Table 5.2—Number of errors made by captains and first officers in the accident flights, by crew position and crew function

Crew function	Captains	First Officers
Flying pilot	147	27
Non-flying pilot	21	92
Total	168	119

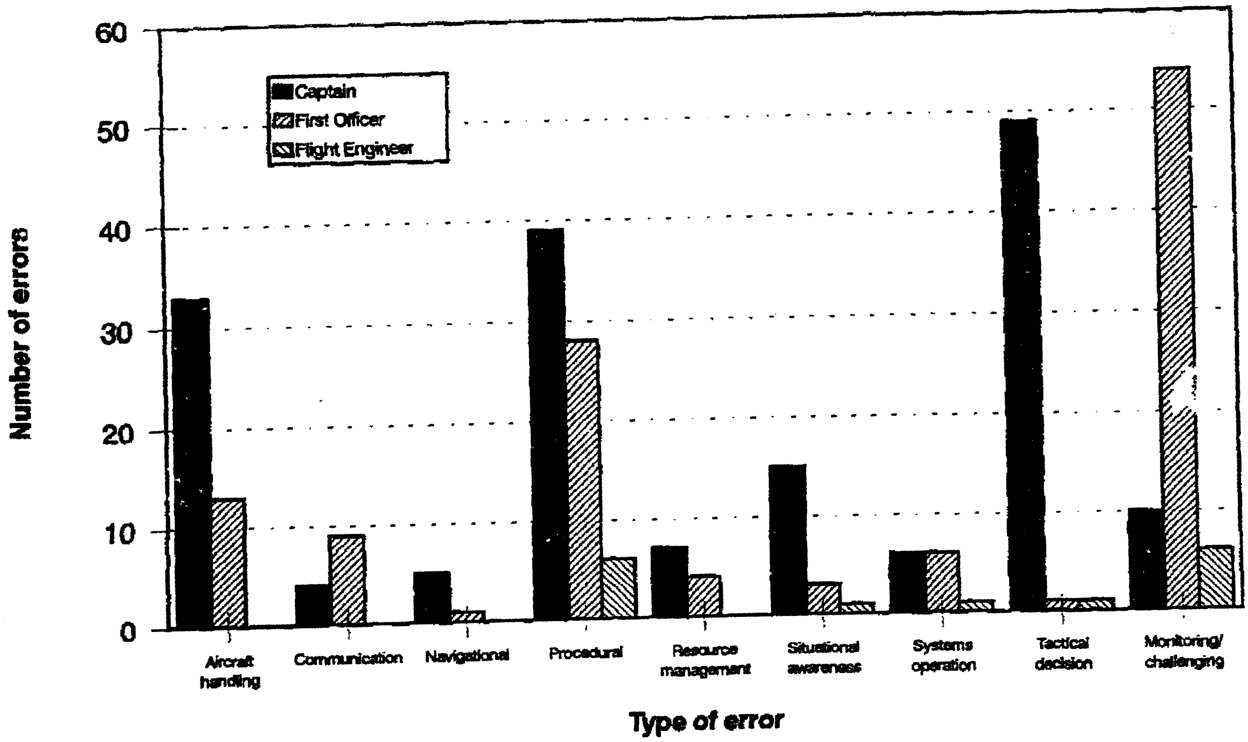

Figure 5.3--Number of errors, by type of error and crew position.

46 aircraft handling errors made by all crewmembers, which is consistent with the captains' serving as the flying pilot on more than 80 percent of the accident flights.

Of the 49 tactical decision errors made by captains, 44 (90 percent) were made while serving as flying pilot; 26 (59 percent) of these were errors of omission. Thus, the most common tactical decision error was the failure of a captain/flying pilot to take action when the situation demanded change.

Of the 26 tactical decision errors made by captains that were errors of omission, 16 (62 percent) involved the captain's failure to execute a go-around during approach. These 16 errors were made during 10 different accident sequences. Of the 16 failures to execute a go-around, 8 involved an unstabilized approach.[47]

Of the 119 errors made by first officers, 54 (45 percent) were monitoring/challenging errors, 29 (24 percent) were procedural, and 13 (11 percent) were aircraft handling. The 54 monitoring/challenging failures by first officers represented 77 percent of the 70 monitoring/challenging errors made by the accident crews, which is consistent with first officers' non-flying pilot function on more than 80 percent of the accident flights. First officers also made 9 of the 13 communication errors (69 percent).

Of the 15 errors made by flight engineers, 6 (40 percent) were procedural errors, and 6 were monitoring/challenging errors.

Monitoring/Challenging Errors

Monitoring the results of one's actions is an important ingredient in consistent, excellent performance of complex tasks. In flying, self-monitoring allows a pilot to recognize inadequate performance, observe changes in the operational environment, and take corrective action. Self-corrections may range from adjusting control inputs to reversing decisions.

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[47] Air carrier SOPs establish discrete points during approaches (for example, 500 feet above ground) at which flight parameters (rate of descent, airspeed, and airplane configuration) must fall within stated limits for the approach to be continued. Exceeding the limits at a discrete point is a cue that the approach is unstabilized and a go-around should be executed. In two accidents, the captain did not execute a go-around at more than one of these discrete points.

In air carrier operations, the monitoring task is shared by two or more crewmembers. This task is well-defined in the SOP of most air carriers; for example, by cross-checking instruments and through the challenge/response formats of critical checklists. The flying pilot is responsible for monitoring his or her own procedures and control inputs. In addition, operational redundancy is provided by the non-flying crewmember, who is given the task of monitoring the flying pilot. Similarly, because captains are responsible for final decisionmaking, the first officer (and flight engineer, if present) is given the task of monitoring the captain's decisions. In moving from only self-monitoring to monitoring another crewmember, whether monitoring a flying pilot's control inputs or a captain's decisions, the monitoring crewmember must also challenge the crewmember perceived to be making an error.

When this challenge is made, the error is caught. When, alternatively, an error is not challenged, the failure to challenge is, itself, an error made by the crewmember who did not monitor or challenge the earlier error. This monitoring/challenging failure is associated with the primary error that it failed to catch, yet it is a distinct error made by a different crewmember.

For the monitoring/challenging errors that were identified from the records of the 37 accidents, it was not possible to determine if primary errors were not caught because one crewmember did not detect or comprehend the other's error, or because one crewmember detected but did not challenge the other's error. The 37 accidents, nevertheless, yielded a substantial record of errors and associated failures by the monitoring crewmember(s) to challenge them.

Of the 302 errors identified in the 37 accidents, 70 (23 percent) were monitoring/challenging errors. This type of error was identified in 31 (84 percent) of the 37 accident sequences.

Most of the errors that were not monitored or challenged played very important roles in the accidents. For example, in one accident the captain did not equate the airplane's remaining fuel with time and distance from the airport, an error that was cited by the Safety Board as causal to the accident. Concurrently, the first officer failed to catch this causal error by not expressing his concern, in a timely manner, about the time remaining to fuel exhaustion. Among all 37 accidents, 53 (76 percent) of the 70 monitoring/challenging errors failed to catch errors that the Safety Board had identified as causal to the accident. An additional 12 monitoring/challenging failures (17 percent) were failures to catch errors that contributed to the cause of the accident.

The last error cited by the Safety Board as causal in an accident sequence often occurred at the time of the crew's final chance to avert the accident, or

Table 5.3—Distribution of unchallenged errors, by type of error, and comparison with the distribution of all primary errors

Type of error	Unchallenged errors		All primary errors[a]	
	Number of errors	Percent	Number of errors	Percent
Aircraft handling	9	12.9	46	19.8
Communication	5	7.1	13	5.6
Navigational	3	4.3	6	2.6
Procedural	11	15.7	73	31.5
Resource management	0	0	11	4.7
Situational awareness	13	18.6	19	8.2
Systems operation	1	1.4	13	5.6
Tactical decision	28	40.0	51	22.0
Total	70	100.0	232	100.0

[a] Primary errors are not dependent on making a prior error.

it was the primary error that made the accident inevitable. In 19 of the 37 accidents (51 percent), a monitoring/challenging error followed the last causal, primary error. For example, the captain's failure to level off at the minimum descent altitude (MDA) in one accident was the last in a sequence of errors that the Safety Board described as an "unprofessionally conducted non-precision instrument approach." In this accident, the first officer did not challenge the captain's descent below MDA. In 8 of the 19 accidents in which a monitoring/challenging error followed the last causal, primary error, the Safety Board also had included the monitoring/challenging failure in the probable cause. Thus, breakdowns in the monitoring/challenging function often were failures to correct the most serious errors made by flightcrews.

For each of the 70 monitoring/challenging failures, information was obtained on the nature and type of error that was not challenged. Regarding the nature, errors of omission accounted for 39 of the unchallenged errors (55 percent), whereas errors of commission accounted for 31 of the unchallenged errors (44 percent). Regarding types of errors, the highest percentage (40 percent) of the unchallenged errors were tactical decision errors, followed by situational awareness errors (nearly 19 percent) and procedural errors (about 16 percent) (table 5.3).

This distribution of unchallenged errors among error types was different from the overall distribution of primary errors. Table 5.3 shows the percentage of all primary errors made, by each error type, compared with the percentage of those errors that were not challenged. Most striking is that tactical decision errors (such as, "continued to hold and accepted a vector away from the airport") and situational awareness errors (such as, "failed to establish a time limit for beginning approach") constituted a much greater proportion of the unchallenged errors than they did of all primary errors.

Crew Assignment and Pattern of Errors

As discussed in chapter 4, more than 80 percent of the accidents involved crew assignment 1, in which the captain was the flying pilot and the first officer was the non-flying pilot. Even when the subset of accidents believed to be least biased toward crew assignment 1 was examined, 13 of the remaining 15 accidents (87 percent) involved crew assignment 1. In contrast, crew assignment 1 prevails during about 50 percent of all non-accident flights, based on the common practice among air carrier pilots of swapping flying duties on alternate flight legs.

Because such a small percentage of the accidents examined in this study involved crew assignment 2, it was not possible for the Safety Board to analyze differences in flightcrew performance with respect to crew assignment. In addition, the Safety Board was unable to determine any particular significance to, or draw any conclusions from, the high percentage of accidents that involved crew assignment 1. Nevertheless, many of the accidents involving crew assignment 1 demonstrated a consistent pattern of errors by captains and first officers.

Crew Assignment and Captain Decisionmaking.—The error type observed most frequently for captain/flying pilots in the 37 accidents was a tactical decision error (see figure 5.3). When serving as the flying pilot, captains must devote at least some of their attention and other cognitive resources to aircraft control. Research on captain decisionmaking suggests that captains take significantly more time to make decisions while flying the airplane than when they are the non-flying pilot. As part of a full-mission simulation experiment, NASA tested captains for the amount of time required to decide to shut down a malfunctioning engine.[48] Captain/flying pilots took more time to make the decision than captain/non-flying pilots.

Also, a captain/flying pilot who decides to make a change must perceive a need to change, then must alter his or her own current plan and behavior. The decision to change a course of action may be inhibited by overconfidence in ability or the earlier decision to engage in the ongoing course of action.[49] These dynamics probably were relevant in the eight accidents involving a failure to execute a go-around during unstabilized approaches.

Crew Assignment and First Officer Monitoring/Challenging.— Tactical decision errors were the error type most frequently associated with monitoring/challenging failures. Fifty-one tactical decision errors were identified in 25 of the 37 accidents; 28 of these errors were not challenged. Of these 28 unchallenged errors (which were identified in 17 of the accidents), 20 (71 percent) were errors of omission. The 20 tactical decision/errors of omission were identified in 13 accidents.

The tactical decision/errors of omission may be particularly difficult to catch, especially for first officers. In monitoring and challenging a captain's tactical decision error, a first officer may have difficulty both in deciding that the captain has made a faulty decision, and in choosing the correct time to question the decision. A first officer may be concerned that a challenge to a decision may be perceived as a direct challenge to the captain's authority. For example, challenging a captain's failure to execute a go-around may be much more difficult for a first officer to do, in a timely fashion, than challenging a straightforward procedural error whose correction is unarguable, such as failure to turn on a transponder prior to takeoff.

The error of omission (absence of action) may not call attention to itself as an error as readily as an error of commission. Also, in many situations there may be a period of seconds or minutes when action could be taken. Thus, there may be no distinct signal or cue that *now* is the time to speak up about another crewmember's error of omission, and a challenge may be deferred in hope that the error will be corrected soon.

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[48] Ruffell Smith (1979).

[49] Nagel, David C. 1988. Human error in aviation operations. In: Weiner, Earl L.; Nagel, David C., eds. Human factors in aviation. San Diego, CA: Academic Press, Inc.: 263-303. Chapter 9.