companies flew aircraft requiring a flight engineer.

Table 3.21
Location of Operators Without Sterile Cockpit Procedures,* Study Data Base

ICAO Region	Number of Operators
Africa	2
Asia-Pacific	3
Eastern Europe	0
Europe	9
Latin America	1
Middle East	1
North America	1
Total	**17**

* As defined by U.S. Federal Aviation Regulations (FARs) Part 121.542.

ICAO = International Civil Aviation Organization

Source: John H. Enders, Robert Dodd et al.

Table 3.22
Location of Operators Using Descent Profiles on Nonprecision Approach Charts, Study Data Base

ICAO Region	Number of Operators
Africa	2
Asia-Pacific	3
Eastern Europe	2
Europe	14
Latin America	2
Middle East	0
North America	3
Total	**26**

ICAO = International Civil Aviation Organization

Source: John H. Enders, Robert Dodd et al.

3.3.b.8 Cockpit Procedures

The responses to questions in Section G were most relevant to issues associated with instrument approaches. These questions elicited information on company policies related to human factors that have been associated with approach-and-landing accidents.

Question G-1 addressed the philosophy of checklist design and use. Lists can be used to trigger flight crew actions or to verify the completion of an action. The former is sometimes referred to as a “do-list” and the latter a “checklist.” Almost half the respondents indicated that their companies employed a format that mixed the two philosophies. Most of the remaining companies emphasized the “read and verify” (i.e., checklist) philosophy.

Questions G-2 through G-4 examined an issue raised by previous accidents. The questions centered around the assignment of pilot-flying (PF) duties during various phases of an instrument approach, as well as the role and duties of the pilot-not-flying (PNF). Responses and comments elicited by question G-2 clearly indicated that trading PF duties between the captain and the first officer, usually on an equal basis, was a universal practice. Respondents also indicated that, for less-than-ideal weather, many operators mandated that the captain assume PF duties. This was most often true during Category II/III approaches and when landing crosswind components were unusually high. Only two of the 63 responding companies considered it important for the captain to fly all nonprecision approaches.

Previous studies on approach-and-landing accidents involving CFIT have highlighted the advantages of having the PNF not only monitor the flying pilot, but assist in keeping the PF aware of altitude as the aircraft descends. Although some cockpits have automated devices that perform the same function, 92 percent of respondents required the PNF to make verbal altitude callouts during the approach. Approximately 78 percent balanced that requirement by mandating that the PF verbally respond to the PNF's altitude callout.

Questions G-5 through G-10, as well as G-12, were designed to determine the extent to which operators mandated flight crew procedures that would result in a stabilized approach. Planning and preparation have been long identified as a key to achieving this. Flight crews who experience task overload during or just before the approach are less likely to establish a stabilized configuration. Responses to question G-5 confirmed that almost all airlines required their flight crews to orally brief themselves prior to flying a particular approach. Question G-6 responses showed that 81 percent of respondents direct that this briefing occur before the top of descent point.

Questions G-8 through G-10, and G-12, addressed aircraft configuration, the next important link in the chain that leads to a stabilized approach. These questions were designed to identify whether operators regarded configuration procedures during nonprecision approaches in a different way than during precision approaches. There was somewhat greater consistency with nonprecision approaches than with precision approaches. Seventy percent of those responding required landing configuration to be established no later than the FAF during a nonprecision approach. Achieving landing configuration by the FAF/outer marker (OM) during precision approaches was required by only 52 percent of the respondents (as indicated in responses to question 10).

Question G-11 assessed whether operators acknowledged the potential problems associated with a large aircraft in level flight at low altitude. Leveling off at the MDA and continuing to the airport or missed approach point is, by definition, an unstabilized approach; however, fully two-thirds of the respondents indicated that this was acceptable. Two operators indicated that their policies on this issue followed those of the aircraft manufacturers, and differed depending on the aircraft type.

Questions G-7, G-14 and G-15 concerned using visual vs. instrument reference when flying approaches in visual meteorological conditions. In responses to question G-7, 83 percent of the respondents said that they required flight crews to monitor cockpit instruments during visual approaches. In responses to question G-14, 94 percent of operators stated that using approach navigation aids, even during visual approaches, was either required or recommended. Question G-15 responses showed that only nine of the 63 respondents allowed flights to operate under visual flight rules and all but one of those nine operators is considered to be small (less than 50 aircraft). Table 3.23 characterizes the nine operators by location.

Table 3.23
Location of Operators Allowing Some VFR Flight, Study Data Base

ICAO Region	Number of Operators
Africa	1
Asia-Pacific	1
Eastern Europe	0
Europe	2
Latin America	0
Middle East	0
North America	5
Total	**9**

ICAO = International Civil Aviation Organization
VFR = Visual Flight Rules

Source: John H. Enders, Robert Dodd et al.

3.3.b.9 Flight Crew Support

Responses to questions H-1 and H-2 indicated that roughly 90 percent of the surveyed operators employed dispatchers or flight followers to assist their flight crews. Providing these resources is presumed to decrease flight crew workloads by having support staff perform most flight planning tasks. Most often, companies indicated that they provided their own dispatch services (depending on location). Some companies used services provided by airports, or contracted with other airlines for such services (again, depending on location).

3.3.c Cross-tabulations

The often uniform responses to the questions did not provide a sufficient basis for bivariate analysis**.** The one or two interesting patterns that emerged when data were cross-tabbed by ICAO region and airline size (based on number of aircraft operated) have been addressed in the commentary on univariate tallies, paragraph 3.2.b.

4.0 Discussion

4.1 Accident Analysis, Airport Factors

This study evaluated 132 accidents that occurred during the landing approach to major airports worldwide for 1984 to 1993. Most aircraft in these accidents were operated by commercial air carriers or charter operators. Each accident resulted in the hull loss of the aircraft; a total of 2,555 passengers and crew were killed.

4.1.a Nonprecision Risk

The primary question that this study tried to answer was, “Is there a significant difference in accident risk for aircraft flying nonprecision approaches compared to precision approaches?” The study found evidence for a fivefold increase in accident risk among commercial aircraft flying nonprecision approaches compared to those flying precision approaches (Table 3.14, page 226). This association was both statistically significant and robust. When stratified by ICAO region, the relationship between nonprecision approach and increased accident risk remained valid, although the values were somewhat different, ranging from a threefold increase in risk to almost an eightfold increase of risk, depending on the region. All these values proved to be statistically significant (Table 3.15, page 226).

That nonprecision approaches appeared to be more dangerous than precision approaches has been discussed elsewhere (e.g., ref. 20), but the increase in risk has not been quantified. The nonprecision approach does not provide the vertical guidance that ends at the runway like the precision approach. As a result, the flight crew must more actively navigate the aircraft vertically during the approach. The chance for error by the crew is probably greater during a nonprecision approach compared to a precision approach, resulting from the increased workload and additional need to maintain situational awareness.

An effort was made to assess the influence of factors other than type of approach on accident risk. This evaluation, however, was hampered by both the limited size of the accident sample and the paucity of data for some important factors that past experience, and the literature, show are significant in accident causation. Most of the data problems centered on aircraft and flight crew variables, because these data were not always available in the summaries used for accident coding. Data on specific airport-related variables, however, were available from sources other than the accident report.

4.1.b Terminal Approach Radar

When TAR was evaluated, it was found that lack of TAR increased accident risk among this population threefold compared to approaches conducted with TAR (Table 3.14, page 226). When the analysis was stratified by ICAO region, the results were not consistent across the regions, primarily because of missing data and small numbers (Table 3.16, page 227). Regions with a high correlation between the presence of ILS and the presence of TAR (namely Europe, Asia-Pacific and North America) show a higher RR for no TAR than regions with a low correlation between the presence of these two factors, indicating a certain correlation between the RRs for no precision approach and for no TAR. It is, however, interesting to note the difference in frequency of TAR use in approaches among the regions. In North America, the ratio of TAR to non-TAR approaches was 44 to 1, while in Africa and Latin America the ratio is 1 to 1. This does not necessarily represent an increased risk, but does provide some insight into the differences in radar services throughout the world.

The apparent protective effect of TAR may be due to the fact that controllers may warn the flight crew if they get too low or stray off the approach course. It may also relate to a higher level of airport services, because small airports, or airports with few movements, may be unable to justify the presence of TAR.

4.1.c High Terrain

High terrain around an airport did not appear to have a significant influence on accident risk compared to airports without high terrain (Table 3.14, page 226). When considered regionally, however, high terrain in Asia-Pacific showed a threefold increase of risk compared to non-high-terrain airports in the same region (Table 3.17, page 227). While this finding is statistically significant, it is not particularly robust.

The finding that high terrain is not a risk factor for aircraft approaching airports does not mean it is not an important consideration. It just means that no association between high terrain and increased risk of an accident was shown, based on the data available for this study.

4.1.d Standard Terminal Arrival Routes

The absence of standard terminal arrival routes (STARs) showed a 1.5 increase in accident risk compared to airports that had STARs (Table 3.18, page 228). When the influence of the absence of STARs was evaluated for each region, it was discovered that this association only existed for Africa and North America. None of the other regions demonstrated statistically significant associations (Table 3.18, page 228).

4.1.e Visual Approach Guidance

Evaluation of the influence of visual approach guidance to runways (VASI and PAPI) showed no increase in risk for runways without visual approach guidance (VAG) (Table 3.14, page 226). This was consistent when evaluated by ICAO region (Table 3.19, page 228). These results do not mean that VAG is not needed. They just mean that in this study, no association was demonstrated, perhaps because most of these accident aircraft were conducting instrument approaches. The main value of VAG may be for aircraft that are conducting visual approaches. The nonassociation may also be due to the fact that the accidents studied all were quite severe, with hull loss one of the inclusion criteria. VAG-related accidents may be less severe and were therefore not captured in the study sample.

4.2 Accident Analysis, Nonairport Factors

Many equipment factors, operating practices, etc. that strongly influence the overall operational risk are outside the direct control of the airport and its authority. These include factors related to the aircraft operator, of course, as well as

ATC, weather, controller and flight crew human factors, and type/condition of the aircraft, to name but a few. The extent of this study was insufficient to gather the substantial amount of data needed to provide detailed commentary on nonairport factors; however, some conclusions can be drawn from the data that were collected.

4.2.a Aircraft Type

The study was limited to commercially operated aircraft on the assumption that these aircraft were being operated by professional flight crews in revenue or business service. The distribution of broad operational types shows that 101 of the 132 accidents (approximately 75 percent) involved air carrier and commuter aircraft, with the balance comprising business jets and turbine-powered aircraft. Activity data for the different categories of aircraft were not available, so rates could not be calculated.

4.2.b Environmental Factors

It is interesting that 55 of the 84 accidents where light conditions were known (65 percent) occurred at night or twilight (Table 3.6, page 223). When weather was considered, it was found that 47 accidents involved IMC of the 72 accidents (65 percent) where weather was known to investigators. Further, 30 of 72 involved fog (42 percent), and 31 of 72 (43 percent) involved rain (Table 3.9, page 224). Severe weather such as ice, thunderstorms, wind shear and strong winds did not appear as factors in most of these accidents.

These findings are not surprising, since most of the accidents involved some aspect of IMC or darkness because most appeared to involve either precision or nonprecision approaches. These are relatively routine conditions for commercial aviation flights.

4.2.c Accident Categories

Evaluation of accident categories shows that 54 of the 132 accidents (41 percent) involved CFIT. Sixteen involved landing overruns or runway excursions. Ten involved unstabilized approaches and 12 involved loss of control of the airplane. Severe weather involving wind shear or airframe ice was identified in only four accidents. Engine problems, system problems or structural problems were involved in 14 accidents. Landing gear problems and failure to extending the landing gear were associated with eight accidents.

5.0 Conclusions and Recommendations

5.1 Conclusions

The following conclusions can be drawn from the accident sample and other data studied as described in this report:

1. The Latin America and Africa ICAO regions demonstrated the highest approach-and-landing accident rates, followed by Eastern Europe. Western Europe and North America had the lowest rates, the rate for North America being seven times lower than that in Latin America.

2. On a worldwide basis, there appears to have been a five-fold increase in accident risk among commercial aircraft flying nonprecision approaches compared with those flying precision approaches.

3. When stratified by ICAO region, the risk increase associated with flying nonprecision approaches compared with those flying precision approaches ranged from three-fold to almost eight-fold, depending on the region.

4. The lack of TAR increased risk among the study population three-fold compared to approaches with TAR. To some extent, this three-fold increase in risk can be attributed to the risk associated with nonprecision approaches, because in certain regions there appears to be a correlation between lack of TAR and lack of precision approach aids.

5. Worldwide, presence of high terrain around an airport did not appear to significantly influence accident risk compared to airports without high terrain; however, this does not mean that high terrain is not an important consideration for aircraft approaching high-terrain airports.

6. Absence of charted procedures for initial arrival to an airport in North America and Africa showed a 1.5 increase in risk of an accident, compared to airports that had STARs.

7. Though visual approach guidance is deemed an important landing aid, no association was demonstrated between the presence or absence of VAG and accident risk for the accident sample considered.

8. Many factors that influence overall approach-and-landing risk are outside the direct control of the airport or authorities.

9. Sixty-five percent of the 84 accidents where light condition was known occurred at night or twilight.

10. Sixty-five percent of the 72 accidents where weather was known involved IMC.

11. Forty-two percent of the 72 accidents where weather was known involved fog.

12. Forty-three percent of the 72 accidents where weather was known involved rain.

13. Severe weather (ice, thunderstorms, wind shear and strong winds) appeared as factors in only two of the accidents studied.

14. Forty-five percent of the accidents studied involved CFIT.

15. Sixteen percent of the accidents studied involved some type of mechanical failure that the crew was unable to successfully manage.

16. Fifty-five percent of the respondents to the operator questionnaire indicated that their approach charts do not provide a stabilized descent profile for nonprecision approaches (to avoid stepdowns).

More detailed analyses of the type carried out in this study could yield additional insight into factors that influence risk of accidents, not only in approach and landing, but also in other phases of flight, and could be influential in further reducing risk of aircraft accidents.

5.2 Recommendations

1. **The comparative risks of flying precision approaches vs. nonprecision approaches should be conveyed to all operators and airport authorities.** Although many other factors influence approach-and-landing risk, precision approaches provide an extra margin of safety, and providing suitable guidance equipment for accomplishing precision approaches should be a high priority. Nevertheless, the best precision guidance equipment will not achieve its full value unless the operators using it are well trained and disciplined in installing and properly using the equipment.

2. **New technologies for providing approach-and-landing guidance (e.g., GPS) should be reviewed periodically by authorities and air carriers to equip airfields with precision guidance capability where present ground-based equipment is too costly or ineffective, because of siting and/or terrain problems.** Both near- and far-term technologies (e.g., GPS) promise solutions to cost and siting problems associated with present-generation ground-based equipment, especially in regions of the world where economics and terrain have frustrated procurement and proper placement of the equipment.

3. **Authorities and airlines should voice strong encouragement to CFIT avoidance, given the high proportion of approach-and-landing accidents involving CFIT.** Existing programs addressing the CFIT hazard should be strongly supported. Authorities should take note of the recommendations of the FSF CFIT Task Force to minimize risk and encourage all operators flying in their airspace to familiarize themselves with these recommendations.

4. **Reducing the approach-and-landing risk variances among ICAO regions should be given international support.** Government and private organization managements should be made aware of risk factors and should be encouraged to address them within their own areas of responsibility.

5. **The international sharing of accident and incident data should be encouraged, to facilitate addressing safety problems quickly and effectively.** Missing data result from several factors, including states' noncompliance with ICAO accident information-sharing requirements, and incomplete accident records. Missing data frustrate the many efforts under way around the world to identify underlying causes of accidents.♦

[Editorial Note: This study was adapted and abridged from a more extensive report prepared under FSF contract to the Netherlands Directorate-General of Civil Aviation (RLD).]

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Appendix A
Accident Sample Listing

Date	ICAO ID	Airport Name	Airport Country	Aircraft
03/13/1984	SKBQ	Ernesto Cortissoz	Colombia	C-46
04/26/1984	EDDW	Bremen	Germany	B-727
06/16/1984	OYSN	Sanaa International	Yemen	IL-18
08/05/1984	VGZR	Zia Ul Hak International	Bangladesh	F-27
09/18/1984	LOWW	Schwechat	Austria	Metro
10/17/1984	ESSA	Arlanda	Sweden	Metro
10/22/1984	SLLP	Kennedy International	Bolivia	CV-440
11/10/1984	TIST	King	Virgin Islands (United States)	Lear 24
12/20/1984	HTDA	Dar es Salaam International	Tanzania	DHC-6
12/30/1984	WRRR	Bali International	Indonesia	DC-9
01/01/1985	SLLP	Kennedy International	Bolivia	B-727
01/09/1985	KMKC	Kansas City Downtown	United States	L-188
02/07/1985	LFPB	Le Bourget	France	CL-600
02/19/1985	LEBB	Bilbao	Spain	B-727
04/11/1985	SASA	Salta	Argentina	HS-125
04/15/1985	VTSP	Phuket International	Thailand	B-737
08/02/1985	KDFW	Dallas–Fort Worth International	United States	L-1011
12/02/1985	SBGL	Rio de Janeiro Galeao International	Brazil	B-747
01/27/1986	SAEZ	Ezeiza International	Argentina	B-707
01/31/1986	EGNX	East Midlands	United Kingdom	SD-360
02/07/1986	OEJN	King Abdul Aziz International	Saudi Arabia	B-737
02/21/1986	KERI	Erie International	United States	DC-9
03/20/1986	WAMM	Sam Ratulangi	Indonesia	CASA-212
06/10/1986	HECA	Cairo International	Egypt	F-27
08/31/1986	KLAX	Los Angeles International	United States	DC-9
09/14/1986	EHAM	Schiphol	Netherlands	Trislander
10/03/1986	WAMM	Sam Ratulangi	Indonesia	Skyvan
10/19/1986	FQMA	Maputo International	Mozambique	TU-134
10/25/1986	KCLT	Charlotte/Douglas International	United States	B-737
12/15/1986	GMMN	Mohamed V	Morocco	HS-125
01/03/1987	DIAP	Port Bouet	Ivory Coast	B-707
01/15/1987	KSLC	Salt Lake City International	United States	Metro
03/04/1987	KDTW	Wayne County Metropolitan	United States	CASA-212
03/31/1987	KOAC	Kansas City Downtown	United States	PA-32
04/13/1987	KMCI	Kansas City International	United States	B-707
05/08/1987	SLLP	Kennedy International	Bolivia	DC-6
05/08/1987	TJMZ	Eugenio Mar de Hostos	Puerto Rico	CASA-212
05/19/1987	SLVR	Viru Viru International	Bolivia	DHC-6
07/31/1987	MGGT	La Aurora International	Guatemala	Lear 23
08/31/1987	VTSP	Phuket International	Thailand	B-737
09/30/1987	GCLA	La Palma	Canary Islands (Spain)	Falcon 20
10/09/1987	KMEM	Memphis International	United States	Beech 18
10/19/1987	EGNM	Leeds Bradford	United Kingdom	King Air
12/21/1987	LFBD	Merignac	France	EMB-120

Source: John H. Enders, Robert Dodd et al.

Appendix A
Accident Sample Listing *(continued)*

Date	ICAO ID	Airport Name	Airport Country	Aircraft
01/02/1988	LTBJ	Adnan Menderes	Turkey	B-737
01/18/1988	KHOU	William P. Hobby	United States	HS-125
01/19/1988	DRO	La Plata County	United States	Metro
02/08/1988	EDDV	Hanover	Germany	Metro
02/08/1988	FNLU	4th of February	Angola	B-707
03/04/1988	LFPO	Orly	France	F-27
04/01/1988	KMKC	Kansas City Downtown	United States	Beech 18
04/15/1988	KSEA	Seattle-Tacoma International	United States	DHC-8
05/26/1988	EDDV	Hanover	Germany	F-27
06/16/1988	WIII	Soekarno-Hatta International	Indonesia	Viscount
07/06/1988	SKBQ	Ernesto Cortissoz	Colombia	CL-44
07/21/1988	DNMM	Murtala Muhammed	Nigeria	B-707
08/02/1988	BIRK	Keflavik	Iceland	CASA-212
08/31/1988	VHHH	Hong Kong International	Hong Kong	Trident
09/09/1988	VTBD	Bangkok International	Thailand	TU-134
09/12/1988	EHEH	Welschap	Netherlands	MU-2B
10/17/1988	LIRF	Fiumicino	Italy	B-707
01/08/1989	EGNX	East Midlands	United Kingdom	B-737
01/30/1989	LPPT	Lisbon	Portugal	Lear 23
02/19/1989	WMKK	Kuala Lumpur International	Malaysia	B-747
02/24/1989	EFHK	Helsinki-Vantaa	Finland	Metro
02/25/1989	MHTG	Toncontin International	Honduras	DC-6
03/06/1989	LTBA	Ataturk	Turkey	Metro
03/21/1989	SBGR	Guarulhos International	Brazil	B-707
04/03/1989	SPQT	Colonel Fransisco Secada V	Peru	B-737
04/10/1989	LFLU	Chabeuil	France	F-27
06/07/1989	SMJP	Johan Adolf Pengel	Surinam	DC-8
07/11/1989	HAAB	Bole International	Ethiopia	B-707
07/19/1989	SUX	Sioux Gateway	United States	DC-10
07/21/1989	RPMM	Ninoy Aquino International	Philippines	BAC 1-11
07/27/1989	HLLT	Tripoli International	Lybia	DC-10
08/10/1989	SPQT	Colonel Fransisco Secada V	Peru	DC-8
08/13/1989	KHOU	William P. Hobby	United States	HS-125
09/07/1989	DNPO	Port Harcourt	Nigeria	BAC 1-11
10/21/1989	MHTG	Toncontin International	Honduras	B-727
12/26/1989	PSC	Tri-Cities	United States	JetStream
01/25/1990	KJFK	J.F. Kennedy International	United States	B-707
03/21/1990	MHTG	Toncontin International	Honduras	L-188
03/27/1990	OAKB	Kabul	Afghanistan	IL-76
05/04/1990	KILM	New Hanover International	United States	Nomad
05/11/1990	YBCS	Cairns International	Australia	Citation I
07/14/1990	HSSS	Khartoum	Sudan	B-707
08/13/1990	MMCZ	Cozumel International	Mexico	Jet Commander
08/24/1990	KBOS	Logan International	United States	PA-31T

Source: John H. Enders, Robert Dodd et al.

Appendix A
Accident Sample Listing *(continued)*

Date	ICAO ID	Airport Name	Airport Country	Aircraft
11/14/1990	LSZH	Zürich	Switzerland	DC-9
11/29/1990	KDSM	Des Moines International	United States	PA-31T
12/04/1990	HKNA	Jomo Kenyatta International	Kenya	B-707
01/11/1991	SBCF	Tancredo Neves	Brazil	Lear 25
02/01/1991	KLAX	Los Angeles International	United States	B-737
03/03/1991	KCOS	City of Colorado Springs	United States	B-737
03/15/1991	SBEG	Eduard Gomes International	Brazil	Lear 35
03/18/1991	SBBR	Brasilia International	Brazil	Lear 25
05/09/1991	WAMM	Sam Ratulangi	Indonesia	F-27
05/23/1991	ULLI	Pulkovo	Russia	TU-154
06/17/1991	SVCS	Oscar Machado Zuloaga International	Venezuela	G-II
07/11/1991	OEJN	King Abdul Aziz International	Saudi Arabia	DC-8
09/03/1991	SKSP	Gustavo Rojas Pinilla	Colombia	TC-690
09/04/1991	WBKK	Kota Kinabalu	Malaysia	G-II
09/14/1991	MMMX	Lic Benito Juarez International	Mexico	TU-154
09/16/1991	SKBQ	Ernesto Cortissoz	Colombia	Herald
12/17/1991	EPWA	Okecie	Poland	DC-9
01/20/1992	LFST	Entzheim Air Force Base	France	A-320
02/15/1992	DNKN	Mallam Aminu	Nigeria	DC-8
03/24/1992	LGAT	Athens	Greece	B-707
03/30/1992	LEGR	Granada	Spain	DC-9
06/07/1992	TJMZ	Eugenio Mar de Hostos	Puerto Rico	CASA-212
06/22/1992	SBCZ	Cruzeiro do Sul International	Brazil	B-737
07/27/1992	MMMX	Lic Benito Juarez International	Mexico	Viscount
07/31/1992	VNKT	Tribhuvan International	Nepal	A-310
09/28/1992	VNKT	Tribhuvan International	Nepal	A-300
10/04/1992	EHAM	Schiphol	Netherlands	B-747
11/07/1992	KPHX	Sky Harbor International	United States	Saberliner
11/15/1992	MDPP	Puerto Plata International	Dominican Republic	IL-18
11/25/1992	DNKN	Mallam Aminu	Nigeria	B-707
12/10/1992	SEQU	Mariscal Sucre International	Ecuador	Saber Jet
12/21/1992	LPFR	Faro	Portugal	DC-10
01/06/1993	LFPG	Charles de Gaulle	France	DHC-8
01/09/1993	VIDP	Indira Gandhi International	India	TU-154
01/15/1993	DIAP	Port Bouet	Ivory Coast	B-707
02/27/1993	SBGL	Rio de Janeiro Galeao International	Brazil	Lear 31
04/06/1993	KCPR	Natrona County International	United States	MU-2B
04/14/1993	KDFW	Dallas–Fort Worth International	United States	DC-10
07/18/1993	MNMG	Augusto Cesar Sandino	Nicaragua	B-737
08/07/1993	AGS	Bush	United States	King Air
09/14/1993	EPWA	Okecie	Poland	A-320
11/04/1993	VHHH	Hong Kong International	Hong Kong	B-747
12/12/1993	GOOY	Yoff	Senegal	DHC-6
01/09/1995	KMKC	Kansas City Downtown	United States	L-188

Source: John H. Enders, Robert Dodd et al.

Appendix B
Taxonomy

The following taxonomy is based primarily on one developed for a current NLR CFIT investigation, also under contract to Directorate-General of Civil Aviation, the Netherlands [Controlled Flight Into Terrain (CFIT): A Taxonomy of Causative Factors, NLR CR 94561 L]. Although a wide range of variables have been included in the taxonomy, many others have been omitted, because of the limited nature of the current investigation.

1. Flight Variables

Local time ____________________

____

Geographical location of the crash site ____________________

____

Aircraft type ____________________

Operator and country of origin ____________________

____

Type of Operation:

☐ scheduled/nonscheduled ☐ passenger/freight
☐ domestic/international flight
☐ repositioning

2. Flight Crew Variables

Pilot Flying:
☐ Captain ☐ F/O ☐ Other ____________

Experience	Captain	F/O	Other
Total Hours	_______	_______	_______
Hours on Type	_______	_______	_______

Crew compatibility:

improper pairing of crews ☐ yes ☐ no
Fatigue-related: ☐ yes ☐ no

Illusions:

visual (e.g., black hole approaches) ☐ yes ☐ no
physical (e.g., somatogravic illusion) ☐ yes ☐ no

Crew errors:

Communications issues
- pilot/pilot ☐ yes ☐ no
- pilot/controller ☐ yes ☐ no

Poor aircraft handling ☐ yes ☐ no

Poor systems operation ☐ yes ☐ no

Navigation error ☐ yes ☐ no

Navaid programmed ☐ correctly ☐ incorrectly

Procedural Errors

attempting visual flight in instrument conditions
☐ yes ☐ no

poor monitoring/challenging ☐ yes ☐ no

descended below minimums prior to acquiring visuals
☐ yes ☐ no

incorrect response to GCWS ☐ yes ☐ no

other ☐ yes ☐ no

3. Environmental Variables

Period of day ☐ day ☐ night

Weather data:
☐ ATIS/VOLMET available ☐ yes ☐ no
☐ fog/snow/rain/icing/windshear/...
☐ cloud base (below FAA minimums)
☐ visibility (< 600 meters [1,969 feet])

4. Airport and Approach Variables

High terrain around airport ☐ yes ☐ no

Lighting

runway lights ☐ yes ☐ no
approach lights ☐ yes ☐ no
VASI/PAPI equipped ☐ yes ☐ no

Navaids

☐ type used: ILS, VOR/DME, NDB, ...

Approach

☐ visual ☐ nonprecision ☐ precision

Procedure design:
stabilized approach ☐ yes ☐ no

5. ATC Variables

Airport and approach control capabilities

terminal approach radar ☐ yes ☐ no
MSAWS capability? ☐ yes ☐ no

Source: John H. Enders, Robert Dodd et al.

Clearance instructions

radar vectoring to final approach? ☐ yes ☐ no

vectoring error? ☐ yes ☐ no

Controller experience issues ☐ yes ☐ no

Controller fatigue issues ☐ yes ☐ no

6. Aircraft Variables

GPWS equipped? ☐ yes ☐ no

RNAV/FMS ☐ yes ☐ no

Radio altimeter ☐ yes ☐ no

Barometric altimeter

set incorrectly? ☐ yes ☐ no

read incorrectly? ☐ yes ☐ no

Structural failure ☐ yes ☐ no

Systems failures ☐ yes ☐ no

Powerplant problems ☐ yes ☐ no

7. Air Carrier Variables

Company management issues ☐ yes ☐ no

Crew training ☐ adequate ☐ inadequate

Maintenance issues ☐ yes ☐ no

8. Regulatory Issues

Operator surveillance—inadequate? ☐ yes ☐ no

Source: John H. Enders, Robert Dodd et al.

9. Accident Type Category

☐ CFIT
  ☐ landing short
  ☐ collision with high terrain
  ☐ collision with man-made obstacle (e.g., masts, power line)
  ☐ landing on water

☐ Landing overrun

☐ Runway excursion

☐ Landing gear problem (e.g., collapse)

☐ Wheels-up landing

☐ Unstabilized approach

☐ Loss of control — crew-caused

☐ Loss of control — airplane-caused

☐ Wind shear

☐ Wake vortex encounter

☐ Icing/snow

☐ Midair collision

☐ Engine problem/loss of power

☐ Aircraft structural problem

☐ Aircraft system malfunction

☐ Fuel exhaustion

☐ Other (specify) ____________________________

Appendix C
Operator Profile Survey Results

The following is a composite of questionnaire returns. *(Parenthetical values are percentages of all respondents.)*

A. Respondent Information

1. What is your position/title within the company?

flight operations manager 29 (46.2)   flight standards manager 1 (1.6)   safety manager 19 (30.2)
chief pilot 7 (11.1)   training manager 5 (7.9)   other/unknown 2 (3.2)

B. Operator Background Information

1. How old is your company? 34.5 year average (years).

2. What types of services does your company offer? (Check all that apply.)

21 (33.3) on-demand charter   43 (68.3) domestic   53 (84.1) passenger   55 (87.3) scheduled air carrier
56 (88.9) international   41 (65.1) freight   8 (12.7) supplemental air carrier
2 (3.2) other, please specify: ______________________

C. Flight Crew Training

1. What forms of *formal* training does your company provide? (Check all that apply.)

54 (85.7) cockpit resource management (CRM)
55 (87.3) line-oriented flight training (LOFT)
44 (69.8) human factors
59 (93.7) circling and visual approach procedures
58 (92.1) GPWS
48 (76.2) terrain awareness
51 (81.0) EFIS & autopilot mode awareness
50 (79.4) nonprecision approach procedures (e.g., NDB, VOR, localizer)
61 (96.8) aircraft performance
59 (93.7) wind shear avoidance/management
54 (85.7) other adverse weather training
45 (71.4) ICAO standard radio phraseology
43 (68.3) TCAS
49 (77.8) night flying operations
51 (81.0) CAT II/III approach procedures

2. Does your company provide training in English language?

29 (46.0) yes, for all flight crew   8 (12.7) yes, for some flight crew   9 (14.3) no
17 (27.0) not applicable — all pilots are native English speakers

3. Does your company have *mandatory* policies/procedures for responding to wind shear alerts, TCAS, and GPWS alerts? (Check all that apply.)

59 (93.7) yes, for GPWS   44 (69.8) yes, for TCAS   57 (90.5) yes, for wind shear
0 (0.0) not applicable — GPWS/TCAS not used   2 (3.2) no   0 (0.0) do not know

4. Does your company use *high-fidelity* (level C or D) simulators in its flight crew training program? (Check only one.)

44 (69.8) yes, for all aircraft types   16 (25.4) yes, for some aircraft types   3 (4.8) no   0 (0.0.) do not know

5. Does your company give route familiarization checks to flight crew members?

58 (92.1) yes   5 (7.9) no   0 (0.0) do not know

6. Does your company use airport familiarization aids (such as videotapes)?

48 (76.2) yes   13 (20.6) no   0 (0.0) do not know   [occasionally: 1 (1.6)]

Source: John H. Enders, Robert Dodd et al.

D. Fleet Composition

1. Please describe your entire company fleet by filling in the following table. (Circle the relevant entries—estimated fleet numbers are acceptable.) [Data are totaled from responses.]

Aircraft Type	Number	Percent of Total Aircraft
A-300	84	1.6
A-306	10	0.2
A-310	70	1.4
A-319	4	0.1
A-320	296	5.8
A-321	12	0.2
A-330	24	0.4
A-340	38	0.7
ATP	21	0.4
ATR-42	4	0.1
ATR-72	4	0.1
B-707	3	0.1
B-727	559	11.0
B-737	419	8.2
B-737 Adv	582	11.4
B-747	311	6.1
B-747 Adv	175	3.4
B-757/B-767	835	16.4
B-777	4	0.1
BAE J41	1	0.0
BAe-146	40	0.8
BE02	12	0.2
C-650	2	0.0
CL-65	10	0.2
Concorde	7	0.1
DC-10	147	2.9
DC-6	1	0.0
DC-8	63	1.2
DC-9	537	10.5
DHC-6	16	0.3
DHC-8	17	0.3
EMB-120	10	0.2
F-100	115	2.3
F-27	10	0.2
F-28	44	0.9
F-50	19	0.4
F-70	3	0.1
HS-748	2	0.0
J-31	6	0.1
L-10/L-15	56	1.1
L-1011	47	0.9
L-382	9	0.2
MD-11	56	1.1
MD-80	184	3.6
MD-87	24	0.5
MD-88	120	2.4
MD-90	5	0.1
RJ-85	6	0.1
RT-70	4	0.1
S-2000	10	0.2
SF-340	30	0.6
TU-134	10	0.2
TU-154	7	0.1
YAK-42	12	0.2
Unknown	15	0.3
Total	**5,102**	**100.0**

Source: John H. Enders, Robert Dodd et al.

Automation Feature	Number of Aircraft	Percent of Total Aircraft
EFIS	2949	57.8
TCAS	3892	76.3
FMS	2762	54.1
GPWS	5034	98.7
Autoland	3225	63.2
Weather Radar	4976	97.5
Wind Shear Detection	3517	68.9
Radar Altimeter	4948	97.0

Maximum Approach Capability	Number of Aircraft	Percent of Total Aircraft
Category I	543	10.6
Category II	1842	36.1
Category III	2449	48.0
Unknown	268	5.3
Total	5102	100.0

2. Indicate if there are *any* aircraft in your fleet with the following. (Check all that apply.)

19 (30.2) radio altitude automated callouts specifically for *nonprecision* approaches (not ILS approaches)
11 (17.5) preselected radio altitudes for automated callouts, *not* heard during normal *nonprecision* approaches
18 (28.6) drum-pointer altimeter (no counter)
5 (7.9) 3-pointer altimeter
19 (30.2) first generation GPWS

E. Flight Crew Scheduling and Qualification

1. Does your company have established flight and duty time limits for flight crew members?

63 (100.0) yes 0 (0.0) no 0 (0.0) do not know

2. Does your company have an established policy for flight crew currency with regard to instrument approaches and landings?

62 (98.4) yes 1 (1.6) no 0 (0.0) do not know

3. For crew pairing purposes, does your company set specific experience requirements for captains and first officers who fly together?

36 (57.1) yes 27 (42.9) no 0 (0.0) do not know

F. Operational Documents, Manuals and Published Procedures

1. Does your company have a flight operations manual that lists and describes company policies and procedures?

62(98.4) yes 0 (0.0) no 0 (0.0) do not know [no response: 1 (1.6)]

Source: John H. Enders, Robert Dodd et al.

2. If yes was checked in response to question 1, please check the topics listed below that are addressed in your flight operations manual:

61 (96.8) stabilized approach criteria
57 (90.5) terrain avoidance procedures
46 (73.0) sterile cockpit procedures
58 (92.1) expanded normal checklist
62 (98.4) standard crew coordination
61 (96.8) mandatory callouts during critical conditions (engine start, rejected takeoff, approach, etc.)
57 (90.5) predeparture briefings regarding terrain/obstacles
62 (98.4) policies on missed approaches/go-arounds
60 (95.2) crosswind/tailwind landing limitations
61 (96.8) recommended flight techniques

3. Which publisher(s) provide(s) your company with instrument approach charts? (Check all that apply.)

44 (69.8) Jeppesen 2 (3.2) U. S. National Oceanic Survey (NOS) 10 (15.9) AERAD
2 (3.2) ATLAS 9 (14.3) charts are internally produced
4 (6.3) other, please explain below *Other Airline:* 2 (3.2) *Government Agency:* 2 (3.2)

4. Do your approach charts depict terrain contours?

12 (19.0) yes — without color shading 45 (71.4) yes — with color shading 5 (7.9) no
0 (0.0) do not know [no response: 1 (1.6)]

5. Do your approach charts provide a stabilized (for example, three-degree) descent profile for *nonprecision* approaches (in order to avoid stepdowns)?

26 (41.2) yes 35 (55.6) no 0 (0.0) do not know [no response: 1 (1.6)]

6. Which flight crew members are provided with independent sets of approach charts? (Check all that apply.)

57 (90.5) captains 57 (90.5) first officers 13 (20.6) flight engineers

7. Does your company have a *written* policy that indicates there will be no negative interpretations made in assessing a flight crew's decision to initiate a missed approach or a go-around?

34 (54.0) yes 25 (39.7) no 1 (1.6) do not know [no response: 3 (4.8)]

G. Cockpit Procedures

1. Please describe your company's protocol for checklists (check only one):

8 (12.7) read and do 23 (36.5) read and verify 30 (47.6) mixture

2. Does your company policy specify that a particular crew member perform pilot-flying duties during approach and landing during normal revenue flights?

0 (0.0) captain is always pilot-flying
2 (3.2) captain is pilot-flying on nonprecision approaches
40 (63.5) captain is pilot-flying on CAT II/III approaches
20 (31.7) captain is pilot-flying when crosswind exceeds a certain limit
20 (31.7) other, please explain below
4 (6.3) no policy exists
0 (0.0) do not know
[no response: 2 (3.2)]

3. Does your company *require* that the pilot-not-flying (PNF) make altitude callouts during approach?

58 (92.0) yes 4 (6.3) no 0 (0.0) do not know [no response: 1 (1.6)]

Source: John H. Enders, Robert Dodd et al.

4. If yes was checked in response to question 3, is the pilot-flying *required* to respond to these callouts?

49 (77.8) yes 9 (14.3) no 0 (0.0) do not know [no response: 5 (7.9)]

5. Does your company require flight crew members to orally brief instrument arrival and approach procedures in the cockpit?

61 (96.8) yes 1 (1.6) no 0 (0.0) do not know [no response: 1 (1.6)]

6. If yes was checked in response to question 5, what is the policy regarding when this briefing should be accomplished? (Check only one.)

51 (81.0) *before* top of descent 1 (1.6) just prior to approach 5 (7.9) during descent
4 (6.3) other, please explain below [no response: 2 (3.2)]

7. Does your company have a formal policy that requires pilots to monitor navigation instruments during visual approaches? (Check only one.)

52 (82.5) yes 10 (14.3) no 0 (0.0) visual approaches are not authorized
0 (0.0) do not know [no response: 1 (1.6)]

8. Does your company have formal rules for determining when, on approach, flaps and landing gear are to be extended?

59 (93.7) yes 2 (3.2) no 0 (0.0) do not know
[Depends on type of approach: 1 (1.6)] [no response: 1 (1.6)]

9. If yes was checked in response to question 8, when is the airplane configured for landing during a *nonprecision* approach? (Check only one.)

44 (69.8) final approach fix 9 (14.3) 1000 feet AGL 3 (4.8) leaving MDA
4 (6.3) other, please explain below [no response: 3 (4.8)]

10. If yes was checked in response to question 8, by when must the airplane configured for landing during a *precision* approach? (Check only one)

15 (23.8) final approach fix 23 (36.5) 1000 feet AGL 0 (0.0) leaving MDA
18 (28.6) outer marker 4 (6.3) other, please explain below [no response: 3 (4.8)]

11. On a *nonprecision* approach, does your company authorize level flight at the MDA to the missed approach point? (Check only one.)

42 (66.7) yes 15 (23.8) no 3 (4.8) only in VMC 0 (0.0) do not know
[Yes, for Boeing airplanes/No, for Airbus airplanes: 2 (3.2)] [no response: 1 (1.6)]

12. Regardless of the type of approach, is there a minimum altitude at which the aircraft must always be fully configured, for either landing or possible go-around?

56 (88.9) yes 5 (7.9) no 0 (0.0) do not know [no response: 2 (3.2)]

13. Does your company prescribe a minimum altitude for the use of flight-level change mode (in aircraft which have such capability)?

24 (38.1) yes 19 (30.2) no 1 (1.6) do not know 17 (27.0) not applicable [no response: 2 (3.2)]

14. To what extent does your company require that all approaches (whether visual or instrument), including those made in VMC, be flown using approach navigation aids?

27 (42.9) required 32 (50.8) recommended 2 (3.2) neither [no response: 2 (3.2)]

Source: John H. Enders, Robert Dodd et al.

15. Does your company allow flights to be conducted under visual flight rules, or does it require that all flights be conducted under an IFR flight plan?

52 (82.5) allows *only* IFR flight   9 (14.3) allows some VFR flight
0 (0.0) allows *only* VFR flight   0 (0.0) do not know   [no response: 2 (3.2)]

H. Flight Crew Support

1. Does your company provide dispatch or flight following services for your flights? (Check only one)

58 (92.1) yes — all   0 (0.0) no   3 (4.8) yes — some
0 (0.0) do not know   [no response: 2 (3.2)]

2. Who routinely supplies flight crews with weather and NOTAM information? (Check all that apply)

56 (88.9) company dispatch/flight followers
7 (27.0) airport flight information office
1 (1.6) other company pilots
6 (9.5) other, please specify below [company dispatch: 3 (4.8) computer: 3 (4.8)]
0 (0.0) do not know

Source: John H. Enders, Robert Dodd et al.

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International Air Carrier Establishes Guidelines For Preventing CFIT Accidents

The Flight Safety Foundation Controlled-flight-into-terrain Task Force reported that the prevention of CFIT is linked to correct use of procedures and equipment. This airline shares one way it has responded to the task force's recommendations.

British Airways Flight Crew Information Bulletin No. 42
Controlled Flight into Terrain
October 1998

1. INTRODUCTION

1.1 Definition

1.1.1 A CFIT accident is defined as an event in which a serviceable aeroplane is inadvertently flown into the ground, water or an obstacle.

1.2 Characteristics of a GPWS Accident

1.2.1 A GPWS warning is often associated with flight crew confusion and disorientation whilst operating under a high workload. The majority of CFIT accidents impact the terrain at a point in line with the intended runway for landing and anywhere from one to several miles away from the airfield. Most CFIT accidents occur during Non-Precision approaches, specifically VOR and VOR/DME approaches. However, some CFIT accidents have occurred during routine operations whilst operating under a normal workload and during the departure or descent phase of flight.

2. OPERATIONAL LIMITATIONS

2.1.1 There are no new operational requirements, limitations or restrictions introduced in this FCIB. The information contained within this FCIB is designed to raise awareness of the known causal factors of CFIT accidents.

3. BACKGROUND

3.1 The history of CFIT

3.1.1 Since the beginning of commercial jet operations, more than 9000 people have lost their lives in aircraft accidents attributable to Controlled Flight into Terrain (CFIT). During the period 1991–1995 there were more accidents due to CFIT than any other cause. Although recent years have shown a decline in the number of CFIT accidents, the risk needs to be reviewed against the rate at which commercial aviation continues to grow. If the current rate of CFIT incidents is applied to the forecast growth of global commercial aviation, CFIT could cause one major hull loss per week by the year 2010. For this reason, there is industry wide resolution required — at all levels — to raise awareness of the factors which can affect an operator's exposure to the CFIT risk. It is imperative that airline operators develop, adopt and maintain a CFIT avoidance strategy in order to contain the increasing risk of a CFIT accident.

3.1.2 The following graph depicts the CFIT Hull-Loss accidents for world-wide commercial jet fleet operators over 27 years [Figure 1].

3.1.3 The Flight Safety Foundation and ICAO have concluded some detailed research on CFIT and have launched an international CFIT task force which was dedicated to reducing CFIT accidents. An explanation of the role and the members of the CFIT task force can be found at Appendix A [page 256].

3.1.4 The International Civil Aviation Organisation (ICAO) are actively supporting the process of education which aims to make all personnel involved in the airline industry aware of the CFIT risk. The CFIT Task Force has analysed previous accidents and incidents and have identified factors which affect the exposure of an airline to the risk of a CFIT accident.

3.1.5 In response to the recommendations made by the CFIT Task Force, the aim of this FCIB is to explain the policies and procedures BA Flight Operations have implemented to manage and minimise the CFIT or CFTT (Controlled Flight towards Terrain) risk.

4. REDUCING THE CFIT RISK

4.1 The Decision Makers

4.1.1 Decision makers are those people who make and influence policy matters. The underlying goal of all aviation industry decision makers should be system safety; the public expects it and assumes it. The reality is that humans make errors and always will, therefore, there will always be some level of risk associated with the aviation industry. The goal of Decision Makers must be the effective management of this risk. Each successive level of authority has the capacity to implement the recommendations borne out of the work of the CFIT task force. The recommendations that have been made involve both cultural changes and the implementation of certain policies within the flight operations department.

4.1.2 Reducing CFIT accidents requires recognition that such accidents are system induced, that is, they are generated by shortcomings in the aviation system, including deficiencies in the organisations which constitute that system, for example:

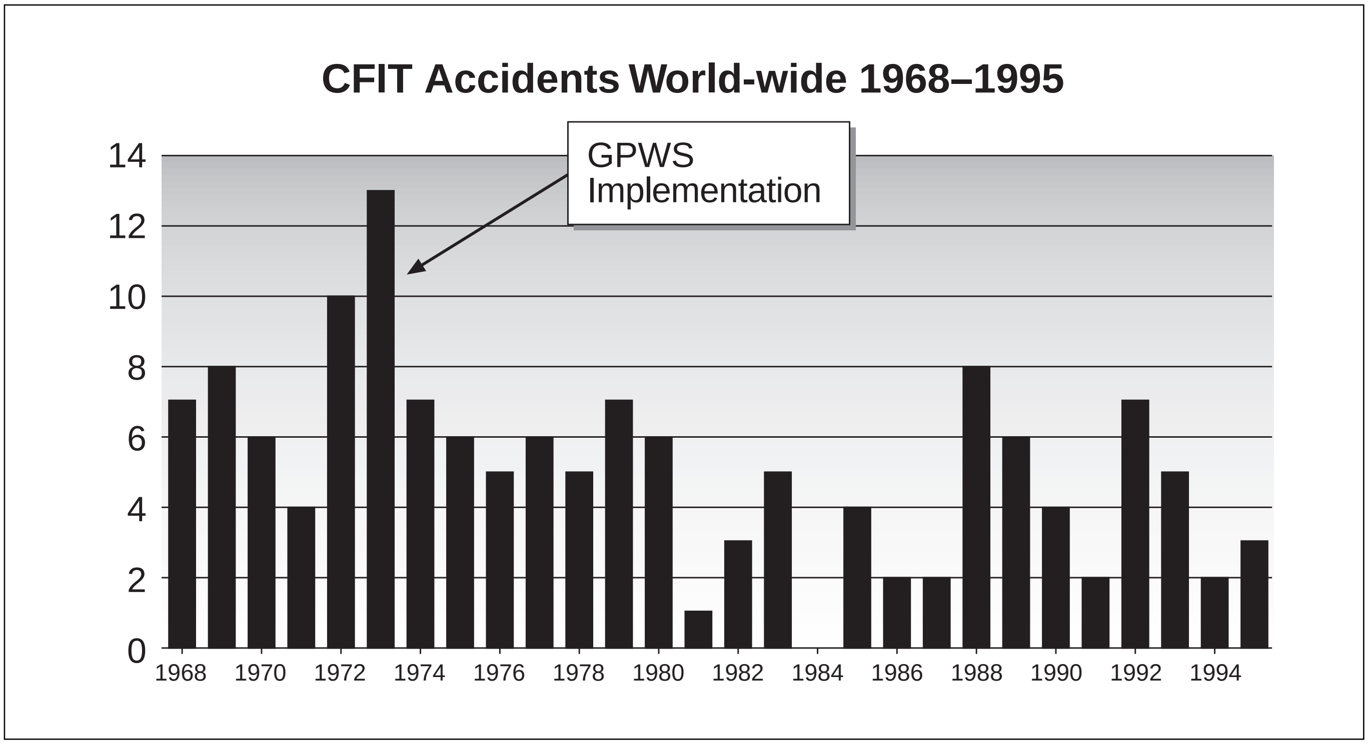

Figure 1

National Aviation Authorities	ICAO
Airline Management	Technical Management
Flight Crew	ATC Management

5. FACTORS WHICH AFFECT THE CFIT RISK

5.1.1 The following sections summarise the risks and recommendations identified by the CFIT task force teams and BA's response to the recommendations.

5.2 Monitored approach philosophy

5.2.1 The majority of CFIT incidents/accidents have occurred in IMC or at night when the pilot flying the approach also lands the aircraft. If the approach is flown in IMC, the CFIT risk is reduced if the First Officer flies the approach and missed approach whilst the Captain monitors approach progress and subsequently lands the aircraft after obtaining sufficient visual reference.

British Airways Policies and Procedures:

BA SOPs require all approaches other than autoland to be flown as monitored approaches. Autoland procedures incorporate a nominal resumption of control at 1000'RA, by the Captain and are optimised for Category 3B and No DH operations. In suitable weather conditions, BA encourages full role reversal allowing the First Officer to attain experience of monitoring the approach and completing the landing.

5.3 The use of Autopilot/Flight Director

5.3.1 Automatic systems reduce pilot workload and their use whilst flying an approach or missed approach in IMC is essential to ensure the flight crew can effectively monitor the progress of a flight. Autopilot/Flight Director and autothrottle modes and sub-modes must be thoroughly understood by crews and procedures developed and practiced in the simulator to ensure the effective use of the automatic systems during all types of approaches.

British Airways Policies and Procedures:

BA operating policy recommends that whenever possible, the use of the Autopilot/Flight Director facilities should be used throughout the flight. Manual flying is encouraged only in good weather conditions with all systems operating.

5.4 Rate of Descent in relation to MSA

5.4.1 High rates of descent when in close proximity to terrain are dangerous and can reduce the warning time afforded by modern GPWS.

British Airways Policies and Procedures:

BA operating policy restricts the rate of descent to 3000 fpm when descending below 3000' above the relevant MSA or SSA.

5.5 Acceptance of ATC clearances

5.5.1 ATC occasionally issue flawed instructions. Flight crews should not assume that ATC instructions will ensure terrain clearance. If ATC issue an instruction which conflicts with the flight crew's assessment of terrain clearance to the known position of the aircraft, the ATC instruction should be questioned and any confusion resolved before the aircraft accepts the instruction.

British Airways Policies and Procedures:

BA operating policy reminds pilots that ATC instructions do not guarantee terrain or obstacle clearance nor constitute authority to descend below the relevant MSA or SSA.

5.6 Route Briefing

5.6.1 Flight crews should be provided with adequate means to become familiar with enroute and destination conditions for routes deemed CFIT critical.

British Airways Policies and Procedures:

BA has route briefing procedures which provide audio visual briefings on restricted aerodromes, visits under training or as an observer and, if necessary, conducts simulator training for all flight crew into any *significantly difficult aerodrome. Enroute training is verified by the attainment and renewal of an 'Area Qualification' and a Route Information Manual is carried on board all aircraft to permit flight crew reference during flight.*

5.7 Use of checklists

5.7.1 The implementation of clearly defined policies for the use of checklists and the completion of checklists at an early stage in the approach phase, minimise the risk of distraction when manoeuvring close to the ground.

British Airways Policies and Procedures:

BA has developed and implemented SOPs for the execution and completion of checklists. Policy statements are provided which explain the checklist philosophy as applied to all BA fleets.

5.8 Stabilised Approaches

5.8.1 Unstable approaches have contributed to many accidents and incidents. The aim should be to fly a continuous descent along an approximate 3° approach beginning not later than the final approach fix or equivalent position. Ideally, the final 3° segment should start at 2000' to 3000' above the airport elevation equating to an eight to ten nautical mile approach.

5.8.2 All approaches should have a defined 'gate' by which the aircraft is to be configured for landing and stabilised in airspeed, power setting, trim, rate of descent and on the defined descent profile.

British Airways Policies and Procedures:

BA has implemented a policy to fly all approaches as continuous descent where that technique is possible. BA procedures state a stabilized 'gate' technique and it is mandatory to reject any approach which exceeds the 'gate' parameters at 500'.

5.9 Crew Resource Management

5.9.1 The normal way of operating should include effective CRM. All recent studies have demonstrated enhanced safety as the benefit of this concept.

British Airways Policies and Procedures:

BA has developed and implemented a CRM training programme for all flying crew and other relevant personnel.

5.10 Approach Procedure Design and Specifications

5.10. 1 Improvement of the non precision approach can be achieved at little extra cost and the aim should be a nominal 3° glidepath. Instrument approach charts should use colour contours to depict either terrain or minimum flight altitudes. All minimum safe altitudes should be displayed in a manner which is easy to recognise, understand, and read under cockpit lighting at night.

British Airways Policies and Procedures:

AERAD charts comply with the depiction criterion recommended including the use of colour contours to depict minimum flight altitudes on instrument charts and terrain on Visual approach charts. BA applies influence and contributes to the development of approach procedure design at an international level.

5.11 Barometric Altimetry

5.1 1.1 The loss of vertical situational awareness has been the cause of many CFIT accidents and the barometric altimeter is often a significant contributing factor to the breakdown of flight crew awareness of hazardous terrain. Using standardised altimeter reference systems and common altimeter setting units of measurement reduces this risk.

British Airways Policies and Procedures:

BA is bound to comply with the altimeter setting procedures of the airspace authorities in which it operates and as a global airline there is wide exposure to all the different standards employed world-wide. However, robust altimeter setting procedures exist to ensure the cross checking of altimeters whenever there is a requirement to change *altimeter settings or revert to local requirements of altitude measurement or reference.*

5.12 Radio Altimetry

5. 12.1 Radio altimetry enhances terrain awareness and the full capability of radio altitude information should be used. Automated voice callouts enhance approach monitoring and should be programmed at appropriate radio altitudes. Associated flight crew procedures should be implemented to ensure effective terrain awareness and cross monitoring.

British Airways Policies and Procedures:

BA uses the automated callout function on all aircraft fitted with the equipment and effective procedures are in place for flight crew callout of radio altitude for those aircraft not fitted with automated callout. BA procedures require the flight crew to verify terrain clearance on activation of the radio altimeter. A 1000' radio call is made on all approaches and on aircraft fitted with automatic callout, a 500' radio call is also made on Non-Precision approaches.

5.13 GPWS Equipment

5.13. 1 The installation of GPWS equipment on all aircraft in an airline's fleet can reduce CFIT accidents. Modern GPWS equipment is one of the major weapons in the growing arsenal of CFIT prevention methods.

British Airways Policies and Procedures:

All BA aircraft are fitted with GPWS. Furthermore, BA has installed the latest versions available in order to reduce the level of false and nuisance alerts.

The implementation of the latest equipment improves flight crew confidence and performance and BA is fitting all its aircraft with Enhanced GPWS. This equipment uses the navigation map display (or weather radar display on older generation aircraft) to depict terrain data in relation to the aircraft position. EGPWS is a major improvement to the CFIT arsenal of preventative measures and provides timely terrain information to enhance pilot situational awareness.

5.14 CFIT Training and Awareness

5.14.1 Specific CFIT awareness training, in both the academic and simulator areas, raises flight crew awareness of the risk of CFIT. Instruction about the factors and causes affecting an airline's risk exposure as well as discussion about how to avoid getting into potential CFIT situations is another part of the prevention strategy.

British Airways Policies and Procedures:

BA conducts CFIT training and the associated GPWS response on an initial and recurrent basis in the simulator and awareness of the CFIT threat will be addressed by this FCIB. A CFIT Awareness and Training module has been incorporated within the BA Command Development Programme for all newly appointed First Officers. Command Refresher Training is also being introduced for all Captains which will include CFIT awareness training as part of a module on Operational Integrity.

5.15 GPWS Warning Response

5. 15.1 When a GPWS warning occurs, pilots should immediately, and without hesitating to evaluate the warning, execute the pull-up action recommended in the company procedure manual. This procedure should be followed except in clear daylight VMC when the flight crew can unequivocally confirm a false GPWS warning. The essential emphasis in this statement is that the response to a GPWS warning must be a trigger reaction and not an evaluated response which may delay the escape manoeuvre and increase the likelihood of a CFIT accident.

British Airways Policies and Procedures:

In the event of a GPWS warning, BA's GPWS policy requires an immediate Pull Up Go-Around to be executed ***in all circumstances*** *if at or below MSA or if proximity to MSA is in doubt. If above MSA an immediate assessment must be made of the aircraft's position, altitude and vertical* *speed and if any doubt exists a Pull Up Go-Around must be flown.*

Time taken to evaluate GPWS warnings erodes the effectiveness of the response and as a result, BA policy further enhances the safety offered by this recommendation by making a pull up go around mandatory regardless of flight conditions when at or below MSA.

5.16 Monitoring system performance

5.16. 1 The enhancement of operational integrity and the process of continual improvement require the implementation of systems to monitor and evaluate the operational performance of management, flight crews and equipment. Flight data recording devices form part of the requirement but the creation of a "Non-punitive" reporting culture and the subsequent trend analysis of flight crew reports are other essential tools in this process.

5.16.2 The operation is further strengthened by the implementation of an independent auditing function and an associated Quality Assurance programme. JAR-OPs regulations now require all JAR operators to implement a Quality System which includes independent auditing and a process to ensure corrective action takes place. This requirement ensures a "closed loop" and a continuous improvement in the operation.

British Airways Policies and Procedures:

SESMA and BASIS are effective system monitors which are supported by the "Non-punitive" guidance detailed in British Airways Standing Instruction (BASI) No. 4 and FCOs.

An independent auditing function has been carried out for some years by the BA Flight Standards Unit which works with all our fleets as part of the required Quality System.

6. BRITISH AIRWAYS CFIT AVOIDANCE STRATEGY

6.1 The British Airways's CFIT GOAL

6.1.1 BA's goal is to prevent a CFIT accident by minimising our exposure to CFIT risks.

6.2 The current trend

6.2.1 The world-wide accident rate for the commercial jet fleet decreased significantly in the 1960s and 1970s. However, the rate of hull losses has stabilised at this level ever since and the proportion of accidents attributable to CFIT has increased. In 1995 there were more lives lost to CFIT than to any other type of accident. Furthermore, during the period 1991–1995, the *number* of accidents attributable to CFIT was higher than any other cause.

6.2.2 The following graph illustrates the latest available data which depicts the number of world-wide hull losses and categorises the reason [Figure 2, page 255].

6.3 Is British Airways at risk?

6.3. l Recent incidents illustrate the vulnerability of BA to a CFIT accident. Despite the development of robust and comprehensive procedures, during the 18 month period of January l997 to June l998, BA has experienced 3 significant CFIT incidents.

- In January 1997 a B747-236 flew a normal descent profile to a point six miles short of the runway — the FO gave an altitude countdown using the wrong chart. This error resulted in the aircraft being l500' below the correct profile. As a result of the RA auto callout at 500', the Captain realised the error and called for a go-around.
- In January 1998 a B747-400 experienced a genuine GPWS "Pull Up" warning whilst flying a SID. The FD had demanded a right turn towards high ground instead of the left turn required by the SID profile. The crew correctly ignored the right turn demanded by the FD and commenced a left turn in accordance with the SID. However, a hard GPWS warning was triggered and the crew executed a 'Pull Up Go-around.'
- In June l998 a B747-400 was in the circuit for landing when ATC issued a flawed instruction to turn left into an area of high terrain. The instruction was refused and the controller acknowledged his error.

6.3.2 These incidents highlight the reality of BA's current exposure to the CFIT accident risk. BA

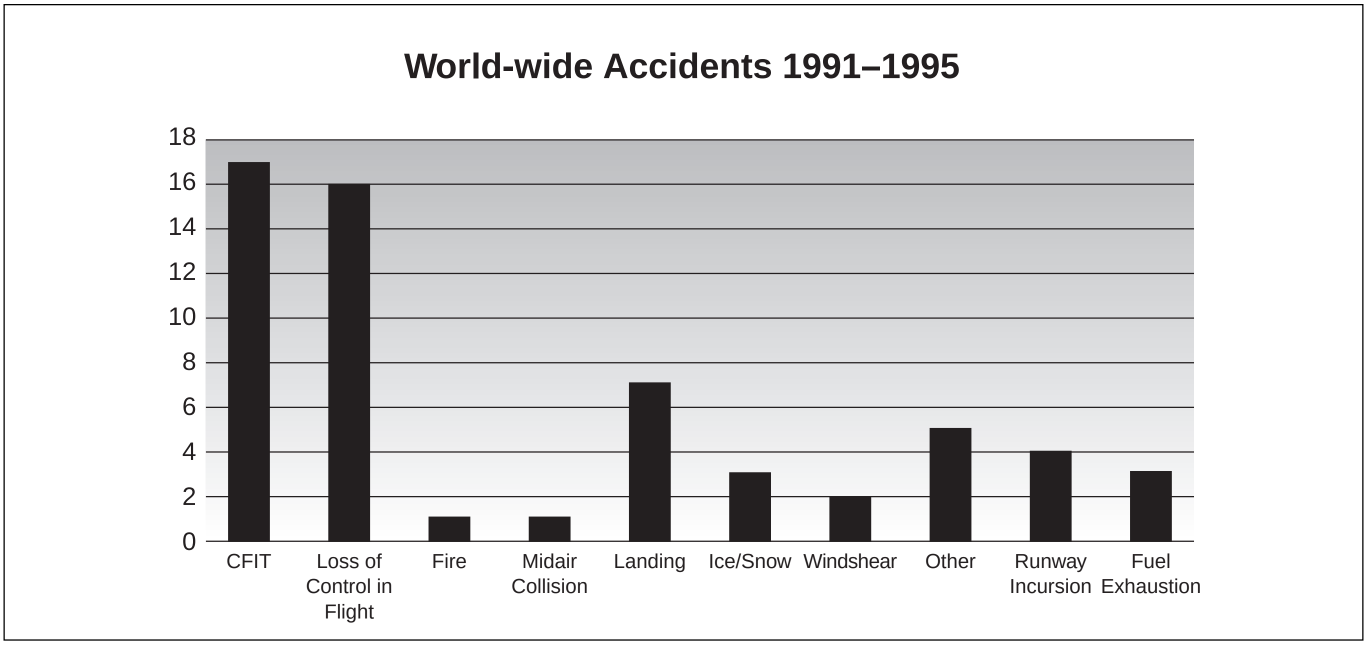

Figure 2

will continue to experience the known causal factors of CFIT accidents and it behooves all BA Flight crew to exercise constant vigilance to ensure that the final link in the safety chain remains intact.

6.4 Realising the Goal

6.4.1 Modern aircraft incorporating the latest safety technology significantly reduce the risk of a CFIT accident. It is BA policy to implement the latest safety technology and fit the most recent versions of equipment to its aircraft.

6.4.2 The industry accepted formula is that for every accident there are 360 incidents which if properly investigated and acted upon may have prevented the accident. Data acquisition and analysis, supported by a safety reporting system is a valuable tool which provides the key to achieving the goal. If correctly utilised, this strategy has profound effects in improving the management of air safety. With this in mind, BA CFIT exposure can be reduced by:

- Implementing policies borne out of the recommendations of the CFIT task force.
- Employing effective reporting and analysis systems which provide management with sufficient information so that an objective risk assessment can be made (e.g., SESMA, BASIS).
- Raising Flight Crew awareness of the CFIT hazard through training and the publication of this FCIB and associated training.
- Researching, developing and installing the best available terrain warning equipment.
- Evaluating the performance of policies, practices and equipment by conducting independent quality audits

6.5 Conclusion

6.5.1 If the current accident rate remains unchanged and traffic growth continues to increase, there is a real risk that public confidence in air transportation could be diminished, initially in individual companies and then in the industry as a whole. If this scenario is realised, the effect of the associated increase in human fatalities would have a devastating effect on BA’s business. Therefore, there is a responsibility at all levels to ensure that BA does not sustain any accident which could have been avoided through greater awareness of the very real risks to which the Airline is exposed in the daily conduct of its global operation.♦

[Editorial note: This document has been repritnted from the original without editorial changes.]

Appendix A

In 1993, the Flight Safety Foundation organised an international CFIT Task Force that was dedicated to reducing CFIT accidents. Five teams were formed to study the causes and factors of CFIT accidents and make recommendations to prevent these accidents. The Task Force comprised representatives respected for their expertise in aviation from sectors across the industry:

[Airbus Industrie, Air Line Pilots Association, Air Transport Association, Alaska Airlines, AlliedSignal Corporation, America West Airlines, American Airlines, The Boeing Co., Britannia Airways, British Airways, Civil Aviation Authority (U.K.), Delta Air Lines, U.S. Federal Aviation Administration, Flight Safety Foundation, FlightSafety International, Gulfstream Aerospace, Honeywell, International Air Transport Association, International Civil Aviation Organization, International Federation of Air Line Pilots' Associations, Japan Air Lines, Jeppesen Sanderson, Joint Aviation Authorities, Lockheed Martin, McDonnell Douglas, National Business Aviation Association, U.S. National Transportation Safety Board, Regional Aircraft Association, Scandinavian Airlines System, United Airlines, US Airways and Varig Airlines.]

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Fatal-accident Rates among Aircraft in Scheduled Services Increased, but Passenger-fatality Rate Decreased, in 1997

The International Civil Aviation Organization said that the 1997 passenger-fatality rate for turbojet aircraft was substantially lower than the passenger-fatality rates for propeller-driven aircraft.

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Preliminary data show that 26 fatal aircraft accidents, involving 916 passenger fatalities, occurred in 1997 during scheduled air-service operations in International Civil Aviation Organization (ICAO) member countries, according to ICAO.[1] That compared with 23 fatal accidents and 1,135 passenger fatalities in 1996 (Table 1, page 258).

ICAO said that there were 0.04 passenger fatalities per 100 million passenger kilometers flown in 1997. In 1996, there were 0.05 passenger fatalities per 100 million kilometers flown.

The fatal accident rate per 100 million kilometers flown and the fatal accident rate per 100,000 landings also increased (Figure 1 and Figure 2, page 259).

"The number of fatal aircraft accidents per 100 million aircraft kilometers flown increased to 0.12 in 1997 from 0.11 in 1996, and the number of fatal aircraft accidents per 100,000 landings also increased, to 0.14 in 1997 from the previous rate of 0.13 in 1996," said ICAO.

Fatality rates varied among turbojet, turboprop and piston-engine aircraft in scheduled services. ICAO said, "For instance, in turbojet aircraft operations, which account for about 95 percent of the total volume of scheduled traffic (i.e., in terms of passenger-kilometers [flown]), there were 11 accidents in 1997 with 752 passenger fatalities; in turboprop and piston-engine aircraft operations, which account for about 5 percent of the scheduled traffic volume, there were 15 accidents with 164 passenger fatalities.

"The fatality rate for turbojet aircraft operations was, therefore, far lower than for propeller-driven aircraft."

The report included preliminary statistics for nonscheduled operations. There were 31 fatal accidents and 305 passenger fatalities in 1997, compared with 25 fatal accidents and 479 passenger fatalities in 1996.

"In nonscheduled operations [conducted] with aircraft of more than 9,000 kilograms [19,841 pounds] takeoff mass, whether by scheduled airlines or nonscheduled operators, there were seven fatal accidents with 198 passenger fatalities in 1997," said ICAO.♦

Reference

1. International Civil Aviation Organization (ICAO). *Annual Report of the Council — 1997*. Montreal, Quebec, Canada: ICAO, 1998. Document no. 9700.

Correction

Sources for Figure 1 and Figure 2, page 20, in *Flight Safety Digest* Volume 17 (October 1998) were Airclaims World Airline Accident Summary and U.K. Civil Aviation Authority. The title for Figure 5, page 22 is *U.K. Airplane Accidents — Public Transport Operations, Maximum Takeoff Weights More than 2,300 Kilograms.*

Table 1

Aircraft Accidents Involving Passenger Fatalities in Scheduled Air Services, 1978–1997

			Passenger Fatalities per 100 million		Fatal Accidents per 100 million		Fatal Accidents per 100,000	
Year	Aircraft Accidents	Passengers Killed	Passenger-Kilometers	Passenger-Miles	Kilometers Flown	Miles Flown	Aircraft Hours	Aircraft Landings
Excluding the USSR up to 1992 and the Commonwealth of Independent States thereafter								
1978	25	754	0.09	0.15	0.29	0.47	0.18	0.24
1979	31	877	0.10	0.16	0.34	0.55	0.21	0.29
1980	22	814	0.09	0.14	0.24	0.38	0.15	0.21
1981	21	362	0.04	0.06	0.23	0.37	0.14	0.20
1982	26	764	0.08	0.13	0.28	0.46	0.18	0.25
1983	20[1]	809	0.08	0.13	0.21	0.34	0.13	0.18
1984	16	223	0.02	0.03	0.16	0.26	0.10	0.14
1985	22	1,066	0.09	0.15	0.21	0.34	0.13	0.19
1986	17	331	0.03	0.04	0.15	0.24	0.09	0.14
1987	24	890	0.06	0.10	0.20	0.32	0.12	0.18
1988	25	699	0.05	0.08	0.19	0.31	0.12	0.18
1989	27	817	0.05	0.08	0.20	0.32	0.12	0.19
1990	22	440	0.03	0.04	0.15	0.25	0.09	0.15
1991	25[2]	510	0.03	0.05	0.18	0.28	0.11	0.18
1992	25	990	0.06	0.09	0.16	0.26	0.10	0.17
1993	31	801	0.04	0.07	0.19	0.31	0.12	0.21
1994	24	732	0.04	0.06	0.14	0.22	0.09	0.15
1995	22	557	0.03	0.04	0.12	0.19	0.08	0.13
1996	22	1,132	0.05	0.08	0.11	0.18	0.07	0.12
1997	25	854	0.03	0.05	0.12	0.19	0.07	0.13
Including the USSR up to 1992 and the Commonwealth of Independent States thereafter								
1986	22	546	0.04	0.06	NA	NA	NA	NA
1987	26	901	0.06	0.09	NA	NA	NA	NA
1988	28	729	0.04	0.07	NA	NA	NA	NA
1989	27	817	0.05	0.07	NA	NA	NA	NA
1990	25	495	0.03	0.04	NA	NA	NA	NA
1991	30[2]	653	0.04	0.06	NA	NA	NA	NA
1992	29	1,097	0.06	0.09	NA	NA	NA	NA
1993	34	936	0.05	0.08	0.20	0.32	0.12	0.22
1994	28	941	0.04	0.07	0.15	0.25	0.10	0.16
1995	26	710	0.03	0.05	0.13	0.21	0.08	0.15
1996	23	1,135	0.05	0.08	0.11	0.18	0.07	0.13
1997	26	916	0.04	0.06	0.12	0.19	0.07	0.14

[1] Includes one collision on the ground shown here as one accident.

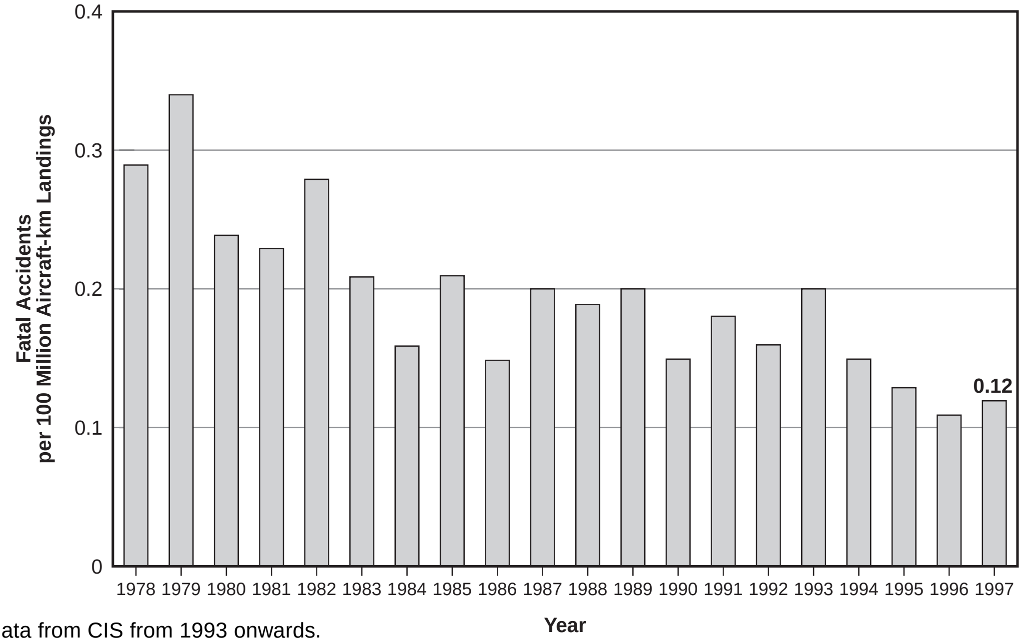
[2] Includes one collision on the ground shown here as two accidents.

NA = not available USSR = Union of Soviet Socialist Republics ICAO = International Civil Aviation Organization

Note: Data are from ICAO member countries.

Source: ICAO Air Transport Reporting Form G and other reports.

Number of Fatal Accidents per 100 Million Aircraft-kilometers Flown in Scheduled Services, 1978–1997

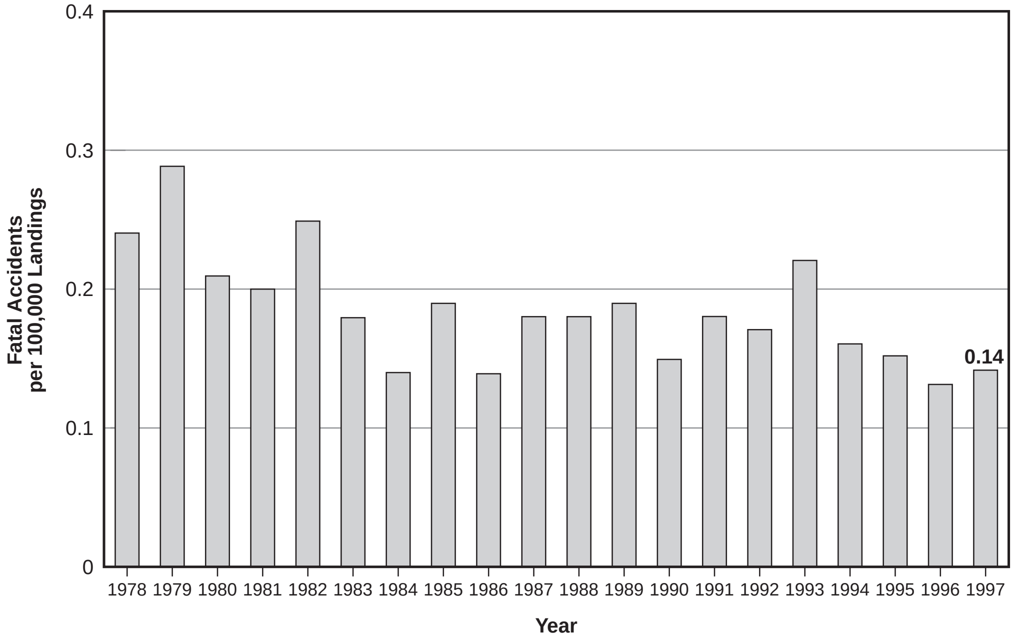


Note: Includes data from CIS from 1993 onwards.
CIS = Commonwealth of Independent States

Source: International Civil Aviation Organization

Figure 1

Number of Fatal Accidents per 100,000 Landings by Aircraft in Scheduled Services, 1978–1997



Note: Includes data from CIS from 1993 onwards. All figures are for ICAO contracting States.
CIS = Commonwealth of Independent States   ICAO = International Civil Aviation Organization

Source: International Civil Aviation Organization

Figure 2

Publications Received at FSF Jerry Lederer Aviation Safety Library

Standards for Engineered-materials Arresting Systems Aim to Provide Runway-overrun Safety Area

U.S. Federal Aviation Administration addresses planning, design and installation of safety measure.

FSF Library Staff

Advisory Circulars

Engineered Materials Arresting Systems (EMAS) for Aircraft Overruns. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) No. 150/5220-22. Aug. 21, 1998. 6 pp. Available through GPO.*

Aircraft occasionally overrun the ends of runways, sometimes with disastrous results. An overrun can occur during an aborted takeoff or while landing when an aircraft stops beyond the end of the runway. In most overruns by air-carrier aircraft, the airplane comes to rest within 1,000 feet (305 meters) of the runway's end and between the runway's extended edges. In an effort to minimize the hazards of overruns, FAA has incorporated into airport design standards the concept of a safety area beyond the end of the runway.

This AC outlines standards for the planning, design and installation of engineered-materials arresting systems (EMAS) in runway safety areas. Engineered materials are high-energy-absorbing materials that will be reliably and predictably crushed under the weight of an aircraft. [Adapted from AC.]

Announcement of Availability: List of Certificated Pilot Schools. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) No. 140-2AA. August 12, 1998. 2 pp. Available through GPO.*

This advisory circular announces the availability of and ordering instructions for AC 140-2AA, which contains a list (current as of April 15, 1998) of pilot schools certificated by FAA. [Adapted from AC.]

Announcement of Availability: FAA-S-8081-20, Airline Transport Pilot and Aircraft Type Rating Practical Test Standards for Helicopter. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) No. 61-129. Aug. 12, 1998. 3 pp. Available through GPO.*

FAA publishes the *Airline Transport Pilot and Aircraft Type Rating Practical Test Standards for Helicopter* to establish the standards for airline transport pilot and aircraft type rating practical tests for helicopters. FAA inspectors, designated pilot examiners, and check airmen (examiners) must conduct practical tests in compliance with these standards. Knowledge of these standards will also be helpful to flight instructors and applicants preparing for the practical test.

This AC announces the availability of and ordering instructions for FAA-S-8081-20, *Airline Transport Pilot and Aircraft Type*

Rating Practical Test Standards for Helicopter. It is available in both printed and electronic formats. [Adapted from AC.]

Reports

Predictors of Perceived Empowerment: An Initial Assessment. Thompson, Richard C.; Bailey, Lawrence L.; Farmer, William L. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report No. DOT/FAA/AM-98/24. September 1998. 5 pp. Tables, references, appendixes. Available through NTIS.**

Keywords:
Empowerment
Organization Climate
Communication

Many private and public organizations including FAA consider empowered employees desirable. These organizations believe that empowered employees will contribute more effectively to the organization's success. Research has shown that other potential benefits include improved customer service, higher individual and organizational performance, and greater employee commitment to the organization's goals and opportunities for growth. Recent studies have suggested that employee empowerment is related to variable factors other than organizational structure or use of self-managed teams. The focus of this study is on organizational context as a predictor of empowerment perceptions. Employees and managers at two federal agencies participated in this study.

Findings support the idea that empowered employees require an understanding of the organization's policies and goals to make decisions that contribute to the organization's mission effectiveness. Results also suggest that empowerment is enhanced when employees perceive that lines of communication up the chain of command encourage open and honest discussion. [Adapted from Introduction and Conclusions.]

National Airspace System: FAA Has Implemented Some Free Flight Initiatives, but Challenges Remain. U.S. General Accounting Office (GAO). Report to Congressional Requesters, September 1998. Report No. GAO/RCED-98-246. 76 pp. Figures, appendixes. Available through GAO.***

Prompted by the expected growth in air traffic along with the aging of air traffic control equipment, U.S. Federal Aviation Administration (FAA) embarked on a multibillion-dollar modernization effort in 1981 to improve the safety, capacity, and efficiency of the U.S. air traffic control system. Because of cost overruns, delays and other problems, FAA in consultation with the aviation community is developing a phased approach to modernization. An integral part of this modernization effort is a new way of managing air traffic known as "free flight." New technologies and procedures will allow FAA to move from its present use of highly structured air traffic control rules and procedures to a more flexible system involving collaboration between FAA and users. These changes are expected to help improve the safety of the air traffic control system, save users time and money, and use airspace and airport resources more efficiently. This report discusses the status of FAA efforts to implement free flight, including a planned demonstration of the Free Flight Operational Enhancement Program (previously known as Flight 2000), and the views of the aviation community and FAA concerning how free flight can be implemented in a cost-effective manner.

Among the findings, FAA will need to provide effective leadership and management of the modernization efforts, establish clear goals for further development of plans to implement free flight, and address outstanding issues concerning technology development and deployment. Finally, all of these efforts must be coordinated with international efforts to help integrate the various technologies used under free flight. [Adapted from Introduction and Results in Brief.]

Book

Beyond the Horizons: The Lockheed Story. Boyne, Walter J. New York, New York, U.S.: St. Martin's Press, 1998. 542 pp.

This illustrated book tells the story of a major participant in the golden age of American aerospace. Lockheed began as a two-man company in 1913, and today (as Lockheed Martin) has become an important defense contractor, involved not only in aviation, but also in missiles, space platforms and satellites. Lockheed aircraft were made famous by pioneering aviators such as Amelia Earhart, Wiley Post and Howard Hughes. During World War II, Lockheed aircraft made significant contributions to winning the war, and the company's efforts also helped end the Cold War.

Contains a detailed Bibliography and Index. [Adapted from Summary.]♦

Sources

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U.S. Government Printing Office (GPO)
Washington, DC 20402 U.S.

** National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161 U.S.
+(703) 487-4600

*** U.S. General Accounting Office (GAO)
P.O. Box 6015
Gaithersburg, MD 20884-6015 U.S.
Telephone +(202) 512-6000; Fax +(301) 258-4066

Updated Regulations and Reference Materials

U.S. Federal Aviation Administration (FAA) Advisory Circulars (ACs)

AC No.	Date	Title
121-29A	June 25, 1998	*Carry-on Baggage.* (Cancels AC No. 121-29, *Carry-on Baggage*, dated Nov. 2, 1987).
61-122B	Aug. 12, 1998	Announcement of Availability: FAA-S-8081-5C, *Airline Transport Pilot and Aircraft Type Rating Practical Test Standards for Airplane*. (Cancels AC No. 61-122A, Announcement of Availability: FAA-S-8081-5B, *Airline Transport Pilot and/or Type Rating (Airplane-Helicopter) Practical Test Standards (Changes 1 and 2)*, dated June 2, 1997).
39-6S	Aug. 10, 1998	Announcement of availability: *Summary of Airworthiness Directives.* (Cancels AC No. 39-6R, *Summary of Airworthiness Directives,* dated May 15, 1996).
23.1419-2A	Aug. 19, 1998	*Certification of Part 23 Airplanes for Flight in Icing Conditions.* (Cancels AC No. 23.1419-2, *Certification of Part 23 Airplanes for Flight in Icing Conditions,* dated Jan. 3, 1992).

International Reference Updates

Joint Aviation Authorities (JAA)

Date	
Oct. 1, 1998	Revision to JAA Administrative and Guidance Material, Section One, General Guidance and Reference Material
Oct. 1, 1998	Revision to JAA Administrative and Guidance Material, Section Two, Maintenance.
Oct 1, 1998	Revision to JAA Administrative and Guidance Material, Section Three, Certification.
Oct 1, 1998	Revision to JAA Administrative and Guidance Material, Section Four, Operations.

Airclaims

Supplement No.	Date	
112	September 1998	Updates *World Aircraft Accident Summary* and includes provisional data for the first half of 1998.
110	Oct. 8, 1998	Updates *Major Loss Record.*

Aeronautical Information Publication (A.I.P.) Canada

Amendment No.	Date	
4/98	Oct. 8, 1998	Updates the General, Communications, Meteorology, Rules of the Air and Air Traffic Services, Facilitation, Aeronautical Charts and Publications, and Airmanship sections of the A.I.P.

Accident/Incident Briefs

Ignition-switch Malfunction Causes DC-9 Cockpit Fire

FSF Editorial Staff

The following information provides an awareness of problems through which such occurrences may be prevented in the future. Accident/incident briefs are based on preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.

Switch Meltdown Prompts Replacement, Tracking Campaign

McDonnell Douglas DC-9. Substantial damage. Two minor injuries.

The captain said that he detected the odor of electrical smoke while taxiing the DC-9, operated by a Canadian airline, into takeoff position on a runway in the United States. The first officer and a flight attendant summoned to the cockpit by the captain confirmed the odor of smoke. The captain taxied the airplane off the runway, and the first officer told the tower controller that the flight had encountered a problem and was clearing the runway.

Dense smoke then began to emerge from the top of the overhead electrical panel. The captain said, “The first officer advised [that] he could see flames behind the overhead electrical panel through the emergency-power switch.” The captain shut down the engines and ordered an evacuation. Two of the 32 occupants suffered minor injuries (sprained ankles) during the evacuation.

The captain said, “I got out of my seat, took the fire extinguisher from the cockpit wall, pulled the pin and, with the first officer’s help, aimed the nozzle behind the emergency-power switch. I fired a short burst, and the flames were extinguished.”

The report said that the fire was traced to an engine-ignition switch that had melted. “A campaign has [begun] to replace these switches on the [airline’s DC-9] fleet,” said the report. “Also, the switches will be [assigned a life limit of] five years. At present, there is [no] life tracking on these switches.”

B-737 Descends Too Low During Instrument Approach

Boeing 737-300. No damage. No injuries.

The flight crew received radar vectors from air traffic control (ATC) for an instrument landing system approach to an airport in England. The airport had broken clouds at 100 feet, an overcast at 300 feet and 1.6 statute miles (2.5 kilometers) visibility with drizzle.

The crew was instructed to descend to 4,000 feet. The controller then saw that the airplane was below 4,000 feet and asked the crew to confirm their altitude. The crew said that the airplane was descending through 2,400 feet. The controller instructed the crew to climb to 3,000 feet. The crew responded immediately and then completed the flight without further incident.

Both flight crewmembers later said that they were cleared to descend to 2,000 feet. Nevertheless, investigators said that no such clearance was issued by ATC. Terrain and obstacle clearance was reduced to 500 feet during the altitude deviation. The report said that higher terrain was within one nautical mile (1.9 kilometers) of the airplane's flight path.

"Since there was no evidence that [the flight crew] was cleared to 2,000 feet, the crew must initially have set the wrong altitude on the MCP [master control panel], or there must have been an uncommanded change on the MCP," said the report. "An uncommanded change on the MCP is not unknown on the B-737, but crews are aware of this possibility and should still be continuously monitoring aircraft altitude."

Ground Vehicle Strikes Parked B-737 after Brakes Fail

Boeing 737-300. Substantial damage. No injuries.

The airplane, with 76 passengers and eight crewmembers aboard, was parked at an airport gate, preparing for departure, when it was struck by a baggage-loading vehicle. The impact caused structural damage in the area of the airplane's forward-baggage-compartment door.

The driver of the vehicle said that the vehicle's brakes did not function. Examination of the vehicle disclosed that a brake-disk caliper had detached and severed the brake-system hydraulic lines, causing a complete loss of hydraulic fluid.

En-route Delays Cited in Shorts Fuel Exhaustion

Short Brothers SC7 Skyvan. Destroyed. No injuries.

The pilot, who had flown the round-trip cargo route in the Skyvan for nearly four years, calculated that 900 pounds (408 kilograms) of fuel were required for the flight. The fuel totalizer showed 956 pounds (434 kilograms) of fuel aboard the airplane at the beginning of the flight.

The first leg of the flight apparently proceeded uneventfully. Before departing on the second leg of the flight, which normally required about 48 minutes to complete, the pilot was told by ATC that weather conditions were causing delays of up to 2.5 hours at the destination.

During the second leg of the flight, the pilot was instructed by ATC to fly a holding pattern. The airplane had been aloft for 52 minutes when it was released from holding. ATC then told the pilot that he would be vectored for a 35-nautical-mile (65-kilometer) final approach. "The pilot then told the controller that he was fuel critical, and the controller vectored him ahead of other airplanes," said the report.

The airplane had been aloft for 85 minutes when the pilot advised ATC that he had shut down the right engine. He declared an emergency and said that he would not be able to reach the airport.

The left engine then lost power, and the airplane struck the ground. The pilot, alone aboard the airplane, was not hurt. Investigators found 1.5 gallons (5.7 liters) of fuel remaining in the airplane's tanks.

Misrigged Ailerons Cause Loss of Control on Takeoff

Beech 1900C. Substantial damage. No injuries.

The pilot was conducting a postmaintenance flight check. During his preflight inspection of the airplane, he checked the flight controls for freedom of movement. He said that he observed the ailerons moving freely, but he did not notice whether the ailerons moved correctly.

The report said that, after lifting off the runway, the airplane entered an uncommanded left bank. "The pilot applied right aileron, but with no effect," said the report.

The airplane struck the runway in a left-wing-low attitude, and the left wing struck a taxiway sign. Damage was substantial, but none of the four occupants was injured.

"An examination of the airplane revealed that the aileron cables were incorrectly connected at the turnbuckles in the wheel well," said the report. "The aircraft maintenance manual contained the following warning: 'Visually check to assure that aileron travel responds properly to the control-wheel movement. When the control wheel is turned right, the right aileron should move up and the left aileron should move down.'"

Corporate
Executive

Learjet Lands Gear-up After a Go-around

Learjet 31. Destroyed. No injuries.

The pilot said that haze restricted flight visibility, and he flew the visual approach too high and too fast. He executed a go-around. The report said, "The pilot and copilot do not recall retracting the landing gear [during the go-around]. During the second approach, the pilot stated [that] he did not extend the gear because he was 'sure in his mind that the gear was already down.'"

The airplane touched down with the landing gear retracted and slid approximately 3,000 feet (915 meters) down the runway. A fire erupted in the area of the right wing root. The pilots, the sole occupants, attempted unsuccessfully to extinguish the fire with hand-held fire extinguishers. The Learjet was destroyed by the fire, but the pilots were not hurt.

Fuel Imbalance Cited In Takeoff Accident

Beech E90 King Air. Destroyed. Two fatalities.

The King Air took off in instrument meteorological conditions. The airplane began turning left soon after takeoff. The pilot asked the controller, "Can you tell if I'm in a turn? I have a problem here."

The airplane struck the ground about 1.6 nautical miles (three kilometers) north of the airport. Both occupants were killed.

Examination of the wreckage revealed no preimpact malfunction or failure. Investigators discovered that three days before the accident, 840 pounds (381 kilograms) of fuel were added to the airplane's left-wing tank. "Then the fuel farm ran out of fuel," said the report, "No further fueling was accomplished, and the pilot was not advised of the uneven fuel load." The report said that the pilot did not discover the fuel imbalance during his preflight inspection.

The report said that the uncommanded left turn caused the pilot to become spatially disoriented and to lose control of the airplane.

Uncontained Engine Failure Prompts Rejected Takeoff

Cessna Citation 500. Substantial damage. No injuries.

The pilot said that, during the takeoff roll, he heard a loud "boom" and lost power from the right engine. He rejected the takeoff and turned off the runway. He said that the right engine "blew" as the airplane entered the taxiway. Debris from the uncontained engine failure penetrated the fuselage and right wing. None of the seven occupants was injured.

The report said that the engine impeller had broken into two large pieces. "A metallurgical examination of the impeller determined that a fatigue crack had originated from the aft face in the area containing a circumferential groove mark that was produced during machining of the aft face prior to blue-etch anodizing."

Other
General
Aviation

High, Fast Approach Leads to Skid off Wet Runway

Beech A55 Baron. Substantial damage. No injuries.

The pilot said that, after touching down at 110 knots, he was unable to bring the airplane to a stop on the wet, 3,900-foot (1,190-meter) runway. The Baron rolled off the end of the runway and down an embankment. The nose landing gear collapsed, and the left wing was substantially damaged. None of the three occupants was injured.

A witness said that the airplane was high on final approach and touched down at about midfield. The witness said that the airplane landed at a high rate of speed. The report said, "The flight manual for the Beech 95-A55 states that the normal approach speed for this airplane is 87 knots."

Cessna 172 Overturned by Wind While Taxiing for Takeoff

Cessna 172G. Substantial damage. No injuries.

The pilot conducted a before-takeoff check with the airplane facing into the wind. The report said, "Following the run-up, the pilot maneuvered the airplane to take the active runway. The tail of the airplane was turned into the prevailing wind, and the airplane nosed over and came to rest … inverted." Airplane damage was substantial, but neither of the two occupants was injured.

Winds recorded at another airport 18 statute miles (29 kilometers) away were at 27 knots, gusting to 33 knots. "The peak wind was reported at 35 knots," said the report.

Worn Spark Plugs Cause Forced Landing on Runway

Grumman American AA-5. No damage. No injuries.

The airplane was on initial climb following a touch-and-go landing when the engine began to misfire and vibrate severely. The pilot declared an emergency and landed the airplane on the remaining runway.

A postincident test of the engine showed that it ran roughly and could not achieve rated takeoff power. A large decrease in power occurred when the engine was operated only on the left magneto. Further inspection revealed that three of the eight spark plugs were worn beyond service limits. The engine operated normally after a new set of spark plugs was installed.

Rotorcraft

Helicopter Loses Power During Instructional Flight

Enstrom F-28C. Destroyed. No injuries.

A flight instructor and a student pilot were conducting takeoffs and landings when the helicopter began to lose power at approximately 400 feet. The instructor turned the helicopter toward the airport and prepared for an emergency landing.

The engine lost power completely during the descent, and the flight instructor conducted an autorotational landing on a taxiway. The report said, "After the touchdown, the instructor noticed flames [emerging] from the engine compartment." The instructor shut down the engine and attempted unsuccessfully to extinguish the fire with a hand-held fire extinguisher. The helicopter was destroyed by the fire.

The helicopter operator discovered a hole above the exhaust port in the no. 2 engine cylinder. "According to the operator, the resulting exhaust-gas leak severed the no. 4 cylinder oil line and started [the] fire," said the report.

Pilot Loses Control at Night, In Instrument Conditions

Eurocopter BO-105S. Destroyed. One fatality, one serious injury.

The helicopter was on a positioning flight for a medevac (medical-evacuation) operation. The night was dark, and instrument meteorological conditions prevailed. The helicopter was cruising at 500 feet and following a highway. "The pilot slowed the helicopter to 70 knots keeping pace with the traffic," the report said.

The medical crewmember said that the ceiling was about 550 feet to 600 feet and visibility was approximately two statute miles (3.2 kilometers). The report said that the company's operations manual requires a minimum ceiling of 1,000 feet and a minimum visibility of three statute miles (4.8 kilometers) for night operations under visual flight rules.

The medical crewmember said that he felt the helicopter shudder as if decelerating through effective translational lift. He heard the pilot use an expletive and felt the helicopter begin to turn left. He then saw sparks overhead and felt Plexiglas strike him.

The helicopter was destroyed when it struck the ground. The pilot was killed, and the medical crewmember was seriously injured. The report said that examination of the helicopter revealed no structural anomalies or mechanical anomalies.

Faulty Fuel Gauges Cause Forced Landing in R22

Robinson R22 Beta. Substantial damage. No injuries.

The pilot calculated that 10 gallons (38 liters) of fuel would be needed for a planned 40-minute flight. The fuel gauges showed that the helicopter had 12 gallons (45 liters) of fuel in the main tank and 3.5 gallons (13 liters) of fuel in the auxiliary tank.

The flight was uneventful until an air traffic controller at the destination airport instructed the pilot to hold position. The pilot said that he was flying in a hover taxi at about six feet when a sudden strong gust of wind caused the helicopter to sink.

The pilot said that the helicopter lost power momentarily and bounced on contact with the ground. One of the main rotor blades struck the tail boom. The pilot immediately shut down the engine. He said that he noticed, for the first time, that the low-fuel light was illuminated.

About a half gallon of fuel was recovered when the fuel tanks were drained. With the tanks empty, the fuel gauges showed that there were five gallons (19 liters) in the main tank and 1.5 gallons (5.7 liters) in the auxiliary tank. The report said that Robinson R22 helicopters are equipped with fuel-tank dipsticks. Nevertheless, the report did not say whether a dipstick was available in the accident helicopter.♦

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Vice President, Regulatory Affairs
Northwest Airlines Government
Relations

Hon. Robert T. Francis
Vice Chairman
U.S. National Transportation
Safety Board

Capt. Hugues Gendre
President
Syndicat National des Pilotes de Ligne

Maj. Gen. Francis C. Gideon
Chief of Safety
U.S. Air Force

R. Curtis Graeber, Ph.D.
Chief Engineer, Human Factors
Boeing Commercial Airplanes Group

Capt. Urpo Koskela
Retired Chief Pilot
Finnair

John K. Lauber, Ph.D.
Vice President
Training and Human Factors
Airbus Service Co. Training Center

Capt. Y.L. Lee
Chairman, President andCEO
Far Eastern Air Transport Corp.

Stuart Matthews
Chairman, President and CEO
Flight Safety Foundation

Capt. Dan Maurino
Coordinator,
Flight Safety and Human Factors
Study Programme
International Civil Aviation Organization

John McCarthy, Ph.D.
Manager for Scientific and
Technical Program Development
U.S. Naval Research Laboratory

Capt. Edward M. Methot
Airline Executive

Jean Pinet
Consultant
SEDITEC

John W. Saull
Executive Director
International Federation of
Airworthiness

Douglas Schwartz
Director of Flight Standards
FlightSafety International

David Sheehan

Capt. Robert Sumwalt
Chairman, Human Performance
Committee
Air Line Pilots Association,
International

Capt. Bill Syblon
AMR Sabre Consulting

Capt. Roberto Tadeu
Safety Advisor
Varig Brazilian Airlines

Capt. Etienne Tarnowski
Senior Director
Training Development
Airbus Industrie

Flight Safety Foundation Members
As of November 1998

A

ABS Partnership
AC Nielsen Corp.
Accident Investigation Board–Finland
ACES–Aerolíneas Centrales de Colombia
ADC Airlines
Adria Airways
Aero Asahi Corp.
Aerolineas Argentinas
Aeromexico
Aeroperu
AeroRepublica
Aerospatiale
Ætna/USHC
Affretair
AFLAC Incorporated
Air 2000
Air Baltic
Air Canada
Air Corps Library
Air Europa
Air EuroSafe
Air France
Air India
The Air League–United Kingdom
Air Liberté
Air Line Pilots Association, International
Air Line Pilots Association–Taiwan
Air Malawi
Air Malta
Air Nelson
Air New Zealand
Air Nippon Co.
Air Niugini
Air Nostrum
Air Pacific
Air Transport Association of America
Air Transport International
Air Transportation Services
Air Wisconsin Airlines Corp.
Air Zimbabwe (Pvt)
Airasia
Airbus Industrie
Airbus Service Co./Training Center
AIRCO–Institut Français de Sécurité Aérienne
Airco-Safe
Aircraft Accident Investigation Board–Denmark
Aircraft Accident Investigation Board–Norway
Airline Professional Association, Teamsters Local 1224
Airline Training International
Airports Authority of India
Airports Council International
Airservices Australia
AirTran Airlines
Alaska Airlines
Alberto-Culver USA
Alcoa
Alertness Solutions
Alitalia
All Nippon Airways
Alliance Air
Allied Pilots Association
AlliedSignal Aerospace
AlliedSignal
Allison Engine Co.
ALM Antillean Airlines
Alumax International
Amerada Hess Corp.
America West Airlines
American Airlines
American Express Co.
American Regional Aircraft Industry (AMRAI)
American Trans Air
Amiri Flight–Abu Dhabi
Amiri Flight–Qatar
Amoco Corp.
AMP
AMR Eagle
Amsterdam Airport Schiphol
Amway
Anadarko Petroleum Corp.
Anheuser-Busch Companies
ANPAC–Associazione Nazionale Piloti Aviazione Commerciale
Ansett Australia
Ansett New Zealand
Aon Corp.
APPL–Associazione Professionale Piloti Linea
AR Group
Arab Insurance Group
ARABASCO
Archer Daniels Midland Co.
ARCO
ARINC (Aeronautical Radio Inc.)
Capt. Angel Arroyo
Ashland
Asiana Airlines
ASPA de Mexico
Associaçao de Pilots da VARIG-APVAR
Associaçao dos Pilotos Portugueses de Linha Aérea–APPLA
Associated Airlines Pty.
Associated Aviation Underwriters
Association of Air Transport Engineering & Research
AT&T Aviation
Atlantic Coast Airlines
Atlantic Southeast Airlines
Atlas Air
ATR
Mr. Scott A. Ault
Australian Aviation Underwriting Pool
Australian Federation of Air Pilots
Avensa
Aviaco Lineas Aereas
Avianca Airlines
Aviation Consultants
Aviation Consumer Action Projects
Aviation Methods
Aviation Personnel International
Aviation Safety Council
Aviation Safety Support
Avicos Insurance Co.

Flight Safety Foundation Members
As of November 1998 *(continued)*

B

Bahamasair Holdings

Ball Corp.

Banc One Corp.

Bank of Stockton

Banyan International

Barnes & Noble Bookstores

Barrick Gold Corp.

Capt. Bart Bakker

Battelle

Bausch & Lomb

Baxter Aviation

Bell Helicopter Textron

BellSouth Corporate Aviation

The BFGoodrich Co.

Biman Bangladesh Airlines

Boeing Commercial Airplanes Group

Boeing Commercial Airplanes Group–Douglas Products Division

Bombardier Aerospace Business Aircraft

Bombardier Aerospace Corp.

Bombardier Business Jet Solutions

Bombardier Club Challenger

Borden Services Co.–Aviation

BP America

Bristol-Myers Squibb Co.

Britannia Airways

British Aerospace Regional Aircraft

British Aerospace

British Airways

British Columbia Telephone Co.

British Midland Airways

British World Airlines

Bureau of Air Safety Investigation–Australia

Mr. Jim Burnett

Business & Commercial Aviation

Business Express Airlines

C

C.R. Bard Inc.

Campbell Helicopters

Campbell Soup Co.–Flight Operations

Canada 3000 Airlines

Canadian Airlines International

Canadian Business Aircraft Association

Canadian Regional Airlines

Canadian Union of Public Employees

Cape Verde Islands Airports & ATC Authority

Cargill

Cargolux Airlines International

Cathay Pacific Airways

CENIPA–Brazil

Central & South West Services

Cessna Aircraft Co.

CFI

Champion International Corp.

Malcolm G. Chan-A-Sue

Chevron Corp.

China Airlines

Chrysler Pentastar Aviation

Chung-Cheng Institute of Technology

Cigna Corp.

CIRA–Italian Aerospace Research

Citiflight

Civil Aeronautics Administration–Taiwan

Civil Aviation Administration–Denmark

Civil Aviation Administration–Finland

Civil Aviation Administration–Iceland

Civil Aviation Administration–Norway

Civil Aviation Authority–New Zealand

Civil Aviation Authority–United Kingdom

Civil Aviation Department–Hong Kong

Clintondale Aviation

The Coca-Cola Co.

Coca-Cola Enterprises

Colegio de Pilotos Aviadores de Mexico

Colleen Corp.

College of Aeronautics

Comair

Commercial Airways

Commercial Financial Services

Conseil Permanent de la Sécurité Aérienne-Marine

Consol

Consorcio Aviaxsa, SA de CV (Aviacsa Airlines)

Contact Air Flugdienst & Co.

Continental Airlines

Corning

Corporate Angel Network

Corporate Jets

Court Helicopters

Cox Enterprises

Cranfield University

Crossair

Crown Central Petroleum Corp.

Crown Equipment Corp.

CSX Corporation

Cummins Engine Co.

Cyprus Airways

D

Dana Flight Operations

Dassault Aviation

Dassault Falcon Jet

Dayton Hudson Corp.

Debonair Airways

Dedale

Deere & Company

Ms. Katia DeFrancq

Delta Air Lines

Dr. H.O. Demuren

Department of Civil Aviation–Mauritius

Department of Civil Aviation–Netherlands

Deutsches Zentrum für Luft-und Raumfahrt

Director General of Civil Aviation–Chile

Directorate General of Civil Aviation–Kuwait

Directorate of Flying Safety–Australia

Directorate of Police Aviation–Oman

Divisão de Investigação e Prevenção de Acidentes Aeronáutico–DIPAA

The Dow Chemical Co.

DreamWorks SKG

Capt. Thomas A. Duke

DuPont Aviation Corporation

Dutch Airline Pilots Association

Flight Safety Foundation Members
As of November 1998 *(continued)*

E

Earth Star

Eastman Chemical Co.

Eastman Kodak Co.

Eaton Corp.

EG&G Special Projects

EgyptAir

Eli Lilly & Co.

Embassy of France (DGAC)–U.S.

Embraer

Embry-Riddle Aeronautical University–Florida

Embry-Riddle Aeronautical University–Prescott, Arizona

Emerson Electric Co.

Emirates, The International Airline of the United Arab Emirates

ENRON Corp.

Entergy Services

Era Aviation

ERG Management Corp.

Mr. Shawn Ericson

Estonian Air

Estonian Civil Aviation Administration

Ethiopian Airlines

Eurocontrol

Eurocopter Deutschland

Eurocypria Airlines

European Regions Airline Association

EVA Airways Corp.

Evergreen International Airline

Execaire

Executive Jet Aviation

Executive Jet International

Express One International

F

Far Eastern Air Transport Corp.

FayAir (Jersey)

Federal Express Corp.

FedEx Pilots Association

Finnair

First Air

Flight Attendants Association–Australia

Flight Dynamics

Flight Safety Foundation International

Flight Safety Foundation–Taiwan

Flight Services Group

Flight West Airlines

FlightSafety International

Florida Power & Light Co.

Flowers Industries

Fokker Services

Ford Motor Co.

Fort James Corp.

Freeport-McMoran

Friedkin Aviation Services Co.

Frontier Communications

Fuerza Aerea de Chile

Fuqua Flight

Futura International Airways

G

Galaxy Aerospace Corp.

Gannett Co.

Garmin International

Gaylord Entertainment Co.

GE Aircraft Engines

Mr. Nathan S. Gedye

General Electric Co.

General Mills

General Motors Corp.

General Transportation Corp.

Georgia-Pacific Corp.

Global Ground Support

Gold Run Aviation

Government of Croatia Flight Department

Great Lakes Aviation

GTE Service Corp.

Guild of Air Pilots and Navigators

Gulf Air

Gulfstream Aircraft

H

H. Beau Altman Corp.

Ms. Kelly Hamilton

Mr. Jerry B. Hannifin

Hapag-Lloyd Flug

Harris Corp.

Hawkaire

Helicopter Association International

Helikopter Service

Heliportugal

Hellenic Airline Pilots Association

Hertie-Stiftung

Hewlett-Packard Aviation

Ms. Yvonne Hill

Hillenbrand Industries

Hilton Hotels Corp.

Hoechst Marion Roussel

Honeywell

Mr. John Howie

Hubbell Flight Department

Hungarian Defense Forces, Air Force Staff

I

IAGSA–International Airborne Geophysics Safety Association

Iberia Airlines of Spain

IBM Flight Operations

Icelandair

IHS TransPort Data Solutions

Imperial Oil

IMS Health

Independent Pilots Association, United Parcel Service of America

Indian Airlines

Institute of Transportation, MOTC

Instituto Nacional de Aviação Civil (INAC)

Inter Assessoria Aeronautica

Inter Hannover Scandinavian Branch

Inter-Canadian

Interlaken Capital Aviation Services

International Federation of Air Line Pilots' Associations

International Federation of Airworthiness

International Society of Air Safety Investigators

Flight Safety Foundation Members
As of November 1998 *(continued)*

Interplan Airport Services
Intertechnique
Iran Air
Ishikawajima-Harima Heavy Industries
ITT Flight Operations

J

J&H Marsh & McLennan
Jabatan Penerbangan Awam
JAL Express
Jamco Corp.
James Markel & Associates
Japan Air System Co.
Japan Aircraft Pilots Association
Japan Airlines
Japan Asia Airways
Japan TransOcean Air
JAT–Yugoslav Airlines
JCPenney Co.
Jeppesen
Jet Airways
Jet Aviation Business Jets
Jetflite
Dr. Daniel Johnson

K

KaiserAir
Mr. Alex Kampf
KC Aviation
Kellogg Co.
Kendell Airlines–Australia
Kenya Airways
KeyCorp Aviation Co.
KLM Cityhopper
KLM Luchtvaartschool
KLM Royal Dutch Airlines
KLM uk
Koch Industries
Korea Air Force Risk Management Agency
Korean Air
Capt. Kent J. Krizman
The Kroger Co.
Kuwait Airways

L

La Réunion Aérienne
Ladeco
Lan Chile
Lands' End
Learjet
Libbey-Owens-Ford Co.
Liberty Mutual Group
Lider Taxi Aereo
Lightning Technologies
The Limited
Lineas Aereas Privadas Argentinas (LAPA)
Linhas Aereas de Moçambique
Litton Aero Products
Lloyd Aereo Boliviano
Lloyd's Aviation Underwriters' Association
Lockheed Martin Corp.
Lockheed Martin Vought Systems
Los Angeles World Airports
Mr. Lincoln Lounsbury
LTE International Airways
Lucent Technologies
Luftfahrt-Bundesamt
Luftfartsverket–Sweden
Lufthansa German Airlines (FRA CF)
Luxair
Luxembourg Air Rescue

M

Maersk Air
Malaysia Airlines
Malev Hungarian Airlines
Malmö Aviation Schedule
Management Air Service Co.
Marathon Oil Co.
Marine Nationale–France
Martinair Holland
Masco Corp.–Flight Department
Massey University, School of Aviation
MBNA America Bank
MCI Communications Corp.
McKee Foods Corp.
Mr. Michael W. McKendry
MedAire
Merck & Co.
Meridiana Aviation Safety Services
Mesa Airlines
Mexicana Airlines
MHS Aviation
MIAT (Mongolian Airlines)
Midway Airlines
Midwest Aviation
Midwest Express Airlines
Dr. C.O. Miller
Milliken & Co.
3M Aviation
Mission Safety International
Mitsubishi Heavy Industries
Mobil Business Resources Corp.
Monarch Airlines
Mr. Thomas Monforte
Monsanto Aircraft Operations
Motorola
Mutual of Omaha

N

Nakanihon Airline Service Co.
NASA Langley Research Center
National Aeronautic Association of the USA
National Aerospace Laboratory (NLR)–Netherlands
National Association of Flight Instructors
National Aviation and Transportation Center
National Business Aviation Association
National Center for Atmospheric Research
National Jet Systems Group
NationsBank Corp.
Nationwide Insurance Enterprise
Natural Gas Pipeline Co. of America
Nippon Cargo Airlines
The NORDAM Group
Norsk Flygerforbund–NALPA
North Carolina A&T State University
Northwest Airlines
NOVA Corp.

Flight Safety Foundation Members
As of November 1998 *(continued)*

O

Olin Corp.

Olympic Airways

Oman Aviation Services Co.

Omniflight Helicopters

Mr. Steve O'Toole

Owens Corning

Owens-Illinois General

P

Pakistan International Airlines

PAMA–Professional Aviation Maintenance Association

Pan Am

Ms. Elaine M. Parker

Parker Hannifin Corp.

Penny & Giles Aerospace

Pepsico

Petersen Aviation

Petro-Canada

Petroleum Air Services

Petroleum Helicopters Inc.

Pfizer

PGA–Portugalia Airlines

Pharmacia & Upjohn

Philip Morris

Philippine Airlines

Pilatus Business Aircraft

The Pillsbury Co.

Pizza Hut Aviation

Polynesian Airlines

Port Authority of New York and New Jersey

PPG Industries

Pratt & Whitney Canada

Pratt & Whitney

PrivatAir

Procter & Gamble

Progressive Corp.

PT. Garuda Indonesia

Q

Qantas Airways

R

Rabbit-Air

Mr. Costas Rapis

Raytheon Aircraft Co.

Raytheon Co.

Region Air

Regional Airline Association

Reno Air

Capt. Otto Rentsch

Republic of Singapore Air Force

Richardson Aviation

Richmor Aviation

Mr. Harry L. Riggs Jr.

Rio Sul Servicios Aereos Regionais

RJ Reynolds Tobacco

Robe Breiling Associates

Robertson Aviation

Mr. Russell D. Robison

Rockwell International

Rockwell Collins

Rocky Mountain Helicopters

Rolls-Royce North America

Royal Insurance Aviation Department

Royal Jordanian Air Force

Royal Jordanian Airlines

Royal Norwegian Air Force

Ryan International Airlines

S

Saab Aircraft

Sabena Belgian World Airlines

Safair (Pty)

Safe Flight Instrument Corp.

SAS Flight Academy

Saudi Arabian Airlines

Saudi Aramco

SBC Communications

Scandinavian Airlines System

Schering-Plough Corp.

Schreiner Airways

Mr. Rusty Scioscia

Sears, Roebuck & Co.

Sedgwick Global Aviation

Sedgwick North America

Mr. Juan De Sendagorta

Shamrock Aviation

Shaw Industries

Mr. John Sheehan

Shell Canada

Shell Services International

Signature Flight Support

SilkAir (S)

Silver Ventures

SimCom International

SimuFlite Training International

Sindicato Nacional de Pessol de Voo da Aviacao Civil–Portugal

Sindicato Nacional dos Aeronautas

Singapore Airlines Limited

Singapore Aviation Academy

Mr. Billy J. Singleton

Skyservice

Skyways AB

SkyWest Airlines

SNECMA

Society of Automotive Engineers

SONAT

South African Civil Aviation Authority (SACAA)

South African Air Force

South African Airways

South Holland Bank

Southern California Safety Institute–Kirtland

Southwest Airlines Pilots Association

Southwest Airlines

Spanair

SPIDELA

SPPA (Swiss Professional Pilots' Association)

Sprint Corp.

Square D Co.

Mr. Mark W. Stallbaum

Statens Haverikommission

Steelcase North America

Flight Safety Foundation Members
As of November 1998 *(continued)*

Sterling Software
Stk Skandinavisk Tilsynskontor
Summa Peto
Sun Oil Co.
Sundstrand Corp.
SunTrust Banks
Sunworld International Airlines
Swiss Air Ambulance
Swiss Air Force
Swiss Pool for Aviation Insurance
Swiss Reinsurance Company–Swiss Re New Markets
Swissair
Syndicat National des Pilotes de Ligne

T

TAAG Angola Airlines
TACA International Airlines
Taco Bell Corp.
TAM (Brazilian Airlines)
TAP Air Portugal
TAROM–Romanian Airlines
TeamLease
Tennessee Valley Authority
Texaco
Texas Instruments
Thai Airways International
The Timken Co.
Tillson Aircraft Management
Time Warner
Tower Air
Trans States Airlines
Trans World Airlines
Transaero Airlines
TransAsia Airways
Transavia Airlines
Transbrasil Linhas Aereas
TransMeridian Airlines
Transmile Air Services
Transport Accident Investigation Commission
Transport Canada Business Centre–Information & Research Services Site
Transport Canada
Transportation Safety Board of Canada
Transportes Aéreos del Mercosur (TAM)
Transportes Aéreos Ejecutivos
Transportes Aeromar
Travelers Group
Tricon–KFC Aviation
TRW Flight Services
Tudor Investment Corp.
Col. Robert R. Tyler

U

U.S. Air Force Headquarters–SE
U.S. Army
U.S. Coast Guard–Washington, D.C.
U.S. Department of the Navy
U.S. Federal Aviation Administration
U.S. Federal Aviation Administration, AAI-1
U.S. Federal Aviation Administration, ASY-10
U.S. Federal Aviation Administration, Aviation System Standards
U.S. Federal Aviation Administration, Civil Aeromedical Institute
U.S. National Aeronautics and Space Administration
U.S. National Transportation Safety Board
U.S. Naval Postgraduate School
U.S. Naval Research Laboratory–Monterey
U.S. Naval Safety Center
U-Land Airlines
Mrs. Denise E. Uhlin
Union Camp Corp.
Union Pacific Railroad Co.
Union Pacific Resources Co.
Union Texas Pakistan
United Airlines
The United Company
United Parcel Service Co.
United States Aviation Underwriters
United Technologies Corp.
Universal Studios
Universal Underwriters Group
Universal Weather & Aviation
University Aviation Association
University of North Dakota
University of Southern California
US Airways
USAA
USX Corp.
Uzbekistan Airways

V

The VanAllen Group
Varig Brazilian Airlines
VASP Brasilian Airlines
Ventura Air Services
Vereinigung Cockpit–German Air Line Pilots' Association
Verzekeringmaatschappij de Nederlandse Luchtvaartpool
Veridian
Vietnam Airlines
VisionAire Corp.
Viva Air

W

W.R. Grace & Co.
W.W. Grainger
Walter Kidde Aerospace
Warner Lambert Co.
Wayfarer Aviation
WCF Aircraft Corp.
Whirlpool Corp.
Widerøe's Flyveselskap
Willis Corroon Aerospace
Wilmington College
Wing Aviation
Winterthur Reinsurance
World Airways
Wyvern Ltd.

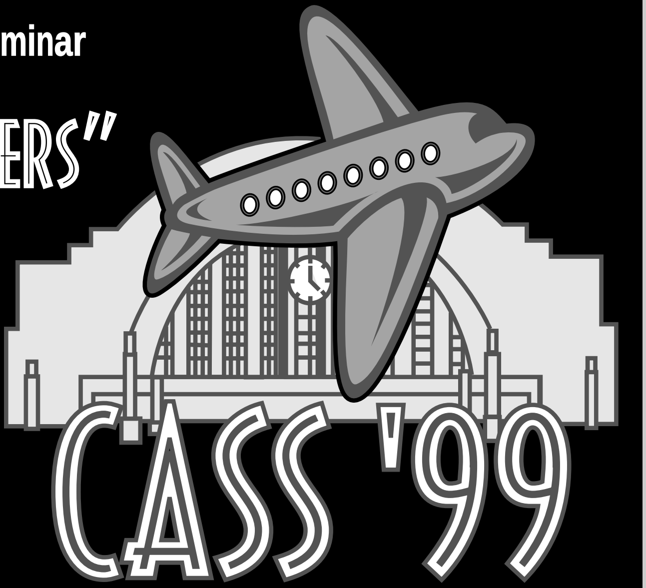
X

Xerox Corp.

Z

Zeno Air

BLANK
INSIDE
BACK
COVER



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