Flight Safety DIGEST

OCTOBER 2005

Analysis of CREW CONVERSATIONS

Provides Insights for Accident Investigation

Flight Safety Digest

Vol. 24 No. 10 October 2005

In This Issue

Analysis of Crew Conversations Provides Insights for Accident Investigation

New methods of examining recorded voice communications can help investigators evaluate interactions between flight crewmembers and determine the quality of the work environment on the flight deck.

— MAURICE NEVILE, PH.D., AND MICHAEL B. WALKER, PH.D.

Cockpit voice recorders (CVRs) are installed in aircraft to provide information to investigators after an accident. They provide records of flight crew activities and conversations, as well as a variety of other auditory information. Information from CVRs has proved useful in determining the events leading up to aircraft accidents for many years. However, there has been little discussion in the safety investigation field about appropriate ways to analyze recorded voice communications, particularly in terms of analyzing the quality of the interaction between crewmembers.

Following the investigation of a controlled-flight-into-terrain (CFIT) accident involving an Israel Aircraft Industries Westwind 1124 jet aircraft, which struck terrain near Alice Springs, Northern Territory, Australia, on April 27, 1995, the Bureau of Air Safety Investigation (BASI, which became part of the newly formed multi-modal Australian Transport Safety Bureau [ATSB] in 1999) evaluated available methods to analyze recorded voice communications.

[CFIT, as defined by the Flight Safety Foundation CFIT Task Force, occurs when an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew.]

As a result of the BASI research, the ATSB contracted independent specialists in an emerging field known as "conversation analysis" to analyze the CVR from the Westwind accident. The project was conducted by Maurice Nevile, Ph.D., and A.J. Liddicoat, Ph.D., both then of the Australian National University. The independent consultants' report provided conclusions regarding the crew interaction that were consistent with the original BASI investigation report. More important, the project showed that the conversation analysis method provided a very useful approach to identify, describe, demonstrate and explain difficulties in conversation between two or more individuals.

This paper discusses the nature of conversation analysis and its potential for use in safety investigation, as well as its potential for demonstrating the importance of appropriate crew communication practices. To help explain the usefulness of the method, information from the original consultancy project's examination of the Westwind CVR is included. This paper is not an investigation of the circumstances of the accident.

It is important to note that a cockpit voice recording provides limited information about activity in a cockpit and cannot provide a complete understanding of all activities and interactions among flight crew. It does, however, provide a good understanding of what happened and why. The analysis can be enhanced by comparing average sound recordings from normal multi-crew communication and activity on a flight with a recording from a particular flight that is being studied. This comparison can provide more detailed insights into crew activities and interactions on a particular operation despite the lack of visual information — for example, from a cockpit video recording.

The methodology is intended to expand the level of understanding that can be obtained from a cockpit voice recording.

It is acknowledged that a perfect understanding of cockpit activity is difficult to achieve without the opportunity to interview the flight crew as a part of an investigation. However, the methodology described in this paper is intended to expand the level of understanding that can be obtained from a cockpit voice recording as a part of an investigation.

Executive Summary

Recorded voice data, such as from CVRs or air traffic control (ATC) tapes, can be an important source of information for accident investigation, as well as for human factors research. During accident investigations, the extent of analysis of these recordings depends on the nature and severity of the accident. However, most of the analysis has been based on subjective interpretation rather than the use of systematic methods, particularly when dealing with the analysis of crew interactions.

This paper presents a methodology, called conversation analysis, which involves the detailed examination of interaction as it develops moment-to-moment between the participants, in context. Conversation analysis uses highly detailed and revealing transcriptions of recorded voice (or video) data that can allow deeper analyses of how people interact.

The paper uses conversation analysis as a technique to examine CVR data from the Westwind accident.

The conversation analysis methodology provided a structured means for analyzing the crew's interaction. The error that contributed directly to the accident — an incorrectly set descent altitude — can be seen as not the responsibility of one pilot but, at least in part, as the outcome of the way the two pilots communicated with one another. The analysis considered the following aspects in particular:

- The significance of overlapping talk (when both pilots spoke at the same time);
- The copilot's silence after talk from the pilot-in-command (PIC);

- Instances when the PIC corrected (repaired) the copilot's talk or conduct; and,

- A range of aspects for how the two pilots communicated to perform routine tasks.

In summary, the conversation analysis methodology showed how specific processes of interaction between crewmembers helped to create a working environment conducive to making, and not detecting, an error. By not interacting to work together as a team, pilots can create a context for error.

When analyzing recorded voice data, and especially for understanding instances of human error, often a great deal rests on investigators' interpretations or analysts' interpretations of what a pilot said, or what was meant by what was said, or how talk was understood, or how the mood in the cockpit or the pilots' working relationship could best be described. Conversation analysis can be a tool for making such interpretations.

Introduction

It is now widely accepted that human error is a contributing factor in most aircraft accidents (Wiegmann and Shappell, 2003). For many of these accidents that involved larger aircraft and crews with two or more pilots, some of the errors related to problems in communication or task coordination between the pilots (Salas et al., 2001).

Consequently, there has been a considerable amount of research that has examined the nature of crew communication and coordination (Helmreich, Merritt and Wilhelm, 1999; Wiener, Kanki and Helmreich, 1993). There also has been a considerable amount of effort expended in training airline pilots in crew resource management techniques (Salas et al., 2001) and a considerable amount of effort expended in developing and applying techniques to evaluate crew performance in these areas, using behavioral markers and techniques such as the line operations safety audit (Flin et al., 2003; Helmreich, Klinect and Wilhelm, 1999).

It is also widely accepted that, even though human error may have been a factor in a particular accident, investigations should focus on identifying the reasons for such errors rather than the errors themselves (Maurino et al., 1995; Reason, 1990, 1997).

These reasons may include a range of factors associated with the task and environmental conditions, as well as the broader organizational context in which the crews operated. However, to identify these underlying reasons, the nature of the crew actions needs to be examined in detail. In addition, the context in which the actions occurred also needs to be considered (Dekker, 2001a, 2001b, 2002; Reason, 1997).

By not interacting to work together as a team, pilots can create a context for error.

This paper discusses a technique that can be used to analyze recorded voice communications in context and shows how this technique can be used to demonstrate how and why communication between two or more pilots was not effective. The technique, called conversation analysis, involves the detailed examination of interaction as it develops between the participants. We use this technique to examine the CVR from an accident flight. We show how specific processes of interaction between crewmembers can help to create a working environment conducive to the pilots making, and not detecting, an error.

The research paper is the outcome of collaboration between an academic researcher with a background in applied linguistics and microsociology who has conducted a major study of routine communication in the airline cockpit (see Nevile, 2004a), and a senior transport safety investigator with an academic background in organizational and cognitive psychology and with substantial experience investigating human factors in aircraft accidents.

Current Methods

Transcriptions of CVR recordings and ATC voice recordings typically list only the speaker, the time at which the utterance began and the words spoken. Detailed information about how the words are spoken usually is excluded. This is probably because investigators have limited tools to analyze this data in a structured manner. However, it also may be due in part to sensitivities associated with releasing CVR information.

Two main types of techniques have been used for more structured analysis of recorded voice communications. The first type, commonly termed "speech analysis" (or "voice analysis") looks at a pattern of voice information and related behavior to identify possible factors affecting an individual's performance. This generally involves measurement of variables such as fundamental frequency (pitch), speech rate (number of syllables per second), intensity (or loudness), speech errors, response time and aspects of the speech quality. The data are then compared with carefully selected samples, generally from the same person under normal conditions. Speech analysis has been successfully employed to examine the influence of factors such as stress and workload (Brenner, Doherty and Shipp, 1994; Ruiz, Legros and Guell, 1990), alcohol (Brenner and Cash, 1991) and hypoxia (ATSB, 2001). However, it focuses on the factors affecting a specific individual, rather than the pattern of communication between individuals.

The second type of technique has involved the coding of speech acts (Helmreich, 1994; Predmore, 1991; Transportation Safety Board of Canada, 2003). This process typically involves coding each utterance in terms of its function or *thought unit* (e.g., command, advocacy, observation, inquiry). It also involves coding *action decision sequences* of utterances in terms of their task focus (e.g., flight control, damage assessment, problem solving, emergency preparation). The coded data are then examined in terms of how they are distributed between the crew and how they change over time during the flight. Where possible, comparisons are made with available data from other crews.

Conversation analysis is a micro-analytical approach to the study of naturally occurring interaction.

Although speech act coding can offer useful insights into communication dynamics, its effectiveness can be limited by a lack of available data on how other crews from similar backgrounds communicated in similar situations. Also, it does not use all the available information about how things are said or communicated, and this information can be important in establishing the context for the crew communications. A technique that focuses on this additional information is conversation analysis.

Conversation Analysis

Conversation analysis is a micro-analytical approach to the study of naturally occurring interaction. As a discipline, its origins are in sociology and are usually traced to a paper written in the mid-1970s by Sacks, Schegloff and Jefferson (1974) on the organization of turn-taking in conversation. The early development of conversation analysis is especially associated with the ideas of Harvey Sacks (Sacks, 1992; Silverman, 1998) and the influence of ethnomethodology (e.g., Garfinkel, 1967; ethnomethodology is a branch of sociology dealing with nonspecialists' understanding of social structure and organization). Conversation analysis shows in detail how naturally occurring interaction is sequentially ordered and collaboratively produced and understood by participants, moment-to-moment, in what has been described as the "intrinsic orderliness of interactional phenomena" (Psathas, 1995).

Conversation analysis looks at how interaction is something people jointly accomplish "locally" (i.e., there and then). Recent introductions to conversation analysis are provided by Hutchby and Wooffitt (1998) and ten Have (1999).

Conversation analysis increasingly is being drawn upon in studies of interaction for work in institutional settings and professional settings, such as in medicine and counseling, education, law and policing, business, human-computer interaction, and control centers (e.g., Drew and Heritage, 1992; Button, 1993; Heath and Luff, 2000; McHoul and Rapley, 2001; Richards and Seedhouse, 2004). Most relevant, one of the authors of this paper has used conversation analysis for a video-based study of routine communication, or "talk-in-interaction," in the airline cockpit (Nevile, 2001, 2002, 2004a, 2004b, 2005b, in press).

In this paper, four features of conversation analysis are central to the presentation and analysis of recorded voice data:

- Conversation analysis is concerned with *naturally occurring data*, not data specifically generated for research purposes. It uses recordings, and the transcriptions made of them, of naturally occurring interactions. Analysts may make use of observation, interviews or other ethnographic techniques, but their emphasis is on how the participants develop and demonstrate their actions and understandings in real time;

- Conversation analysis uses *highly detailed and revealing transcriptions* of recorded voice (or video) data that can allow deeper analyses of how people interact. The process of transcribing is an important part of the discovery process and involves repeatedly listening to the recording. Transcribing is undertaken with an open mind about what might be there, a process called *unmotivated looking*;

- Conversation analysis is data-driven and relies for its claims on the *evidence available in the data itself*, on what the participants themselves say and do, and just how and when they do so as the interaction develops. Claims about participants' understandings and actions must be based on, and demonstrated in, analyses of the transcription data. Conversation analysis looks at what happens and at what happens next and asks "Why that now?" Analysts avoid preconceptions of participants or settings, and ascribing to participants' mental, motivational or emotional states, but seek evidence for these in the details of how interaction develops; and,

- Conversation analysis examines what people say and do *in context*, seeing how these actions occur in sequence relative to one another, rather than isolating actions from their contexts of occurrence. Conversation analysis shows how actions are both shaped by context and also shape context by influencing participants' subsequent actions and understandings of what is happening.

Using conversation analysis meets recent calls to analyze human error in context (e.g., Dekker, 2001a, 2001b), to "reconstruct the unfolding mindset" of the people involved "in parallel and tight connection with how the world was evolving around these people at the time" (Dekker, 2001a). With conversation analysis, the analyst can use highly detailed transcriptions of spoken data (or even visual data) as indications of how the pilots *themselves* create particular patterns of communication and interpret and understand what they are doing and what is going on, in context. The technique, therefore, offers a means for describing, in terms that are defensible because they are grounded in the voice data, how members of a flight crew are working together.

Conversation analysis examines what people say and do *in context*.

The Accident

We will focus on data from the Westwind accident and use this accident as an example of what can be done, and what can be found, using methods and principles of conversation analysis. This paper is not an attempt to outline and understand all the complex factors that contributed to the accident. Instead, we focus on the way in which the pilots interacted with one another.

The Westwind was being operated on a night cargo flight (BASI, 1996; see "'Cockpit Relationship' Cited in Westwind Accident Report," page 6). The two-pilot crew was conducting a practice nonprecision approach in clear, moonless conditions. The approach involved a stepped descent in three stages using three navigation aids. The flight proceeded normally until the aircraft crossed the final approach fix, at which point the pilot-in-command (PIC) asked the copilot to set the "minima" in the altitude alert selector. The copilot responded by calling out and setting 2,300 feet, and this action was acknowledged by the PIC. However, the relevant minimum height that applied to the accident aircraft at that stage in the approach was 3,100 feet. Soon after leveling off at 2,250 feet, the aircraft struck the top of a mountain and was destroyed.

Continued on page 7

'Cockpit Relationship' Cited in Westwind Accident Report

Communication between the pilot-in-command (PIC) and the copilot was among the factors contributing to the April 27, 1995, accident nine kilometers (five nautical miles) northwest of the airport in Alice Springs, Northern Territory, Australia, in which the Israel Aircraft Industries Westwind 1124 was destroyed and all three people in the airplane (two pilots and one passenger) were killed, the Australian Bureau of Air Safety Investigation (BASI) said in the final report on the accident.[1]

Night visual meteorological conditions prevailed when the accident occurred at 1957 local time as the crew conducted a practice locator/nondirectional beacon (NDB) approach[2] to the airport to complete the second leg of a four-leg scheduled cargo flight from Darwin to Sydney. The report said that the skies were clear and moonless and that visibility was 40 kilometers (25 statute miles).

The approach involved a stepped descent in three stages. The PIC was flying the airplane; the report said that he had briefed the copilot that "the 'not below' altitude after the final approach fix for the approach (2,780 feet) would be used as 'the minimum' for their purposes.

"The flight proceeded normally until the aircraft passed overhead the final approach fix, when the [PIC] asked the copilot to set the 'minima' in the altitude-alert selector. The copilot responded by calling and setting '2,300 feet.' This altitude was the Category A/B aircraft minimum descent altitude, as depicted on the Jeppesen chart for the approach. The minimum descent altitude for the Westwind, which is a Category C aircraft, was 3,100 feet. The 2,300 feet called by the copilot was acknowledged by the PIC, and the aircraft then descended to that altitude. Shortly after leveling at about 2,250 feet, the aircraft struck the top of the Ilparpa Range."

The report said that investigators had found "evidence of difficulties in the relationship between the two pilots before the flight, at least from the copilot's perspective," and that the cockpit voice recorder (CVR) revealed that those difficulties continued during the accident flight.

"The [CVR] indicated that these difficulties affected the copilot's willingness to communicate with the [PIC]," the report said. "There were also indications that his task performance was affected and that he was reluctant to query the instructions or the performance of the [PIC]. For example, there were no questions from the copilot concerning the approach briefing, even though a number of significant items were omitted. Also, he did not comment on the performance of the [PIC] during the approach, despite the fact that tracking and descent rate limits were exceeded."

Several elements of crew behavior — "communication between the crew, the approach briefing, the approach method and the [premature] descent to 2,300 feet" — were identified in the report as contributing to the accident.

The CVR showed a "low standard" of crew resource management (CRM) by both pilots, the report said.

"The [PIC] was critical of the copilot and did not adequately inform the copilot of his intentions," the report said. "The copilot did not use an appropriate, assertive style in communicating with the [PIC]. Had the pilots communicated more effectively, the accident may have been avoided."

The report said that the significant factors in the accident sequence included the following:

- "There were difficulties in the cockpit relationship between the [PIC] and the copilot;
- "The level of [CRM] demonstrated by both crewmembers during the flight was low;
- "The Alice Springs locator/NDB [nondirectional beacon] approach was unique;
- "The briefing for the approach conducted by the [PIC] was not adequate;
- "When asked for the 'minima' by the [PIC], the copilot called, and the [PIC] accepted, an incorrect minimum altitude for the aircraft category and for the segment of the approach;
- "The technique employed by the [PIC] in flying the approach involved a high cockpit workload; [and,]
- "The crew did not use the radio altimeter during the approach."■

— FSF Editorial Staff

Notes

1. Bureau of Air Safety Investigation (BASI; 1996). Investigation Report 9501246, *Israel Aircraft Industries Westwind 1124 VH-AJS, Alice Springs, NT, 27 April 1995*. Department of Transport and Regional Development, Canberra, Australia. (BASI became part of the newly formed multi-modal Australian Transport Safety Bureau in 1999.)
2. The Alice Springs locator/nondirectional beacon (NDB) approach that was in use when the accident occurred required the pilot to "fly overhead the Alice Springs NDB not below 5,000 feet," the report said. "The aircraft was then to track approximately 11 [nautical] miles [20 kilometers] northwest to the Simpson's Gap locator at a minimum altitude of 4,300 feet. After passing overhead this position, the aircraft had to complete a procedure turn through 180 degrees to again track overhead Simpson's Gap onto the final segment of the approach. This segment involved the aircraft tracking overhead the Temple Bar locator to the Alice Springs NDB while descending from 4,300 feet. The minimum altitude permitted between Simpson's Gap and Temple Bar was 3,450 feet, and between Temple Bar and the Alice Springs NDB, 2,870 feet. After passing the Alice Springs NDB, the procedure required the aircraft to continue straight ahead to the minimum descent altitude. For aircraft Categories A and B, the minimum descent altitude was 2,300 feet (using actual QNH) and for Category C aircraft, it was 3,100 feet. The Westwind is a Category C aircraft. On a normal profile, the Category C minima would be reached between Temple Bar and the Alice Springs NDB."

The PIC was a former airline pilot with 10,108 hours total flight experience, including 2,591 flight hours in Westwinds. The copilot had 3,747 hours total flight experience, most of it in helicopters. He had 80 flight hours in the Westwind. The PIC was the handling pilot for the flight.

The accident investigation identified a number of factors that contributed to this accident, including that the technique employed by the PIC in flying the approach involved a high cockpit workload. A number of the contributing factors involved problems in the communication between the crew. The report concluded that there were difficulties in the cockpit relationship between the PIC and the copilot, and that the level of crew resource management demonstrated by both pilots during the flight was low. Most of the information for these conclusions came from the 30 minutes of recorded voice communication on the aircraft's CVR. Although the investigation team considered that there was ample evidence to support the conclusions, it experienced difficulty in clearly substantiating the conclusions in a precise manner. Based on this experience, a variety of techniques were explored for assisting in the analysis of recorded voice communications. One of these techniques was conversation analysis.

A transcript of the CVR for the accident flight was included in the BASI report on the accident. This paper contains no substantially new information on what was said but contains new information in terms of *how* things were said. This additional information has been released by the ATSB for the purposes of enhancing aviation safety.

What Happened, and Why

Prior to reviewing segments of conversation from the focus accident, we need to outline the nature of conversation analysis transcription. Conversation analysis has developed particular notation for representing systematically many details of talk (or non-talk activities) that studies have shown to be significant to participants themselves (i.e., for how participants interpret what is going on, as evidenced in what they do next; see "Transcription Notation," page 8). One advantage of transcribing recorded data by using notation developed in conversation analysis is that the transcriptions can show much more about what actually happened, and why. Conversation analysis shows how transcribing voice data involves much more than recording what people say — it involves showing just how they say it. Typically, conversation analysis transcriptions of audio data can indicate at least the following:

- How talk is sequentially ordered as turns, or how and when participants exchange roles as speaker and listener (recipient);
- Exact measures of silence in and between utterances (timed to the tenth of a second);
- Periods when two or more people are talking at once (overlapping talk), and the exact points in talk when such periods begin and end;
- Features of the manner of talk, such as lengthening of sounds, pitch contours and marked rises and falls in pitch, talk that is faster or slower, or louder or quieter than surrounding talk, talk that is incomplete (e.g., cut off), and aspects of voice quality (e.g., breathiness, creaky voice);
- *Tokens* such as "oh," "um" and "ah"; and,
- Laughter (in individual pulses), and exactly when laughter begins and ends.

To highlight some of the features of conversation analysis transcription, we show for comparison two transcriptions of the same segment of talk from the focus CVR. The first (Example 1) is a basic transcription, in the form it appeared in the investigation report (BASI, 1996). It shows mainly who is speaking to whom, the words spoken and the time of speaking. (PIC is pilot-in-command, CP is copilot.)

Example 1

Time	From	To	Text
1934.05	PIC	CP	we'll go down to forty-three hundred to there and if you can wind in thirty-four fifty and when we when we get over there wind in twenty-seven eighty that'll be the minimum we'll see how it looks for a giggle and you can put the steps in now too if you wouldn't mind but you only need to put the steps in below the lowest safe (non-pertinent transmissions)

Transcription Notation

The transcription notation used in this article is adapted from a system originally developed by Gail Jefferson. Recent variations and explanations of the system can be found in Hutchby and Wooffitt (1998),[1] ten Have (1999)[2] or Lerner (2004).[3]

PIC	pilot-in-command
CP	copilot
rnav	area navigation
(.)	a pause less than two-tenths of a second
(0.3), (1.4)	pauses represented in seconds and tenths of seconds
bravo one	talk in italics is spoken over the radio
>five<	talk which is noticeably faster than surrounding talk
<five>	talk which is noticeably slower than surrounding talk
five	talk which is noticeably louder than surrounding talk
°five°	talk which is noticeably quieter than surrounding talk
five,	flat or slightly rising pitch, talk which can be heard as incomplete
five.	terminal falling pitch contour
five?	terminal rising pitch contour
fi::ve	rising pitch within word
fi::ve	falling pitch within word
you:.	rise fall pitch
you:.	fall rise pitch
↑five	marked rise in pitch
=	talk which is latched to other talk (i.e., follows immediately)
[alpha]	talk produced in overlap (simultaneous) with other talk (or noise). "[" indicates beginning of overlap; "]" indicates end of overlap
( )	talk which could not be transcribed
(five)	doubt about the talk transcribed
(now/yeah)	doubt about the talk transcribed, with possible alternatives indicated ■

— Maurice Nevile, Ph.D., and Michael B. Walker, Ph.D.

Notes

1. Hutchby, I.; Wooffitt, R. (1998). *Conversation Analysis: Principles, Practices and Applications*. Cambridge, England: Polity Press.
2. ten Have, P. (1999). *Doing Conversation Analysis: A Practical Guide*. London, England: Sage.
3. Lerner, G.H. (Ed.) (2004) *Conversation Analysis: Studies From the First Generation*. Amsterdam, Netherlands/ Philadelphia, Pennsylvania, U.S.: John Benjamins.

In Example 2, we present the same segment of talk transcribed using notations developed in conversation analysis.

Example 2

	(18.0)
PIC	we'll go down to fortythree hundred to there, (0.5) and if you c'n wind in thirtyfour fifty,
	(0.6)
PIC	and when we- (0.9) when we get over there wind in twentyseven eighty.
	(0.3)
PIC	°that'll be the minimum°.
	(1.8)
PIC	see how it looks.
	(2.5)
PIC	just for a ↑giggle,
	(6.4)
PIC	ah::: you c'n put the steps in there too if you wouldn't mind.
	(1.5)
PIC	>but you only need< to put the steps in <below the lowest safe>.

To highlight the key differences, we can see that the conversation analysis transcription does the following:

- Represents the PIC's talk as a number of separate turns, rather than as one long turn — the breaks in talk, shown on separate lines as periods of silence between turns, represent points where the copilot could have heard the PIC's talk as complete in some way, and so the copilot could have taken a turn to talk (e.g., even if just to say "yeah" or "okay");
- Shows and times all silences, and their lengths in seconds, both within and between the PIC's turns — for example, (1.8);
- Shows details of the manner of talk, including marked rises in pitch (↑) and intonation that is falling (.) or slightly rising (,) (i.e., hearably incomplete), also talk which relative to

surrounding talk is louder (“wind”) or quieter (“°minimum°”) or faster (“>but you only need<”) or slower (“<below the lowest safe>”), and shows talk that is lengthened (“ah:::”), or cut off (“we-“) or repeated (“when we- (0.9) when we”);

- Includes overheard radio talk (e.g., an ATC transmission directed to another flight) as part of the communicative environment in which the pilots are working; and,

- Includes the token “ah.”

Context for Error

Our suggestion in this paper is that the final crew errors that contributed to the accident emerged from an immediate work environment that was conducive to errors occurring and not being identified. The ways in which the pilots communicated with one another created a context for error. We will discuss, with some segments of representative CVR data, the following features of interaction:

- There were many instances of overlapping talk (i.e., both pilots speaking at the same time);

- There were many instances when the PIC said something and the copilot said nothing in reply (was silent), even though some form of a response would have been a relevant and projectable (expected) next action;

- The PIC often corrected (or repaired) the copilot’s talk or conduct when there was no sign of any problem, from the copilot’s point of view, in the copilot’s talk or conduct itself; and,

- Many aspects of how the two pilots communicated to perform routine tasks suggest that the pilots were not working together in harmony as a crew.

Individually, each of these features may mean little, but together they can have a cumulative effect. It is not our intention, and it is not necessary, to conduct a quantitative analysis of particular features of the talk data. This is usually difficult or impossible with the limited data available in recorded voice data. However, these features were identified because they were noticeably recurrent in the CVR data and can be taken as indications of the patterns of interaction developed by these two crewmembers over a period of that accident flight. We have no interest in making wider claims about the pilots’ talk or conduct other than in relation to the CVR data for this flight.

The ways in which the pilots communicated with one another created a context for error.

Unless we specify a source, we will be grounding our comments on well-established principles and findings of conversation analysis, as emerging in research over the past three decades and discussed in general texts, such as Hutchby and Wooffitt (1998) and ten Have (1999). We will also refer to research on routine cockpit communication using conversation analysis, focusing on airline crews, conducted by one of the authors (Nevile, 2004a). The CVR data here are from a cargo flight, not a passenger flight, but we will assume that there are common shared mission goals (safe landing) and activities (flight tasks), and so preferred practices for clear and effective communication for flying multi-engine commercial aircraft.

Note that *many or most data examples exhibit more than one of the features we focus on in this paper*. However, to avoid repetition of data, in most cases, we have placed examples under just one of the main headings.

Overlapping Talk

In both ordinary conversation and talk in work and institutional settings, it is common for there to be points when more than one person talks at a time. Such instances of overlapping talk often occur at points where one person is heard to be possibly coming to the end of their turn at talk. The overlapping talk occurs as someone other than the speaker begins to talk and often emerges as the next speaker and produces the next turn at talk. Overlapping talk at the end of turns is usually *not* treated by participants as interruption, but as part of the normal flow of talk to exchange turns and switch speaker/listener roles.

However, Nevile (2004a, 2005a) has found it to be unusual for flight crews to overlap their talk. That is, pilots usually do not begin talking when another pilot is still talking. This was seen to be the case even when pilots were talking and exchanging turns very quickly — for example, during the performance of a checklist.

Pilots seem oriented to allow one another's talk to emerge in the clear. Overlapping talk does occasionally occur, but relatively rarely in task-oriented talk.

In the CVR data for the accident flight, there were more than 20 instances of overlapping talk. On its own, this is a noticeable feature of the accident flight. The great majority of these instances of overlapping talk occurred when the PIC began to talk when the copilot was already talking. That is, the PIC was the participant responsible for initiating the overlapping talk. Many of these instances were at points in the copilot's talk where the PIC could expect that the copilot's turn was coming to a close. That is, the PIC was predicting or projecting the end of the copilot's turn and beginning his own turn at talk in response (see Example 3 and Example 4). As we have said, this kind of overlap is common in everyday conversation but is uncommon in cockpit communication. Overlapped talk is shown by [square brackets].

Example 3

(10.1)
PIC now the minute we go over Spring Hi:ll, (0.6) or whatever it's called Simp- err=
CP =Simpsons [ga:p
PIC [Simpson is it?
(0.2)
PIC yea:h.
(1.4)

Example 4

(2.2)
CP gear's down (.) three greens co[nfirm?
PIC [c:o:::nfi::rm.
(4.3)
CP okay hydraulic pressure's checked in two:::, anti[skid,
[((tone, 1 second))
PIC one to run.
(0.4)

More significantly, however, there were also numerous instances in the data where the PIC began to talk even though the copilot had not finished his turn at talk, where there was potentially *still talk of substance to be uttered and heard* (see Example 5, Example 6 and Example 7). In lay terms, the PIC could be heard as interrupting the copilot. This occurred even at times when the copilot was presenting important information for the pilots' joint conduct and understanding of the progress of the flight.

Example 5

(1.1)
CP >Alice on< number one,
(1.0)
PIC ye::p.
(0.4)
PIC Alice on number one,
(0.5)
CP? (yep).
(2.6)
CP Simpson's gap? (.) o:n [(0.2) number two,]
PIC [Simpson's gap's] on number two::,
(0.7)

Example 6

(0.4)
CP thrust rever[sers check(ed).]
PIC [(it's on) light's] out.
(1.0)

Example 7

(1.5)
CP below the: (.) lowest safe so, (0.5) twentynine (here) [(on the) ( )]
PIC [(twentynine)]
five and eight (two)
( )
(3.5)

These instances of overlapping talk suggest, at the very least, that these two pilots are not coordinating the timing of their communicative contributions in the smooth manner found to be typical of commercial flight crews. However, where one pilot initiated such points of overlapping talk far more than the other pilot, that pilot could be heard to be dominating the other pilot's communication, and so also their contributions to the work of operating the aircraft. Overlapping talk is also possibly a problem because it can increase the chances of something being misheard, or not heard at all. The pilots may be speaking simultaneously, but they may not both be listening.

Silence

A great deal of research in conversation analysis has shown how people speak in sequences of turns at talk and orient to (or are sensitive to) the sequential nature of conversational exchange. This means that, overwhelmingly, when one person in an interaction produces a turn at talk (the first of a pair of utterances – or "first pair part"), the other person produces talk that is appropriate as a response to that first turn ("second pair part"). Moreover, particular types of turns at talk are associated with particular types of response and indeed can be thought of as expecting (or "preferring") particular types of response (e.g., question and answer, telling and acknowledging).

Conversation analysis studies have consistently found that silences between the turns of a sequence, from as little as 0.3 or 0.4 of a second, are noticeable to participants and are interpreted by participants as meaning certain things, and can prompt action of some kind. For example, the silence possibly signals a problem with the first turn, such as it was not heard, or was not understood, or was unexpected, or will be disagreed with or declined. The lengths and meanings of silences in work settings can vary significantly from ordinary conversation, but in work settings, people also talk in sequences, and the cockpit is no exception (Nevile, 2004a, 2005b). When one pilot talks, the other usually responds, and in a way that can be heard as appropriate.

In the CVR data from the accident flight, there were many instances where the PIC said something, the first pair part of a sequence (e.g., a telling/informing, an instruction, or a question), but the copilot did not produce any appropriate and expectable spoken response (e.g., an acceptance/acknowledgment, or compliance, or an answer). An excellent example of this was presented above in Example 2; additional examples are in Example 8, Example 9 and Example 10.

Example 8

	(1.2)
PIC	so you can put the inbound course up there::.
	(22.8)
PIC	thank you::.
	(5.5)

Example 9

	(9.8)
PIC	okay you can take the rnav out tha:nks:::
PIC	just put Alice up,
	(high pitch tone, 1 second))
	(18.8)

Example 10

	(8.4)
PIC	okay we're assuming we've got the ah::: (0.9) the ident on a- (.) all the time okay? (.) if you just identify 'em and then (1.9) turn them off,
	(21.1)

Some examples of the copilot's silence occurred after the PIC corrected the copilot's performance of some action or failure to do something (see Example 11). Also, a pattern of the PIC talking with no spoken response from the copilot was seen to occur, even when the PIC appeared explicitly to pursue a response from the copilot, as in Example 12, page 12, (especially in the PIC's comment, "'n fact, it's a fair way out, isn't it?"). This example occurred after a problematic exchange of turns where the PIC corrected an error by the copilot and the copilot attempted to defend his conduct. The copilot appeared to choose to be silent and finally only spoke when he had to complete a prescribed sequence of reciprocal turns for setting the speed bugs ("set on the right.").

Example 11

	(8.6)
PIC	okay if you can put the rnav (0.3) up thanks::.
	(1.4)
PIC	whoo::::h.
	(0.6)
PIC	do that fir:::st.
	(1.6)
PIC	bring em both out,
	(0.4)
PIC	o:kay.
	(4.3)
	((alert sound - beep))
	(0.8)
PIC	righto.
	(46.6)
PIC	ah::: have you got the ILS preed up there just in ca:se::?
	(34.8)
PIC	thanks.
	(35.3)

Example 12

	(0.5)
PIC	yeah I dunno how we're gonna get rid of tha::t.
	(1.5)
PIC	I guess: all you can do if it doesn' go away::, (1.0) is:: ah:: (1.0) put my information on your si:::de.
	(2.7)
PIC	it's no good the way it i:s:.
	(5.8)
PIC	'n fact it's a fair way out isn't it?
	(33.8)
PIC	>there you go.<
	(1.9)
PIC	's got rid of it for a whi::le anyway.
	(1.6)
PIC	okay we're gonna do this: (.) for a bit of a giggle,
	(1.3)
PIC	u:::m (.) elevation's eighteen hundred feet, (1.5) we got enough fuel to ho:ld for one point four hours if need be, (1.5) a::nd ah:: we gotta vee ref of one twenty set on the left,
	(0.2)
CP	set on the right.
	(4.8)

In some of these cases, it is possible that the copilot could indeed have been responding, but with a nontalk activity (e.g., a nod or an activity at an instrument panel). The cockpit is a workplace where the response to talk is often nontalk activity; however, such activity almost always is accompanied by talk (Nevile, 2002, 2004a, 2004b, 2005b). A possible exception to this is during a formal briefing, when pilots can speak in longer (extended) turns, but even in briefings, there usually is evidence of the pilots acknowledging one another's contributions and orienting to a need to communicate verbally as they work together (Nevile, 2004b). Other than during briefings, it is extremely unusual to have a string of turns at talk where one pilot talks and the other pilot says nothing in reply.

Conversation analysis discusses silence in terms of "conditional relevance." The copilot's silence can be seen as an absence of speech in a context where the PIC's talk made it relevant for the copilot to say something. The copilot was entitled to say something and, indeed, could be expected to say something. In conversation analysis terms, speech from the copilot would have been a "projectable" next action. In these instances, silence is not simply a case of no one speaking, but a case of the copilot not speaking. In terms of verbal communicative exchange between fellow pilots, for whatever reason one party — the copilot — regularly withheld talk and opted out.

Correction (Repair)

Conversation analysts have identified a general conversational practice, *repair*, which may be of particular relevance to understanding error in aviation and how it is managed. Repair refers to those points in spoken interaction where participants deal with communicative problems of some sort. Conversation analysts have found that in everyday conversation, people typically do not correct each other. There is a marked tendency for *self-repair* (Schegloff, Jefferson and Sacks, 1977); that is, for the person who produced the "problem talk/conduct" (the *repairable*) to repair that talk or conduct, and to be granted the opportunity to do so by the other person.

Conversation analysts have shown that participants distinguish between the *initiation* of the repair (i.e., showing that there is a problem) and *actually doing* the repair (i.e., fixing the problem). So, even where the *other* might initiate the repair, there is still the tendency for self-repair. This preference for self-repair is seen in data for flight crews (Nevile, 2004a). Conversation analysts have shown that, when another person *both* initiates *and* performs a repair (called *other-initiated other-repair*), that repair is typically delayed, hedged or qualified in some way. The person doing the repair softens the blow.

In the CVR data for the accident flight, there were many instances of other-initiated other-repair. The pilot who produced the problem talk or conduct did not initiate repair and did not repair that talk or conduct. Overwhelmingly, the pattern of these instances involved the PIC both initiating and performing the correction/repair of the copilot's talk or conduct (see Example 13, page 13, and Example 14, page 13, and also Example 11). The PIC repaired the copilot's talk/conduct when there was no sign of any trouble, in the copilot's talk/conduct itself, from the copilot's point of view. The first the copilot knew that there was something to be corrected in his talk or conduct was when the

PIC corrected it. More than this, the PIC did not delay, hedge, or qualify his repairs of the copilot. The PIC gave the copilot no or little opportunity to correct the problem for himself.

Example 13

	(0.4)
CP	and it's a seven mile f-f-
	(0.5)
?	( )=
CP	=seven mile final.=
PIC	=no:: el↑even.
CP	eleven.
	(6.9)

Example 14

	(6.2)
CP	the only trouble we might get is, (0.5) if they lea::ve.
	(1.3)
CP	if they leave before us (0.3) they might depart out on, (0.4) one two.
	(0.7)
PIC	well they ca::n't, (0.2) we got their freight.
	(1.6)
CP	°(that's right)°
	(9.3)

Example 13 is a clear example of other-initiated other-repair and warrants further explanation. The copilot, as part of his preparation for the approach, informed the PIC that it will be a "=seven mile final.=". The copilot had two goes at saying this, abruptly stopping his first attempt with "seven mile f-f-."

The PIC corrected the copilot's "seven" by saying "=no:: el↑even."

The "=" symbols indicate that the PIC's turn is "latched" to the end of the copilot's turn (i.e., the PIC produced his talk with no delay whatsoever after the end of the copilot's turn). Recalling that in interaction there is a tendency (or "preference" in conversation analysis terms) for self-repair, the copilot was given no opportunity, after completing his problem turn, himself to repair the incorrect number. That is, the PIC did not say something like "Seven?" or "Are you sure it's seven?" or "Is that right?" or even just wait a second or so to give the copilot a chance to rethink and possibly identify and say the correct number himself. Note that the copilot actually said the problem number, "seven," twice, the first time in the turn that he cut off. Therefore, it is possible that the PIC heard the problem "seven" twice and let it go the first time, giving the copilot the chance to get it right. However, that first talk by the copilot was not completed ("seven mile f-f-"), and it was when he completed his turn and presented the number he had actually settled on ("=seven mile final.=") that the PIC *immediately* corrected him.

Not only did the PIC do the repair himself immediately, with no delay, no hedging and no qualification, the repair began with an explicit marker of negation. This had its prominence increased because it was said with increased volume and was also lengthened ("<u>n</u>o::"). The PIC continued his turn by simply saying the repaired number "eleven," and in the following turn, the copilot accepted this repair without question, indeed without delay. The PIC's saying of "eleven" was a claim that this number was the correct one, and this claim was immediately accepted by the copilot. So, a possible problem of crew understanding about the length of the final leg was resolved by one individual telling another, effectively, that he was wrong, and the other individual accepting this without question.

Performing Tasks

Finally, we consider how the two pilots generally performed routine flight tasks for this period of the flight. Our general finding is that it was typically the PIC who talked to initiate tasks, and he did so in ways that can make prominent his authoritative status as PIC for the flight, and the other pilot's junior status. That is, the PIC's wording can be heard to present tasks as being performed *for* him, as the PIC, *by* the copilot, rather than as being performed collaboratively for both pilots as a crew, and by both pilots as a crew, albeit that it is often appropriately the case that the copilot is doing the required task activity. Such wording could be heard as creating a sense that the copilot was serving the PIC, rather than that the two pilots were working together as team members with different but equally necessary and valuable contributions to flight tasks. The nature of the copilot's participation in task performance could deepen this sense of how the pilots were working.

To demonstrate these points, we describe a number of specific aspects of the pilots' communication and interaction as they performed routine tasks. We stress, however, that many segments actually exhibit more than one of the aspects described below.

The collection of segments makes it easier to understand how, over time, the effect of particular aspects of communication can accumulate and create a context in which the pilots seem not to be working together but instead more according to their individual statuses and roles.

First, the PIC typically initiated tasks with commands to the copilot.

In grammatical terms, he used imperative structures that communicate "Do X," as shown in Example 15, Example 16 and Example 17.

Example 15

	(10.1)
PIC	now the minute we go over Spring Hi:ll, (0.6) or whatever it's called Simp- err=
CP	=Simpsons [ga:p
PIC	[Simpson is it?
	(0.2)
PIC	yea:h.
	(1.4)
PIC	ah:::m (.) set the next altitude ↑u:p, (0.5) and the nex:t:, (0.5) NDB.
	(2.5)

Example 16

	(4.7)
PIC	keep going.
	(4.8)
PIC	keep going. (.) checks th[anks.
CP	[okay vee ref (0.2) one three set. (.) fuel balance,
PIC	it's within limits:::.
	(1.4)

Example 17

	(1.4)
HT?	*hotel tango* ( ) *good night (and thanks).*
PIC	he said to call Adelaide no:w didn't he?
CP	yeh.
	(0.3)
PIC	well you can go off, (0.5) go (on/off) tha:t.
	(4.5)
?	(s-) (respond).
	(9.5)

The PIC also very frequently used the first person singular personal pronoun "I," which presented him as central to the task and as the recipient for performance of the task, and the second person pronoun "you," which presented the copilot as the one doing the task. That is, the PIC's usual wording can convey the sense that "you are doing the task for me." Such use of "I" and "you" by a PIC and handling pilot is not in itself exceptional as a means for making salient relevant individual cockpit identities (Nevile, 2001, 2004a). However, their use almost to the exclusion of more inclusive plural forms (e.g., we/our/us) can mark this CVR data as unusual for cockpit talk. Coupled with his use of "I" and "you" pronoun forms, the PIC regularly used verbs such as "want" and "have" (e.g., "I want X" and "Can I have X?"), making further salient his individual roles on this flight as the PIC and handling pilot, and the other pilot's individual role as copilot doing actions *for* him (see Example 18 and Example 19, page 15).

Example 18

	(9.3)
PIC	okay.
	(1.3)
PIC	on number one, (0.5) I want ah::: (1.3) Alice NDB?
	(3.2)
CP	°(alright)°
	(2.9)
PIC	number two I want that one,
	(3.5)
PIC	so we want tha::t, (0.9) and tha::t, (2.5) and that one [( )
	[((static sound))
EAO	*Melbourne control good evening echo alpha oscar posit[ion quebec*
PIC	[that to
EAO	*[two three bravo one zero zero two, (0.5) maintaining flight level three*
PIC	[number one, (0.5) that to number two, (0.4) and that is (0.2) pree::d
EAO	*[f i::ve zero]*
PIC	[up, (0.7) on number two.]
	(0.5)
EAO	*(correct) two three charlie [(0.2)] one zero two seven.*
CP	[okay::.]
	(1.3)

Example 19

(0.7)
PIC can I have? (0.7) an rnav (0.3) fo:::r, (0.2) <an eleven mi:le (.) fi:nal?,>
(1.1)
PIC runway one: (.) two:.
(1.8)
CP yep,
(5.8)
PIC I only want it (.) preed up.
(0.6)
CP okay.
(3.2)

The PIC's wording often included some form of instruction, tutoring or unsolicited advice to the copilot on how, when or why some activity should or should not be done. These were done in ways that can be heard as directive. The PIC's wording also rarely included a politeness or mitigation marker when initiating a task and calling on the copilot to do some activity.

Sometimes the PIC said "thank you" or "thanks" (as in Example 20 and Example 21), but it should not be assumed that these conveyed appreciation. Our comments here are less securely based on existing conversation analysis research, and therefore are more tentative, but the interactional impact and meaning of "thanking" depends greatly on the prosody (i.e., *how* the "thanking" is said). Certain prosodic patterns can convey appreciation, others mere acknowledgement, and others might even imply sarcasm, complaint or some other action. Appreciation is usually expressed with rise-fall or falling intonation, with the stress and pitch rise early in "thanks" or on "thank" in "thank you" and falling pitch and stress for the end of "thanks" or on "you" in "thank you." The CVR transcription data of the accident flight showed many departures from this usual pattern, and we hear them as making salient the copilot's role in doing tasks for the PIC, tasks that are required of him as the copilot. We hear in the thanking a sense that the copilot was understood to be performing an obligatory duty. The "thanking," especially when occurring last in the sequence of turns at talk for a task, acted as an acknowledgement that this duty had been done.

The PIC often included an assessment such as "that'll do" or "that's fine," presenting himself as an assessor of the copilot's talk/conduct for a task (see Example 20).

Example 20

(0.8)
PIC next one, (0.2) and [the altitude thanks::.]
[((tone, 1 second))]
CP thirtyfour fifty I'll put in thirtyfi::[:ve.
PIC [ye::p.
PIC that's fine.
(2.5)
CP an:::,
(2.3)

The copilot often responded by performing the called-for activity in silence, as noted earlier, or made only a minimal and non-explicit verbal response such as "okay" or "yep," as shown in Example 21, Example 22 and Example 23.

Example 21

(4.4)
PIC 'kay thirty mi:les we're tracking to the rnav position to start the approa:ch:.
CP okay.
(1.2)
PIC so you can put the inbound course up there::.
(22.8)
PIC thank you::.
(5.5)

Example 22

(0.9)
CP complete to pre-landing=
PIC =okay we're cleared down, we know the traffic so you can <set our steps up tha:nks::.>
CP okay::.
(2.9)

Example 23

(1.6)
PIC now the minute we get close to Simpsons gap s- (.) minute we get he::re, (0.6) can you read, (0.5) whatta we gotta be at forty three:?
(0.3)
CP yep.
(0.3)
PIC okay.
(0.5)

As we consider the pilots' talk to perform tasks, we are not saying that the aspects exemplified in the examples above are not found in other crews or that different aspects of communication are not found elsewhere in the talk of this crew. Also, each aspect occurring on its own, or occurring only on occasion, could contribute to quite a different sense of working relationship. However, our suggestion is that these aspects, taken together and occurring over a substantial period on the CVR for this flight, point to a tendency for tasks to be performed in a way that can emphasize the pilots' different individual statuses and roles, rather than a harmonious collaborative team working relationship. (The difference in status between pilots is often referred to as the trans-cockpit authority gradient. Gradients that are too flat or too steep are generally considered to contribute to less effective crew coordination and communication [Hawkins, 1987].)

Conclusion

Our aim has been to describe the context for a human error, or to consider how an error can be understood as emerging from the immediate working environment as created by the pilots, in the ways in which they communicated and interacted with each other. We used a specific approach to naturally occurring communication and interaction, conversation analysis, to transcribe and analyze CVR data of one aviation accident, involving a commercially operated jet aircraft. We did not focus on the moment of error itself, but instead on the context in which it occurred, or what we have called *an interactional context for error*. We used segments from the CVR data, transcribed in rich detail using notation from conversation analysis, to suggest that aspects of the pilots' interaction show the pilots to be acting according to, emphasizing, their individual statuses and roles as PIC and copilot, rather than a sense of working collaboratively as a team.

We suggest that such aspects of interaction contribute to a working relationship that can be conducive to an error occurring and not being identified: They can allow for a *collaborative construction of error*. The error that contributed directly to the accident, an incorrectly set descent altitude, can be seen as not the responsibility of one pilot, but at least in part as the outcome of the way the two pilots communicated with one another.

We considered the following aspects in particular: the significance of overlapping talk (when both pilots spoke at the same time); the copilot's silence after talk from the PIC; instances when the PIC corrected (repaired) the copilot's talk or conduct; and lastly, a range of aspects for how the two pilots communicated to perform routine tasks. It is significant to note that in pointing to evidence that the pilots' communication was problematic for their work as a team, it was not necessary to rely on analyzing instances of overt conflict or communication breakdown. Communicative problems can build up, and be evidenced, over time.

We hope to have demonstrated the value of looking closely at recorded voice data as a means for interpreting human performance and for interpreting human error in aviation in the light of the world evolving around the pilots at the time (Dekker, 2001a), and indeed as the pilots themselves create it. The approach we have used can allow systematic and data-based assertions about human action. How one represents data affects greatly what one is able to see in it and subsequently able to say about it. Conversation analysis is a micro-approach to the transcription and analysis of naturally occurring interaction, and richly detailed transcriptions using notation of conversation analysis can make maximally visible how pilots themselves develop and understand their respective contributions to interaction and to the work required to operate their aircraft. This paper has shown what kind of analyses and findings conversation analysis transcriptions can make possible.

When analyzing recorded voice data, and especially for understanding instances of human error, often a great deal rests on investigators' interpretations or analysts' interpretations of what a pilot said, or what was meant by what was said, or how talk was understood, or how the mood in the cockpit or the pilots' working relationship could best be described. Conversation analysis can be a tool for making such interpretations. A particular value of conversation analysis as a qualitative method is that it can be applied to even very small amounts of data, even a single exchange of turns. By drawing on transcription and analytic methods arising from conversation analysis, it is possible to eschew attempts to "get into people's heads" and conjecture what they are thinking and feeling. Actually analyzing language in use in aviation, or any other work setting, can involve much more than classifying and counting this or that type of utterance or action. It can involve seeing how language emerges in interaction in context, and serves to create context. ■

[FSF editorial note: To ensure wider distribution in the interest of aviation safety, this report has been reprinted from the Australian Transport Safety Bureau (ATSB) publication *A Context for Error: Using Conversation Analysis to Represent and Analyse Recorded Voice Data*, Aviation Research Report B2005/0108, June 2005. Some editorial changes were made by FSF staff for clarity and for style. Maurice Nevile, Ph.D., is affiliated with the Division of Business, Law and Information Sciences at the University of Canberra (Australia), and Michael B. Walker, Ph.D., is with the ATSB.]

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On-board Fatalities Lowest Since 1984 for Large Commercial Jets

Boeing data assembled according to a new taxonomy created by an international team indicate that controlled flight into terrain and loss of control in flight were, by a considerable margin, the leading causes of on-board fatalities in accidents from 1987 through 2004.

— FSF EDITORIAL STAFF

Western-built, large commercial jet airplanes[1] were involved in 32 accidents worldwide in 2004, the same number as in 2003. The accidents included 14 hull-loss accidents[2] (Table 1, page 19), compared with 12 the previous year. The 180 on-board fatalities represented a 63 percent reduction from the 483 on-board fatalities in 2003 and was the lowest number since 1984 (Figure 1, page 20).

The data were published in the 2005 edition of the annual statistical summary by Boeing Commercial Airplanes.[3]

Half of the 2004 accidents (16) occurred in the landing phase of flight. Nine accidents (28 percent) occurred during takeoff, four (13 percent) during taxi, two (6 percent) in climb or initial climb, and one in cruise.

Flight hours and departures both increased for Western-built, large commercial airplanes in 2004. Flight hours totaled 37.1 million and departures totaled 17.5 million, compared with 33.9 million and 16.9 million, respectively, in 2003. The number of airplanes in the category increased to 19,077 in 2004 from 17,991 in 2003.

Data for accident rates by the number of years following introduction of each generation[4] of large commercial jet showed that accident rates were highest among first-generation jets in the first five years and again after being in service for more than about 30 years (Figure 2, page 20). By comparison, the current generation showed its highest accident rate in the first two years of service and the lowest accident rate of all generations in nearly all of the following 23 years.

According to the Boeing data, the 10-year hull-loss and/or fatal-accident rate for scheduled passenger operations was 0.88 per million departures and 2.55 per million departures for all other operations (unscheduled passenger and charter, cargo, ferry, test, training and demonstration).

Figure 3 (page 21) shows hull-loss rates and/or fatal accident rates by airplane type. The current generation of large commercial jets (11 types with

Continued on page 21

Table 1
Worldwide Commercial Jet Airplane Accidents, 2004*

Date	Airline	Airplane Type	Accident Location	Hull Loss	Fatalities	Phase	Description
01-Jan-04	Japan Air System	MD-81	Tokunoshima, Japan		0	Landing	Main landing gear collapsed
03-Jan-04	Flash Airlines	B-737-300	Sharm El-Sheikh, Egypt	X	148	Climb	Airplane struck terrain after takeoff
05-Jan-04	Austrian Airlines	F70	Munich, Germany	X	0	Landing	Emergency landing in field
15-Jan-04	Iran Air	B-747-SP	Beijing, China		0	Landing	Nose landing gear collapsed
19-Jan-04	Air Malta	A320-210	Malta		0	Taxi	Collision with light pole
20-Feb-04	Austral — Cielos del Sur	MD-81	Buenos Aires, Argentina		0	Takeoff	Main landing gear wheels departed
25-Feb-04	First Air	B-737-200C	Edmonton, Canada		0	Landing	Offside landing
01-Mar-04	Pakistan International Airlines	A300-B4	Jeddah, Saudi Arabia	X	0	Takeoff	Nose landing gear tire failure
02-Apr-04	Air Memphis	B-707-300	Cairo, Egypt	X	0	Takeoff	Right main landing gear collapsed
09-Apr-04	Emirates	A340-313X	Johannesburg, South Africa		0	Takeoff	Takeoff overrun, go-around
20-Apr-04	Alitalia	MD-82	Trieste, Italy		0	Taxi	Collision with dump truck
27-Apr-04	Aerosvit	B-737-500	Moscow, Russia		0	Takeoff	Runway excursion, nose landing gear collapsed
28-Apr-04	Centurion Air Cargo	DC-10-30F	Bogota, Colombia	X	0	Landing	Landing overrun
29-Apr-04	Turkish Airlines	B-737-800	Gaziantep, Turkey		0	Landing	Runway excursion
13-Jun-04	Turkish Airlines	A321-210	Istanbul, Turkey		0	Landing	Hard landing, tail strike
17-Jun-04	EgyptAir	A300-B4-200F	Khartoum, Sudan		0	Landing	Hard landing, runway overrun
06-Jul-04	Iberia Airlines	A319-110	San Pedro Sula, Honduras		0	Landing	Veered off runway
21-Jul-04	Aero California	DC-9-14	Mexico City, Mexico	X	0	Takeoff	Settled after takeoff
25-Jul-04	Inter Airlines	F100	Istanbul, Turkey		0	Landing	Main landing gear collapsed
03-Aug-04	Volare Airlines	A320-210	Valencia, Spain		0	Initial Climb	Severe hail damage
09-Aug-04	Swiss	BAe RJ100	Frankfurt, Germany		0	Cruise	Dual engine damage
11-Aug-04	Air Guinee	B-737-200	Free Town, Sierra Leone	X	0	Takeoff	Rejected takeoff, runway overrun
28-Aug-04	Transair Cargo	SA Caravelle	Gisenya, Rwanda	X	0	Landing	Landing overrun, post-accident fire
08-Oct-04	Biman Bangladesh Airlines	F28	Sylhet, Bangladesh	X	0	Landing	Landing overrun
14-Oct-04	MK Airlines	B-747-200	Halifax, Canada	X	7	Takeoff	Struck terrain after takeoff
23-Oct-04	BETA	B-707-300	Manaus, Brazil	X	0	Taxi	Right main landing gear collapsed
07-Nov-04	Air Atlanta Icelandic	B-747-200F	Sharjah, United Arab Emirates	X	0	Takeoff	Rejected takeoff, runway overrun
07-Nov-04	AirAsia	B-737-300	Kota Kinabalu, Malaysia		0	Landing	Runway excursion
28-Nov-04	KLM-Royal Dutch Airlines	B-737-400	Barcelona, Spain	X	0	Landing	Runway excursion
30-Nov-04	Lion Air	MD-82	Solo City, Indonesia	X	25	Landing	Struck terrain during landing
09-Dec-04	ASTAR	B-727-200	Atlanta, Georgia, U.S.		0	Taxi	Main landing gear collapsed after landing
29-Dec-04	Chanchangi Airlines	B-727-200	Lagos, Nigeria		0	Landing	Nose gear–up landing
32	**Total**			**14**	**180**		

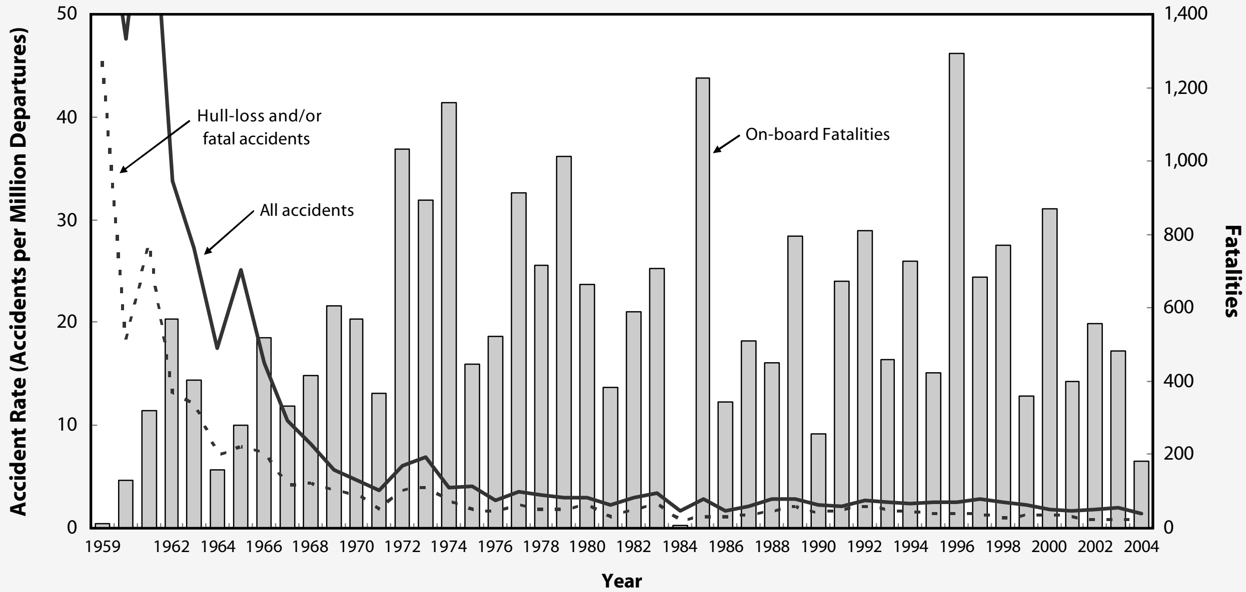
A = Airbus B = Boeing BAe = British Aerospace DC = Douglas F = Fokker MD = McDonnell Douglas SA = Sud Aviation

*The data apply to commercial jet airplanes worldwide that are heavier than 60,000 pounds/27,000 kilograms maximum gross weight. Commercial airplanes operated in military service and airplanes manufactured in the Soviet Union or the Commonwealth of Independent States are excluded.

Source: Boeing Commercial Airplanes

Figure 1

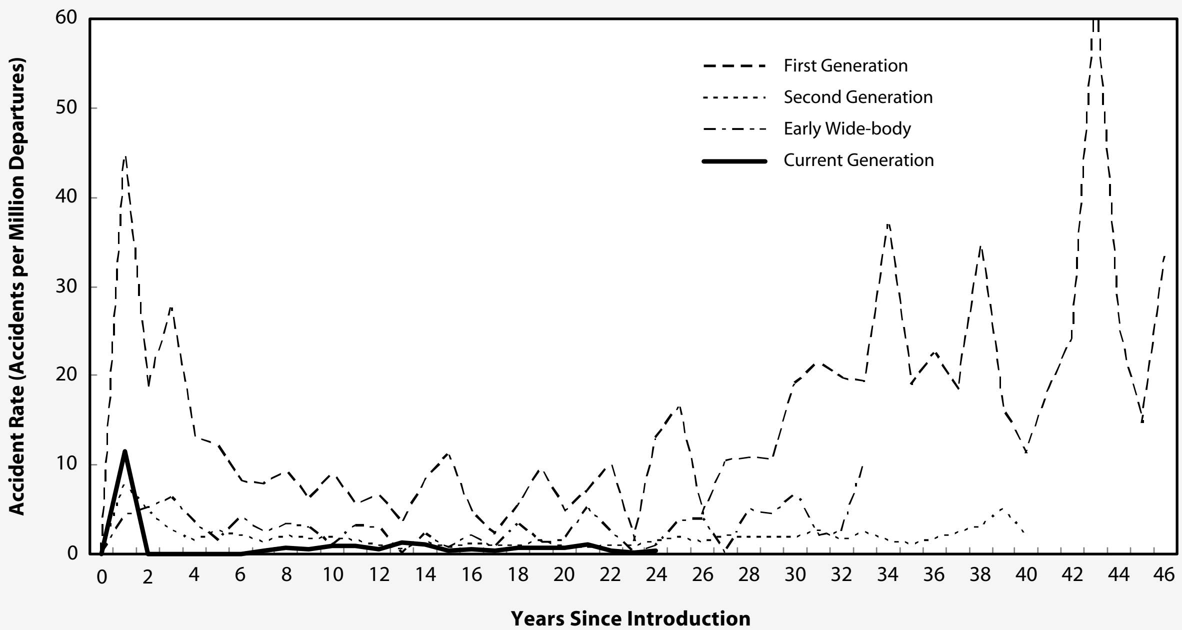
Accident Rates and Fatalities by Year, Worldwide Commercial Jet Fleet, 1956 Through 2004



Source: Boeing Commercial Airplanes

Figure 2

Accident Rates by Years Following Introduction, Hull-loss and/or Fatal Accidents, Worldwide Commercial Jet Fleet, 1959 Through 2004

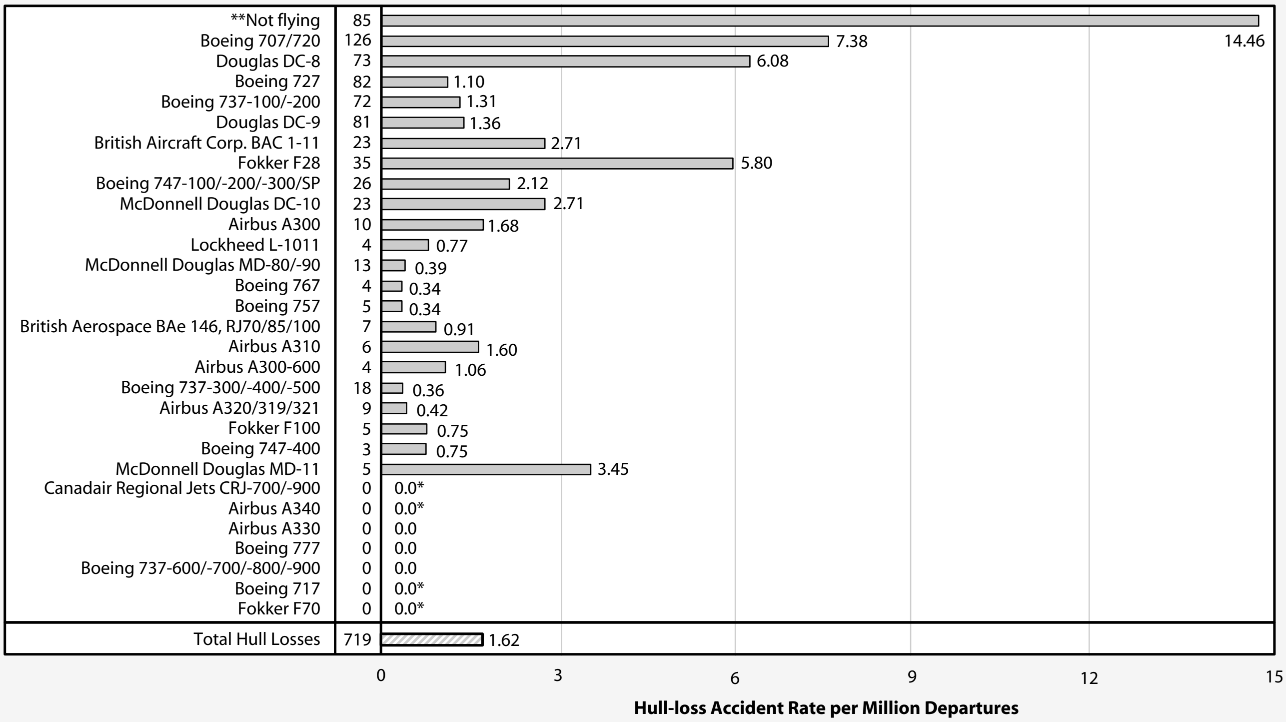


Note: Generations are defined as follows: First — Boeing 707 and 720; Convair 880 and 990; Dassault Mercure; de Havilland Comet 4; Douglas DC-8; and Sud Aviation Caravelle. Second — Boeing 727; British Aircraft Corp. BAC 1-11; Douglas DC-9; Boeing 737-100/-200; Fokker F28; Hawker Siddeley Trident; and Vickers VC-10. Early wide-body — Airbus A300; Boeing 747-100/-200/-300/SP; Lockheed L-1011; and McDonnell Douglas DC-10. Current — Airbus A310, A300-600, A330, A340; BAe 146, RJ70/85/100; Boeing 757, 767, 737-300/-400/-500/-600/-700/-800/-900, 717, 747-400, 777; Canadair Regional Jets CRJ-700/-900; Fokker F70, F100; and McDonnell Douglas MD-80/-90, MD-11.

Source: Boeing Commercial Airplanes

Figure 3

Accident Rates by Airplane Type, Hull-loss and/or Fatal Accidents, Worldwide Commercial Jet Fleet, 1959 Through 2004



* These types have accumulated fewer than one million departures.

** The Comet, CV-880/-990, Caravelle, Concorde, Mercure, Trident and VG-10 are no longer in commercial service, and are combined in the "Not flying" bar.

Source: Boeing Commercial Airplanes

sufficient departure data available) had lower hull-loss rates (an average of less than one per million departures) than 11 earlier-generation types that remained in commercial service (an average of three per million departures).

Data for hull-loss accidents and/or fatal accidents by phase of flight for the 10-year period 1995–2004 (Figure 4, page 22) show that approach and landing accounted for 4 percent of typical flight time ("exposure" based on an assumed flight duration of 1.5 hours); approach-and-landing accidents comprised 51 percent of the total and resulted in 16 percent of the fatalities.

Takeoff and initial climb — 2 percent of flight time — were the phases of flight for 20 percent of accidents and 25 percent of fatalities. Among the phases of flight, the highest percentage of fatalities occurred in accidents during climb following retraction of the flaps, a phase that comprised 14 percent of flight time. Accidents during climb resulted in 28 percent of fatalities and 9 percent of accidents.

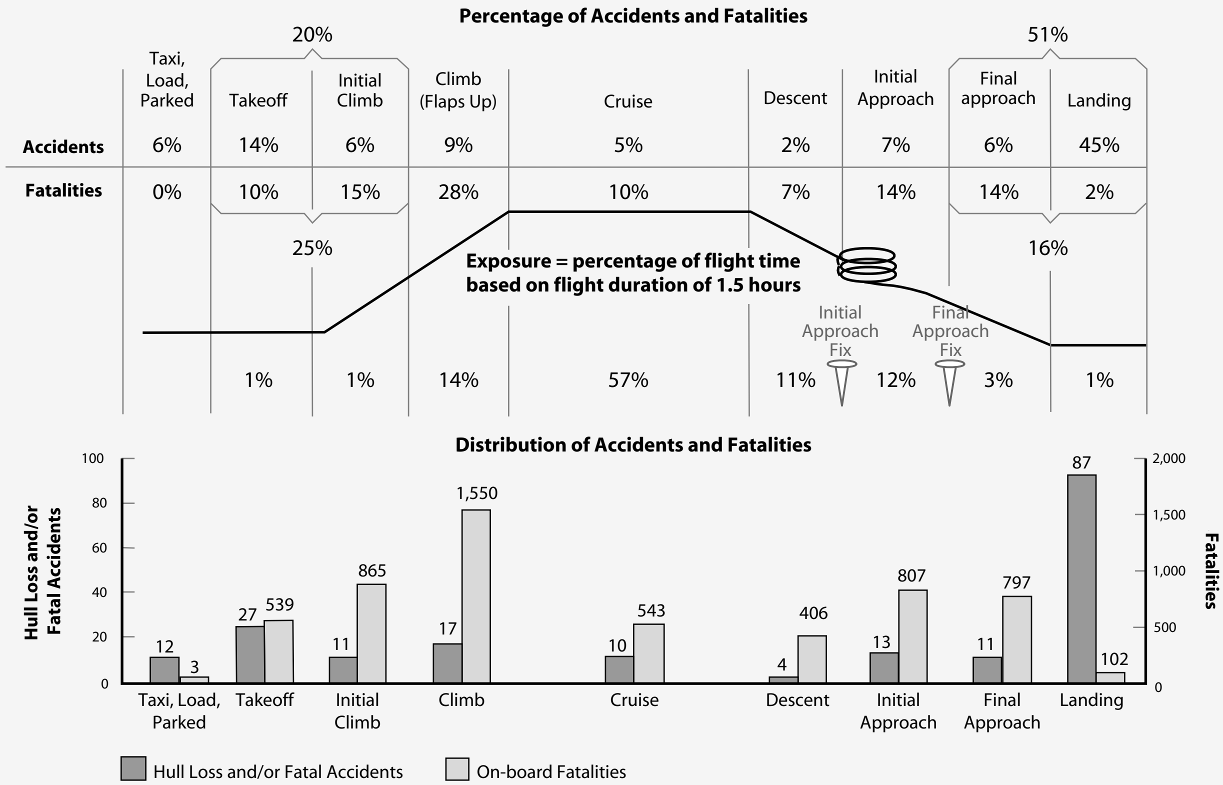
Fatal accidents in the 1987–2004 period were categorized according to a taxonomy of causal factors devised by the U.S. Commercial Aviation Safety Team (CAST) and the International Civil Aviation Organization (ICAO) Common Taxonomy Team (CICTT; Figure 5, page 23).5 The largest number of on-board fatalities (3,631, or 38 percent of the total of 9,541) and the largest number of fatal accidents (56, or 25 percent of the total of 226) were attributed to controlled flight into terrain (CFIT), defined by CICTT as "in-flight collision or near-collision with terrain, water or obstacle without indication of loss of control." The second largest category was loss of control in flight (LOC-I in the CAST-ICAO taxonomy), defined by CICTT as "loss of aircraft control while in flight." LOC-I was responsible for 2,524 fatalities (26 percent of the total) and 36 fatal accidents (16 percent of the total).

Other categories, ranked in descending order of on-board fatalities, were system/component failure or malfunction (non-powerplant), fire/smoke (non-impact) and system/component failure or malfunction (powerplant).

For the first time in the 1983–2004 period, no large commercial jet was subject to sabotage or terrorist acts,

Figure 4

Accidents and On-board Fatalities by Phase of Flight, Hull-loss and/or Fatal Accidents, Worldwide Commercial Jet Fleet, 1995 Through 2004



Source: Boeing Commercial Airplanes

categorized as hostile actions. It was the second successive year when there were no on-board fatalities caused by hostile actions; the last such act occurred May 7, 2002, when a China Northern Airlines McDonnell Douglas MD-82 struck the sea near Dalian, China, with 112 fatalities, following a cabin fire believed to be the result of arson.

Non-hostile events in 2004 (excluded from this article) were responsible for injuries, aircraft damage and one fatality, Boeing said. Severe turbulence resulted in no injury in eight events; flight attendant injury in seven events; passenger injury in four events; both passenger and flight attendant injury in eight events; and minor injury (not otherwise specified) in three events.

Ground operations comprised five events in which an airplane was damaged while taxiing, by striking another airplane, a ground vehicle or a jetway; four events in which an airplane was damaged by foreign object debris; one fatality caused by engine ingestion; and three events in which crewmembers or maintenance personnel fell.

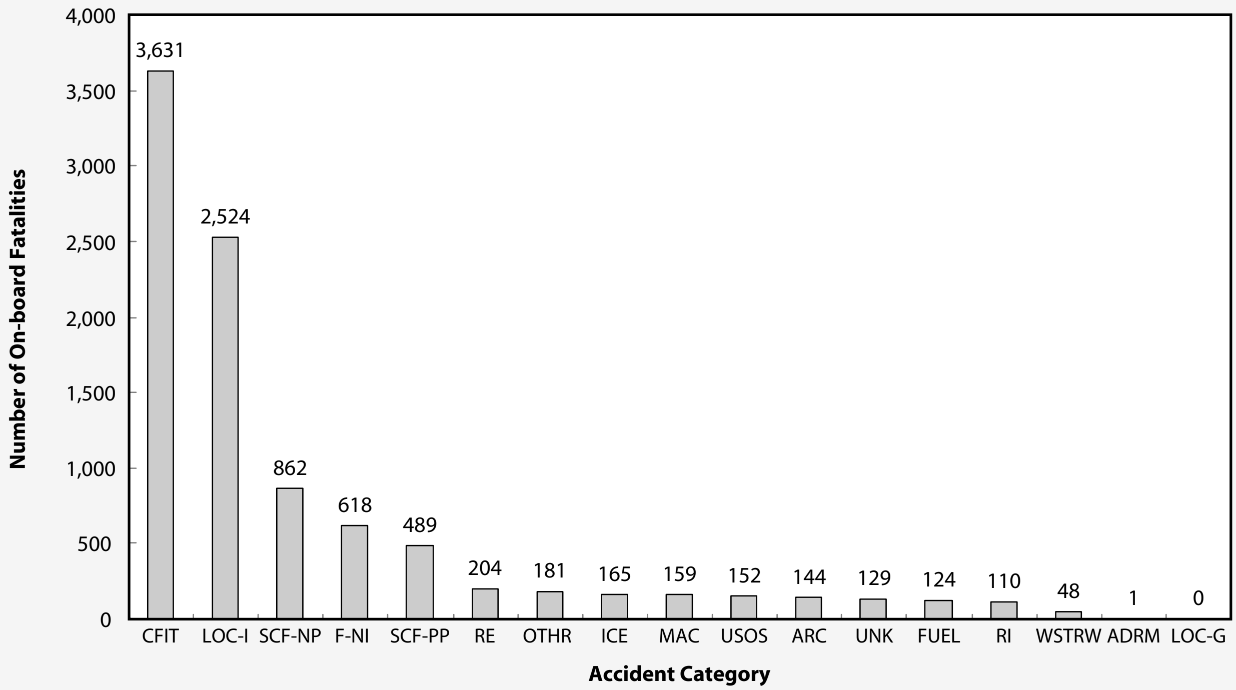
Emergency evacuations resulted in minor injuries in three events.■

Notes

1. The data represent commercial jet airplanes worldwide with maximum gross weights more than 60,000 pounds/ 27,000 kilograms. Commercial airplanes operated in military service and airplanes manufactured in the Soviet Union or the Commonwealth of Independent States were excluded because of the unavailability of operational data.
2. A *hull-loss accident* was defined as one resulting in "airplane damage that is substantial and is beyond economic repair. Hull loss also includes events in which the airplane is missing; search for the wreckage has been terminated without it being located; [or the] airplane is substantially damaged and inaccessible."
3. The publication, *Statistical Summary of Commercial Jet Airplane Accidents, Worldwide Operations, 1959–2004*, can be downloaded on the Internet at <www.boeing.com/news/techissues/>. Some data in this article from earlier years are derived from previous editions of the Boeing publication.
4. Generations were defined as follows: First — Boeing 707 and 720; Convair 880 and 990; Dassault Mercure; de Havilland Comet 4;

Figure 5

Fatalities by CAST/ICAO Taxonomy Accident Category, Fatal Accidents, Worldwide Commercial Jet Fleet, 1959 Through 2004



	CFIT	LOC-I	SCF-NP	F-NI	SCF-PP	RE	OTHR	ICE	MAC	USOS	ARC	UNK	FUEL	RI	WSTRW	ADRM	LOC-G
Number of Fatal Accidents 266 TTotal →	56	36	12	10	15	19	3	6	2	10	39	2	8	3	3	1	1

CAST = U.S. Commercial Aviation Safety Team ICAO = International Civil Aviation Organization

Note: CAST/ICAO accident categories are as follows: ARC = abnormal runway contact; ADRM = aerodrome; CFIT = controlled flight into terrain or toward terrain; F-NI = fire/smoke (non-impact); FUEL = fuel-related; ICE = icing; LOC-G = loss of control — ground; LOC-I = loss of control — in flight; MAC = midair/near-midair collision; OTHR = other; RE = runway excursion; RI = runway incursion; SCF-NP = system/component failure or malfunction (non-powerplant); SCF-PP = system/component failure or malfunction (powerplant); USOS = undershoot/overshoot; UNK = unknown or undetermined; WSTRW = wind shear or thunderstorm.

Source: Boeing Commercial Airplanes

Douglas DC-8; and Sud Aviation Caravelle. Second — Boeing 727, British Aircraft Corp. BAC 1-11; Douglas DC-9; Boeing 737-100/-200; Fokker F28; Hawker Siddeley Trident; and Vickers VC-10. Early wide-body — Airbus A300; Boeing 747-100/-200/-300/SP; Lockheed L-1011; and McDonnell Douglas DC-10. Current — Airbus A310, A300-600, A330, A340; British Aerospace (BAe) 146, RJ-70/-85/-100; Boeing 757, 767, 737-300/-400/-500/-600/-700/-800/-900, 717, 747-400, 777; Canadair Regional Jets CRJ-700/-900; Fokker F70, F100; and McDonnell Douglas MD-80/-90, MD-11.

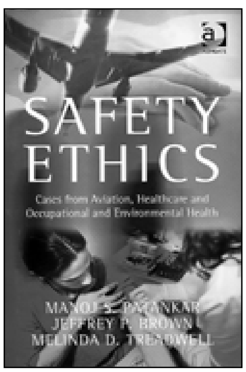
5. The U.S. Commercial Aviation Safety Team (CAST), which includes regulatory officials and aviation industry representatives, and the International Civil Aviation Organization (ICAO) chartered the CAST/ICAO Common Taxonomy Team (CICTT). CICTT includes specialists from air carriers, aircraft manufacturers, engine manufacturers, pilot unions, regulatory authorities, accident investigation boards and other interested parties. The CICTT Internet site is <http://intlaviationstandards.org>.

STATS

Ethics Is a Safety Issue

‘Data smoothing,’ ‘pencil whipping,’ ‘normalization of deviance’ — they’re all tempting shortcuts against which aviation personnel must take a principled stand in a safety culture.

—FSF LIBRARY STAFF



Books

Safety Ethics: Cases from Aviation, Healthcare and Occupational and Environmental Health. Patankar, Manoj S.; Brown, Jeffrey P.; Treadwell, Melinda D. Aldershot, England: Ashgate Publishing, 2005. 246 pp. Figures, tables, appendix, index.

In their preface, the authors say that in studying the industries that are their respective specialties, they discovered that day-to-day decision making involved ethical issues at the personal, organizational and public-policy levels.

Despite working in one of the most heavily regulated industries in the world, where there seems to be a law, procedure or company policy that applies to every situation, aviation professionals still face ethical decisions — most related to “conflicting priorities such as safety versus economic survival or speed versus accuracy,” says Patankar, author of the introduction and the three chapters about ethics in aviation. “In general, the industry provides the safest mode of transportation, but it is plagued by the ferocious need to survive in the face of harsh economic pressures.”

In his chapter, “Ethical Challenges in Aviation Maintenance,” Patankar says that the ethical challenges can be categorized under three general headings:

- *Data smoothing*. Patankar describes this technique as “falsify[ing] data so that it is within certain allowable limits. For example, when a mechanic torques a bolt to 20 inch-pounds when the manual clearly states that the torque should be 21–23 inch-pounds. The mechanic limited his torque to 20 inch-pounds because he could not physically torque it to the prescribed range, or in a previous attempt when he did torque it to the prescribed level, the bolt sheared. Instead of reporting this problem to the supervisor, he decided that it was okay to under-torque the bolt.”

- *Pencil whipping*. “‘Pencil whipping’ is signing for a job that has not been performed,” says Patankar. “In part, pencil whipping is an unintentional snowballing of a longstanding industry norm. … However, acute resource limitations and poor organizational safety culture have led to severe cases of pencil whipping, wherein multiple job/task cards have been falsely and intentionally signed off as complete. Such large-scale or routine pencil whipping takes place mainly due to lack of resources. In a desperate need to keep the airplanes flying on schedule while fighting the gruesome fare wars, managers are forced to 'accomplish' maintenance checks in a fraction of the required time and also with a fraction of the human resources and parts required to accomplish such checks in accordance with the manufacturer's recommendations."

- *Not knowing when to act.* Patankar says, "Procedural violations in aviation maintenance are inevitable because (a) there are just too many procedures, (b) maintenance procedures are part of federal regulations, (c) it is practically impossible for management or the FAA to ensure consistent compliance [and] (d) increased emphasis on on-time performance rather than safety has encouraged shortcuts. So, procedural violations occur on the part of all parties: mechanics, managers, stores personnel, planners, utility personnel [and] ramp agents."

Patankar credits another researcher, Diane Vaughan, with coining the term *normalization of deviance* to describe a gradual drift from published procedures or required procedures that is reinforced each time a slight deviation creates no immediate negative consequence. It then becomes a baseline for further deviations that in turn become norms.

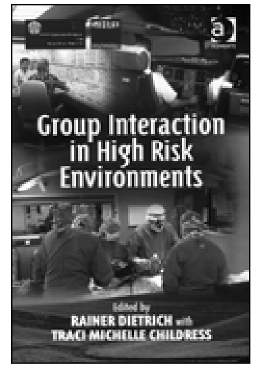
"Many mechanics tend to complain about a drastic deterioration of safety ethics — everything seems to be focused on survival, trying to make the company last for one more quarter or fiscal year," says Patankar.

Nevertheless, despite the pressure that some say they work under, the maintenance technicians interviewed by the author were adamant in asserting that they maintain the ethical standards of their profession.

In another chapter that discusses the ethical responsibilities of aviation educators, regulators and organizations, Patankar notes that regulatory authorities, trade unions and pilot unions have professional codes of conduct that they take seriously. And he notes that airline management's steps to transform a "blame" culture into a "reporting" culture through programs such as the U.S. industry's Aviation Safety Action Program (ASAP) have helped labor, management and regulators work together so that they can all be "in the picture" rather than engage in an adversarial situation.

"In general, the practice of ethical behavior seems to be associated with the notion of trust building," says Patankar. "Alaska Airlines, for example, goes to great lengths to emphasize the importance of ethical behavior throughout their organization and presents such conduct as imperative to the survival of the individual as well as the organization."

Group Interaction in High Risk Environments.
Dietrich, Rainer; Childress, Traci Michelle (editors). Aldershot, England: Ashgate Publishing, 2004. 299 pp. Figures, tables, appendixes, bibliography, index.



The book is the product of an interdisciplinary project, Group Interaction in High Risk Environments (GIHRE), underwritten by the Gottlieb Daimler and Karl Benz Foundation. Its purpose was to investigate group behavior in four representative workplaces, including the flight deck of a commercial airliner.

"The general scientific aim [was] to describe the interrelation between conditions of high task load and threat, as well as team members' behavior in such situations," say the editors.

The availability of a large body of cockpit voice recorder (CVR) transcripts from simulator sessions and accident investigation reports provides raw material to researchers for the many types of analysis described in the book.

Robert L. Helmreich and J. Bryan Sexton discuss the use of problem-solving communications on the flight deck. Problem-solving communications, described as "task-related communications regarding the management of threats and errors during a flight," include such sentences as the following:

- "And if we execute a missed approach, we have two procedures we could follow";
- "I don't want to dump any fuel, in case we might need it"; and,
- "Got a little bit of crosswind, not much, 240 at eight I believe he said."

The researchers say, "Problem-solving communications are a prime example of what distinguishes superior [performance] from substandard performance. For example, captains of high-performing crews used problem-solving utterances seven to eight times more often than their low-performing counterparts. Furthermore, there were no differences in how *high-performing* captains used problem-solving utterances as a function of workload. High-performing captains consistently devoted a third of their utterances to problem solving, whether it was a routine or an abnormal flight. In fact, the more frequent use of problem-solving utterances was not unique to outstanding captains — outstanding first officers and second officers used problem-solving utterances in approximately one-third of their overall communications."

In another chapter, Manfred Krifka discusses research about familiarity among crewmembers.

"Members of crews can be rather familiar with each other (as, typically, doctors and nurses in a hospital or operators in a power plant are), or they might be working together for the first time, as is often the case with pilots in big airlines," the author says. "Familiarity among crewmembers is advantageous, as members have knowledge about one another's behavior in general as well as in times of crisis. As a side effect, the frequency of communication becomes lower. But there are disadvantages to this situation: if a regular crewmember has to be temporarily replaced, the newcomer receives a special status. Familiarity among crewmembers may lead to a certain sloppiness in behavior that could possibly be avoided when crewmembers do not know one another well."

Reports

Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods. 2005–2006 edition. Doc. 9481. Montreal, Quebec, Canada: International Civil Aviation Organization (ICAO). Available from ICAO.*

More than 3,400 items, all listed in this report, are identified by ICAO as dangerous goods — capable, if improperly packaged or stowed, of producing smoke, toxic fumes and/or fire aboard an in-flight aircraft.

The guidelines in this publication describe principles for responding to dangerous-goods incidents in different types of cargo compartments and in passenger cabins. For example, the report says, "In general, water should not be used on a spillage or when fumes are present, since it may spread the spillage or increase the rate of fuming."

Both basic and expanded checklists are included for flight crewmembers and cabin crewmembers to consult in dangerous-goods incidents. The main part of the document is a chart of 11 emergency-response drills, describing the source of risk each is designed for, the nature of the risk (e.g., "high fire risk if any ignition source [is] present"), the spill or leak procedure and the fire-fighting procedure. Each dangerous-goods item number lists the correct drill to perform in response.

Relationship of the Aircraft Mix Index With Performance and Objective Workload Evaluation Research Measures and Controllers' Subjective Complexity Ratings. U.S. Federal Aviation Administration (FAA) Office of Aerospace Medicine. DOT/FAA/AM-05/16. Final report. August 2005. Pfleiderer, Elaine M. 16 pp. Tables, references, appendixes. Available via the Internet at <www.faa.gov> or from the National Technical Information Service (NTIS).**

Aircraft mix — the variety of aircraft with different performance characteristics in an air traffic control (ATC) sector — has been cited as a complexity factor in en route ATC. The study described in this report was designed to examine statistically the relationship of aircraft mix and traffic complexity. [This publication is the third in a series. Earlier studies were reported in Pfleiderer, *Multidimensional Scaling Analysis of Controllers' Perceptions of Aircraft Performance Characteristics* (DOT/FAA/AM-00/24, 2000); and Pfleiderer, *Development of an Empirically-based Index of Aircraft Mix* (DOT/FAA/AM-03/8, 2003)].

The Aircraft Mix Index, a scale of aircraft size and weight developed in an earlier study, was calculated for 36 30-minute samples of recorded data for low-altitude and high-altitude sectors, divided between en route control centers at Fort Worth, Texas, U.S., and Atlanta, Georgia, U.S. Three controllers individually viewed re-creations of the air traffic situation at two-minute intervals throughout the 30-minute sample time frames. They rated the complexity of the traffic on a scale from one to seven (lowest to highest).

The Aircraft Mix Index failed to contribute significantly to the prediction of controllers' complexity ratings. The report cautioned, however, that the results might not be generally applicable. It suggested that the aircraft mix's contribution to complexity might be mis-attributed by controllers, or that it might be a relevant factor in only a few sectors, but that in those sectors it might be a major contributor to complexity.

Regulatory Materials

Occupational Health and Safety On-board Aircraft: Guidance on Good Practice. U.K. Civil Aviation Authority (CAA). Civil Aviation Publication (CAP) 757. August 2005. 22 pp. References. Available on the Internet at <www.caa.co.uk> or from The Stationery Office.***

The guidance in the document is not mandatory, but "aircraft operators that observe its provisions will be following good practice and will normally find that this satisfies the provisions of the law," the CAP says.

The general principles for risk management include "eliminating the risk; replacing the dangerous by the non-dangerous or the less dangerous; combating risks at [the] source; developing a coherent overall prevention policy which covers technology, organization of work, working conditions, social relationships and the influence of factors relating to the working environment; adapting to technical progress; adapting the work to the individual; giving collective protection measures priority over individual protective measures; [and] giving appropriate training and instructions to staff," the CAP says.

Chapters include "Manual Handling Guidance" (concerning activities such as maneuvering carts and trolleys, opening and closing aircraft doors, and lifting passenger and crew baggage into stowage compartments); "Burns and Scalds in the Aircraft Cabin" (from hot liquids, foods and galley equipment); and "Slips, Trips and Falls Guidance" (addressing hazards such as slippery flooring, falling during turbulence encounters and open aircraft exits). A final chapter is devoted to incident reporting and investigation.

North American Route Program (NRP). U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 90-91J. July 30, 2005. 14 pp. Appendixes. Available from FAA via the Internet at <www.airweb.faa. gov>.

The NRP is a joint FAA and Nav Canada program, whose objective is to harmonize and adopt common procedures, to the extent possible, applicable to random-route flight operations at and above Flight Level 290 (about 29,000 feet) within the United States and Canada. The program allows aircraft operators to select operationally advantageous routings, based on factors such as minimum time, cost, fuel, weather avoidance and aircraft limitation.

This AC describes the approved procedures for flight operation according to the NRP. Aircraft participating in the NRP remain limited to a route that can be flown in accordance with the communication and navigation equipment aboard the aircraft.

Appendixes define the departure procedures and standard terminal arrival routes for listed airport areas.

[This AC cancels AC 90-91H, dated July 30, 2004.]

Identification and Registration Marking. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 45-2C. Aug. 5, 2005. 13 pp. Tables. Available from FAA via the Internet at <www.airweb.faa. gov>.

The AC offers guidance in complying with the requirements for identifying aircraft, aircraft engines or propellers with identification plates and identifying aircraft with nationality and registration marks as detailed in U.S. Federal Aviation Regulations Part 45, *Identification and Registration Marking*.

[This AC cancels AC 45-2B, dated July 16, 2003.] ■

Sources

* International Civil Aviation Organization
Document Sales Unit
999 University St.
Montreal, Quebec, Canada H3C 5H7
Internet: <http://icaodsu.openface.ca>

** National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161 U.S.
Internet: <www.ntis.gov>

*** The Stationery Office (TSO)
P.O. Box 29
Norwich NR3 1GN U.K.
Internet: <www.tso.co.uk>

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Flight Crews Cleared for Near-simultaneous Takeoffs From Intersecting Runways

A preliminary report from the U.S. National Transportation Safety Board quotes the first officer as saying that the captain delayed rotation of their Boeing 737 as an Airbus A330 passed overhead with 'very little separation.'

— FSF EDITORIAL STAFF

The following information provides an awareness of problems through which such occurrences may be prevented in the future. Accident/incident briefs are based on preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.

AIR CARRIER

Clearances Issued by Two Controllers

Airbus A330. No damage. No injuries, Boeing 737. No damage. No injuries.

Daytime visual meteorological conditions prevailed at an airport in the United States when two controllers in the airport's air traffic control tower cleared the crews of two airplanes for departure from intersecting runways.

At 1939:10 local time, one controller cleared the Airbus crew for takeoff on Runway 15R for a flight to Ireland; five seconds later, the other controller cleared the Boeing crew for takeoff from Runway 9 for a domestic flight.

"The copilot of [the B-737] reported that he had called 'V_1' [critical engine failure speed] and then noticed the [Airbus] rotating just prior to the intersection of [Runway] 15R and [Runway] 9," the report said. "He told the captain to 'keep it down' and pushed the control column forward.

"He further stated, 'The Airbus passed overhead our aircraft with very little separation, and once clear of the intersection, the captain rotated, and we lifted off toward the end of the runway. I reported to departure control that we had a near miss, at which time [a flight crewmember in the Airbus] reported, 'We concur.'"

Landing Airplane Departs Runway After Uncommanded Turn

Boeing 737. No damage. No injuries.

Daytime meteorological conditions prevailed for the landing at an airport in Sweden. After the airspeed decreased to about 60 knots and the captain took control of the airplane to taxi to the terminal, the airplane yawed right. The captain used nosewheel steering, rudder and differential braking but was unable to steer the airplane back onto the runway centerline.

The airplane departed the runway to the right. The crew shut down the airplane, and passengers deplaned using the stairs.

The report said that the incident occurred "because the design of the nosewheel steering on this aircraft type permits a spontaneous turn without operation by the pilots. A contributory factor is that the aircraft manufacturer considers the malfunction to be acceptable if the failure rate is lower than [one per 100,000 flights]."

Airplane Strikes Passenger Steps

Boeing 767-200. Minor damage. No injuries.

After a flight from Russia to England, the flight crew was told to taxi the airplane to Stand [Gate] 32M, one of three parking positions available at Stand 32. Before the airplane's arrival, motorized passenger steps were positioned left of Stand 32, with adequate clearance for the aircraft to be taxied to Stand 32M, and parking aids were put in place.

As the airplane was taxied to the area, the crew turned toward Stand 32L, instead of Stand 32M. Ground personnel, believing that the parking aids had been positioned incorrectly, then moved the aids from Stand 32M to Stand 32L.

The incident report said, "With the aircraft now approaching Stand 32L, the aircraft's left wing was overhanging the inter-stand clearway on which the motorized steps were parked. The driver of the steps realized that the aircraft was approaching the wrong stand; he moved away from the steps and attempted to … attract the pilot's attention, without success."

The leading edge of the left wing struck the handrail of the motorized passenger steps.

The report said that during the incident, ground personnel failed to activate a "stop" button that would have told the flight crew to stop the airplane.

After the incident, the ground-handling agent "issued a notice to its entire staff about the use of the 'stop' button," the report said.

Crew Incorrectly Identified 'Rapid-exit' Taxiway

Bombardier Dash 8 Q400. Minor damage. No injuries.

Daytime visual meteorological conditions prevailed for the domestic flight in Denmark — the last of five flights for the flight crew that day — and the landing runway and taxiways at the destination airport were wet. The captain flew the airplane on an instrument landing system (ILS) approach; when the airplane crossed the runway threshold at 50 feet, the indicated airspeed was 134 knots, or 13 knots higher than recommended. The airplane touched down at an indicated airspeed of 131 knots, or 10 knots higher than recommended.

"Just before vacating Runway 22L, the flight crew was not sure that the present speed versus the remaining distance to Taxiway B5 was appropriate for vacating the runway," the report said. "At that time, it was the opinion of the flight crew that Taxiway B5 was a rapid-exit taxiway. The commander [captain] initiated the turnoff at Taxiway B5."

The airplane's groundspeed when being turned off the runway was about 60 knots. On the taxiway, the captain selected full reverse thrust on the left engine and partial reverse thrust on the right engine. The airplane departed the side of the taxiway at a groundspeed of 34 knots and traveled about 26 meters (85 feet) across soft grass before stopping. Passengers remained in their seats until a bus arrived to transport them to the terminal.

An investigation found that the "design and the presentation of Taxiway B5 in the operator's OM [operations manual] … might lead flight crews to think that Taxiway B5 is a rapid-exit taxiway," the accident report said. "The Danish AIB [Accident Investigation Board] believes that commuter aircraft often vacate [the runway] at Taxiway 5B … and that commuter flight crews consider Taxiway B5 to be a rapid-exit taxiway."

The OM did not discuss taxi speed limitations but said that aircraft should not turn from a slippery runway "until the speed was reduced to a safe level," the report said. "The Danish AIB does not find a final turnoff speed of 60 knots safe."

The report said that the crew's opinion that the taxiway was a rapid-exit taxiway, "combined with a decision making based on standard routines [instead of considering all operational parameters, such as the wet runway, high touchdown speed and calm wind] and a high turnoff taxi speed most likely caused the aircraft to run off the taxiway."

The report also said that fatigue "might have influenced" the captain's decision making.

Incorrect Part Cited in Landing-gear Collapse

Fairchild SA227-AC Metro III. Minor damage. Three minor injuries.

At the end of a scheduled domestic flight in Canada, the flight crew completed the approach and landing checklists and confirmed the landing-gear-down indication. They landed the airplane in a crosswind, with touchdown about 1,000 feet (305 meters) beyond the runway threshold.

As the airplane touched down, the left wing lowered and the propeller struck the runway. The airplane veered left, despite the crew's use of full right rudder and full right aileron. The crew applied maximum right wheel braking and shut down the engines as the airplane departed the runway and continued about 300 feet (92 meters) into a nearby grassy area. The nose landing gear and the right main landing gear were "torn rearwards," and the left main landing gear collapsed into the wheel well.

An investigation found that an incorrect roller, "of a smaller diameter and type," had been installed on the left main landing gear bell-crank assembly, the report said.

The maintenance technician (aviation maintenance engineer [AME]) believed that the roller had been "re-designed to alleviate roller breakage," the report said. In addition, "the AME did not follow established industry [practices] or company practices in checking the part number against the manufacturer's parts manual to ensure that the correct part was being installed. A rigging check was not completed, which likely would have established that the roller was undersized."

Pilot Reports No Braking Action Before Runway Overrun

Cessna 525 CitationJet. Substantial damage. One minor injury.

The pilot was flying the airplane in daytime visual meteorological conditions on a business flight in the United States. As he conducted a visual approach, clouds formed over the airport in association with a thunderstorm about 1.0 statute mile (1.6 kilometers) to 2.0 statute miles (3.2 kilometers) north of the airport. The pilot told air traffic control that he was conducting a missed approach and requested a global positioning system (GPS) approach to Runway 24.

After the approach, he landed the airplane "on the numbers," extended the flaps and applied full wheel brakes. The pilot said that braking action was "nil" and that he "could feel no braking at all." About one-third of the way along the runway, he attempted to reject the landing, but "the airplane did not accelerate as he expected," a preliminary accident report said.

The airplane rolled off the departure end of the runway and struck a fence.

Weather conditions at the time of the accident included winds from 160 degrees at 11 knots with gusts to 14 knots.

Turbulence Cited in Landing Accident

Piper PA-46-500TP Malibu Meridian. Substantial damage. No injuries.

Daytime visual meteorological conditions prevailed for the landing of the business flight at an airport in the United States. The pilot was conducting a final approach to land when, because of turbulence, he initiated a go-around.

During the second approach, the pilot again encountered turbulence. A loss of control occurred, and the airplane departed the runway to the right.

Both main landing gear collapsed, and the propeller struck the runway.

OTHER GENERAL AVIATION

Airframe Parachute System Credited With Averting Fatal Accident

Cirrus Design SR20. Substantial damage. No injuries.

Nighttime visual meteorological conditions prevailed for the flight in Canada. The pilot was flying the airplane through 8,800 feet when it veered left; the pilot corrected the heading and continued the climb.

About 45 seconds later, the airplane again veered left, and the pilot corrected the heading. Three minutes later, after the pilot leveled the airplane at 9,500 feet, the airplane rolled 90 degrees left. The pilot disconnected the autopilot as the airplane entered a spiral dive. The pilot was unable to recover the airplane from the dive, so he shut down the engine and deployed the airframe parachute system. The airplane descended to a steep mountainside; the pilot and three passengers were rescued the next morning by personnel in a military helicopter.

An investigation revealed that the airplane had been overweight during departure on a previous leg of the flight and for part of the occurrence leg and was "being operated outside of the envelope established by the manufacturer's flight testing," the report said. Investigators did not determine what caused the 90-degree roll.

The report said that the airframe parachute system probably prevented fatal injuries.

Pilots Encounter Aileron Control Resistance During Flight

Reims F 406. No damage. No injuries.

Daytime visual meteorological conditions prevailed for the fisheries patrol flight off the coast of Scotland in the North Sea. As the airplane was flown over a fishing vessel at 200 feet, the first officer banked the airplane 30 degrees left to allow another crewmember to take photographs. After completion of the pass, as the first officer attempted to return the airplane to straight-and-level flight, he encountered "a strong resistance" to aileron control inputs, the accident report said. As the first officer and the captain worked to resolve the problem, they found that excessive force was required to maintain the airplane in straight flight. They flew the airplane to 1,000 feet, where they found that turns to the right required normal control force, but returning the airplane to a wings-level attitude required "excessive effort when the control yoke was some three degrees to five degrees left of the central position," the report said.

The captain took control of the airplane, declared pan-pan, an urgent condition, and landed the airplane at a nearby airport.

"The control difficulties continued during the approach, with corrections to the left requiring considerable effort," the report said.

After the landing, the pilots encountered the same resistance on the controls until the first officer felt "a jolt, and the control restriction disappeared," the report said.

The crew suggested that a small object might have restricted movement of a related bell crank, lever or cable quadrant. No such object was found, however.

An investigation revealed that all four aileron attachment bearings were "stiff in operation," and that the race bearings were corroded, but there was no indication that the race bearings had seized or that their condition was responsible for the control restriction. Nevertheless, the manufacturer planned to issue a service bulletin for periodic inspections of aileron bearings and rudder bearings, the report said.

Landing Gear Fails After Repairs for Previous Wheels-up Landing

Glasair RG. Substantial damage. No injuries.

The owner-pilot was conducting an annual permit-renewal flight test following the completion of repairs after a wheels-up landing seven months earlier. An inspector had signed off the airplane as fit to fly.

After takeoff from an airport in England, the pilot observed that the nose landing gear indicator light was green, indicating that the nose landing gear was still extended. Observers on the ground said in radio transmissions that the landing gear appeared to be fully retracted and offered to take a closer look if the pilot conducted a low pass over the airport.

"He accepted," the final accident report said. "However, on the downwind leg, before doing the fly-by, the pilot decided to recycle the landing gear down and then up to see if the fault would clear. On doing so, the nose gear remained green throughout and both main landing gear functioned correctly.

"The pilot then decided that there was little point in doing the fly-by, so he selected the landing gear down and, on obtaining three greens, said that he was returning to land. As he had indications of the landing gear being down, he did not use the emergency lowering system."

Observers on the ground twice said that the landing gear appeared to be extended. After a normal approach, the airplane touched down on the main landing gear. The nose descended until the propeller struck the runway, and the airplane slid to a stop.

An inspection found that the nosewheel "failed to make its geometric lock due to the undercarriage pump motor locking out early when the nosewheel [indicator light] indicated green and had thus folded up under the aircraft."

The report said that there was no explanation of why the indicator light remained green after the landing-gear lever was moved to the up position.

ROTORCRAFT

Hard Landing Follows Approach in Ground Effect

Robinson R44 Raven II. Minor damage. No injuries.

Daytime visual meteorological conditions prevailed for the flight in South Africa to inspect cellular-telephone towers. The pilot flew the helicopter toward a tower, which was atop a ridge, and planned — because of the high temperature and high density altitude — to begin a final approach in ground effect.

As he turned the helicopter right, the main-rotor revolutions per minute (rpm) decreased, and an audio warning sounded. The rate of descent increased during the turn. The pilot realized that there was insufficient altitude to complete the turn into the wind; he leveled the rotors before touchdown. The main-rotor blades struck the tail boom during the hard landing.

The report said that the probable cause of the accident was that "the pilot attempted a landing in mountainous terrain, [and] while maneuvering the aircraft to land into wind, he allowed the main-rotor rpm to decay. He was unable to recover from the condition due to limited height being available, aggravated by rocky terrain, resulting in a hard landing and the main rotor contacting the tail boom."

Helicopter Strikes Terrain After 'Uncontrollable' Yaw

Eurocopter AS 350B2. Substantial damage. One serious injury, one minor injury.

Daytime visual meteorological conditions prevailed for the law enforcement flight in a mountainous region of the United States. The pilot and passenger were conducting an aerial search when the pilot flew a descent into the search area and began a shallow right turn, which placed the helicopter in a downwind position. The helicopter rotated five or six times to the left and struck the ground at an elevation of 4,900 feet above mean sea level.

The pilot said that he had encountered an "uncontrollable left yaw."

Other law enforcement personnel said that winds at the time of the accident were from the southwest at 14 knots to 20 knots with higher gusts. The temperature was 86 degrees Fahrenheit (30 degrees Celsius). ■

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Flight Safety Digest

 ISSN 1057-5588

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