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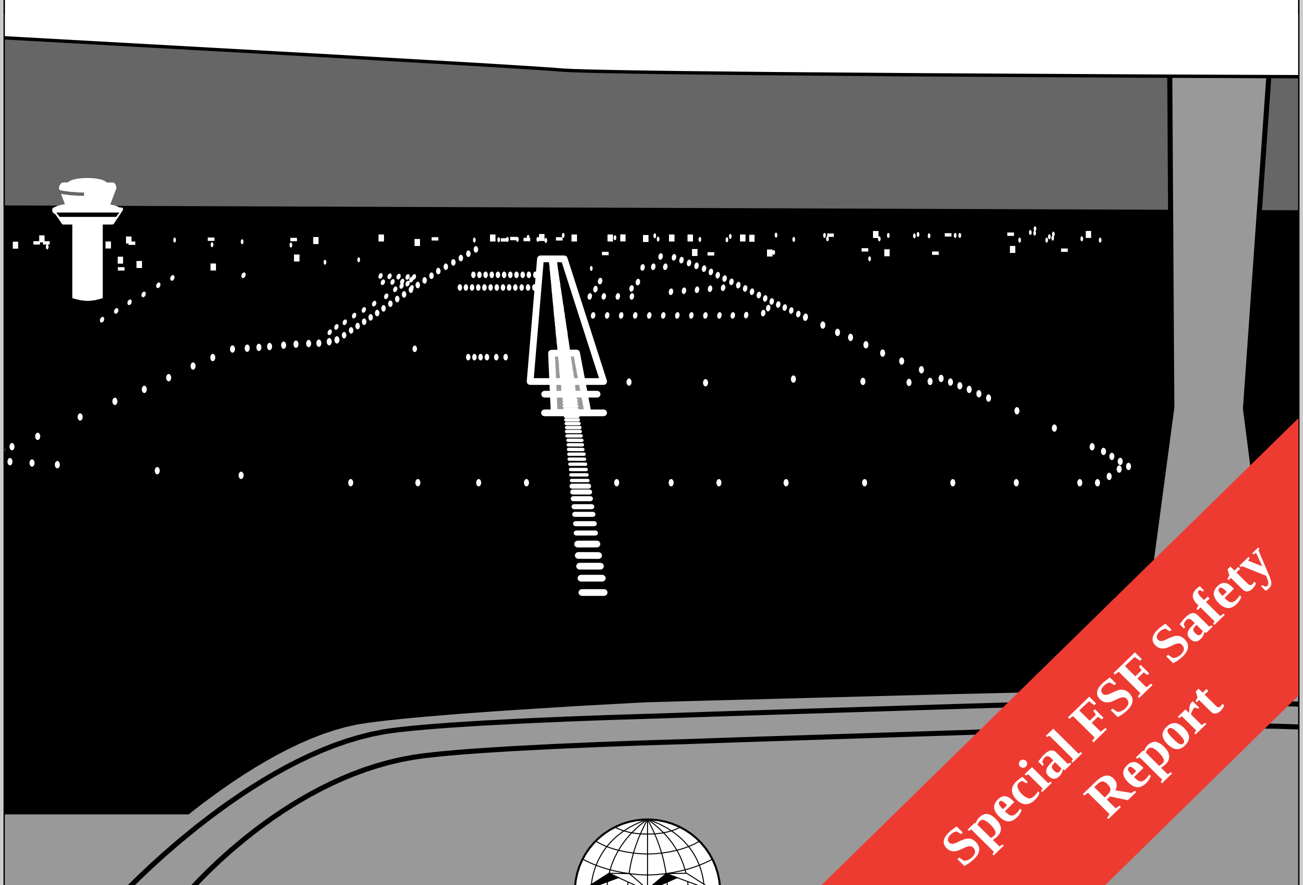
Airport Safety: A Study of Accidents and Available Approach-and-landing Aids



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In This Issue

Airport Safety: A Study of Accidents and Available Approach-and-landing Aids

This month's Flight Safety Digest *is a special report prepared under Flight Safety Foundation (FSF) auspices for the Netherlands Directorate-General of Civil Aviation (RLD). The ground-breaking study focused on the influence of precision terminal approach and guidance equipment (or the lack of it) on risk.*

A sample of 557 airports from around the world was examined, along with 132 accidents. A survey questionnaire was also sent to international and regional air carrier operators. The survey asked questions relating to flight crew training, cockpit procedures and operational documents.

The report also focused on factors beyond the direct control of airport authorities that can affect approach-and-landing risk. Those factors included air traffic control and surrounding terrain and other obstacles.

The report concluded that airport authorities can significantly increase approach-and-landing safety with precision approach-and-landing guidance facilities.

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Acronyms

ACI	Airports Council International
ADREP	Aviation Data Reporting Program (ICAO)
AOPA	Aircraft Owners and Pilots Association
ARP	Airport reference point
ATC	Air traffic control
ATIS	Automatic terminal information service
BASI	Bureau of Air Safety Investigation (Australia)
CAA	U.K. Civil Aviation Authority
CFIT	Controlled flight into terrain
CRM	Crew resource management
DME	Distance-measuring equipment
EFIS	Electronic flight instrumentation system
ESA	European Space Agency
FAA	U.S. Federal Aviation Administration
FAF	Final approach fix
FAP	Final approach point
FMS	Flight management system
FSF	Flight Safety Foundation
GPS	Global positioning system
GPWS	Ground-proximity warning system
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ID	Identification
IFALPA	International Federation of Air Line Pilots' Associations
ILS	Instrument landing system
IMC	Instrument meteorological conditions
LOC	Localizer
LOFT	Line-oriented flight training
MAP	Missed-approach point
MDA	Minimum descent altitude
MLS	Microwave landing system
NASA	U.S. National Aeronautics and Space Administration
NDB	Nondirectional beacon
NLR	Nationaal Lucht-en Ruimtevaartlaboratorium (National Aerospace Laboratory, Netherlands)
NM	Nautical mile
NOTAM	Notice to airmen
NTIS	U.S. National Technical Information Service
NTSB	U.S. National Transportation Safety Board
PAPI	Precision approach path indicator
PAR	Precision approach radar
PF	Pilot-flying
PNF	Pilot-not-flying
RLD	Rijksluchtvaartdienst (Directorate-General of Civil Aviation, Netherlands)
RMS	Records management systems
RR	Risk ratio
STAR	Standard terminal arrival route
TAR	Terminal approach radar
TCAS	Traffic-alert and collision avoidance system
VAG	Visual approach guidance
VASI	Visual approach slope indicator
VHF	Very high frequency
VMC	Visual meteorological conditions
VOLMET	Meteorological information for aircraft in flight
VOR	VHF omnidirectional radio range

Definitions

Key terms are defined, for the purposes of the report, as follows:

A **precision approach** is an instrument approach with lateral and vertical guidance from the final approach point (FAP) to the runway touchdown zone, with system accuracy, integrity and obstacle clearance (including go-around) guaranteed until the descent limit (decision altitude or decision height) is reached. In this report, instrument landing system (ILS), microwave landing system (MLS) and precision approach radar (PAR) are considered precision approaches.

A **nonprecision approach** is an instrument approach with lateral guidance only from the final approach fix (FAF) to the runway environment. Descent limit is the minimum descent altitude (MDA), and obstacle clearance (including go-around) is guaranteed if the approach is discontinued no farther than the missed-approach point (MAP). In this report, approaches with lateral guidance from localizer, very high frequency omnidirectional radio range (VOR), nondirectional beacon (NDB) or global positioning system (GPS) are considered nonprecision approaches. Although often a helpful tool for lateral and vertical navigation during approach, multisensor flight management system (FMS) guidance is not a certified approach aid, and therefore FMS approaches are not explicitly considered in this report.

A **stabilized approach procedure** is an approach procedure along the extended runway centerline with a constant, in-flight verifiable, descent gradient from the final approach altitude to the runway touchdown zone. Except for offset-localizer approaches, an ILS approach is inherently a stabilized approach procedure. Nonprecision approaches can be constructed as a stabilized approach procedure by choosing the FAF accordingly and by publishing a distance-vs.-altitude (VOR + distance-measuring equipment [DME], NDB+DME, or localizer [LOC]+DME) or waypoint-vs.-altitude table (GPS) to be able to verify adherence to the (imaginary) glidepath.

When referring to the way the approach is actually flown by the crew, a **stabilized approach path** is an approach without speed and/or configuration changes during final descent. A stabilized approach procedure is required to fly a stabilized approach.

Data and Study Limitations

This study's limitations need to be considered when interpreting the results.

Accident Data:

One of the most important limitations was the relatively small size of the accident sample. Although these 132 accidents represent the majority of commercial aircraft accidents that occurred on approach during the study period, the small number of events limited the analysis to one- and two-factor analysis. These results should, therefore, be considered general in nature.

Accident Analysis:

Statistically significant associations demonstrated between airport and nonairport factors, and risk of accidents for commercial aircraft approaching to land, *do not* prove causation. Such associations only suggest that an increased risk for an accident appears when the factor under consideration is present.

The overall risk of an accident is the result of many individual and interrelating factors. A single factor carrying a high risk may be countered by other factors carrying low risk without negatively affecting the overall risk. However, the accumulation of a large number of lowered-risk practices and procedures through equipment, crew training and strict adherence to high operating standards will undoubtedly lower the overall risk of accidents. Operators and authorities should avail themselves of every possible means to control the overall risk to the lowest practical level.

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:

$$RR = \{a/A\} / \{f/N\}$$

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 10) shows the distribution of aircraft type (by broad category) involved in the approach accidents.

Table 3.3 (page 10) 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 11) 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 11) 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 11) 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 11) 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 3.2
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 3.8 (page 11) 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 12) 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 3.10 (page 12) shows the mean value of the cloud ceiling and visibility for accidents where the information was provided.

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.

As with the pilots' flight experience, only a small percentage (34 percent) of the accident reports or summaries recorded this information.

Table 3.11 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 13) 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 3.13 (page 13) 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.

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.

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 3.13
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 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.

The results presented in Table 3.14 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

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.

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 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 movement ratio of 16.6, while Latin America had the lowest, with a ratio of 3.2.

Table 3.16 (page 15) 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

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.

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.

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 13), 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

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.

and Latin America, the number of TAR-assisted arrivals just about equaled the number of arrivals without radar (procedural guidance only).

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 (page 15) shows the RRs associated with high terrain around the airports. Only Asia-Pacific had a significant

RR associated 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 (page 16) 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 (page 16) 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 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.

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.

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 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

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.

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 3.22
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 (page 21) characterizes the nine operators by location.

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).

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.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 14). 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 14).

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 14). 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 15). 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 14). 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 15). 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 16). 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 16).

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 14). This was consistent when evaluated by ICAO region (Table 3.19, page 16). 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 11). 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 12). 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 standands 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
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
50 (79.4) nonprecision approach procedures (e.g., NDB, VOR, localizer)

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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