Research Identifies Common Errors Behind Altitude Deviations

Nearly 500 pilots and 48 air traffic controllers provided data in a recent study designed to analyze an alarming increase in altitude deviations.

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by
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Altitude deviations have been problems for pilots and air traffic controllers since the first days of instrument flight and air traffic control (ATC). Although the problem has been recognized and studied, the number of altitude deviations continues to increase and is of great concern to the aviation community.

An altitude deviation occurs when an aircraft is flown at an altitude that is not assigned by an air traffic controller. Typical of such situations are failure to level at the assigned altitude while ascending or descending; failure to maintain the assigned altitude; and failure to attain level flight at the assigned altitude by the time specified by ATC.

Reports from the U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) confirm that the number of altitude deviations is increasing. Data shown in Figure 1 (page 2) include reported altitude deviations across all ASRS "operator" categories (scheduled and supplemental carrier, fixed-base operator (FBO)/flying school, commuter, corporate, government, military, air taxi, charter, private and others) and for all ASRS "purpose of flight" categories (passenger, cargo, business, training, pleasure and miscellaneous). The chart indicates that the number of all altitude deviations in 1983 was nearly 570, but in 1990, altitude deviations increased to approximately 10,000 — a 17-fold increase in seven years. Altitude deviations caused by flight crews increased from 360 in 1983 to 8,840 in 1990 — a 24-fold increase. (The data does not take into account factors such as the amount of traffic or changes in the type aircraft flown.) There is no definitive explanation for the increase in altitude deviations, but reasons such as increasingly heavy air traffic controller workloads and a greater number of shorter flights have been suggested. Commercial aircraftdeviated from

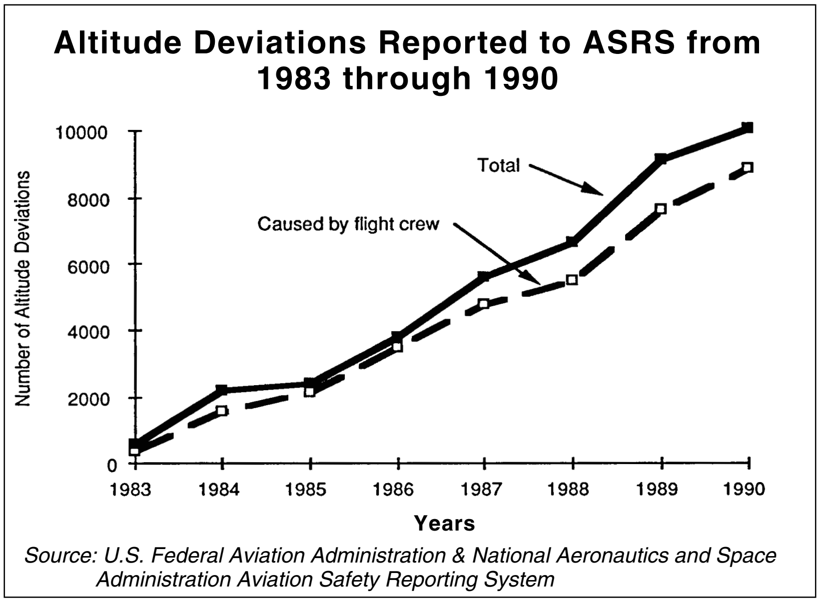


Figure 1

their assigned altitudes because of malfunctioning auto pilots and mode control panels (MCPs), miscommunication between pilots, and between pilots and air traffic controllers, issuance of incorrect altitude clearances by air traffic controllers and the transposition of expected and assigned altitudes by both pilots and air traffic controllers.

The U.S. Federal Aviation Administration (FAA) has released *Altitude Deviation Study: A Descriptive Analysis of Pilot and Controller Incidents*, an October 1992 document that delineates the findings of an FAA-funded human factors study that sought to acquire an understanding of causal factors related to altitude deviations. The study was conducted with USAir, an airline with an increasing number of altitude deviations during 1989 and 1990. The airline instituted an Altitude Awareness Program that was developed by USAir and the Air Line Pilots Association (ALPA). The study provided the opportunity for an air carrier, the pilots' labor union, air traffic controllers (and their labor union, the National Air Traffic Controllers Association [NATCA]) and the FAA to work together on a safety issue that is sensitive to regulatory discipline. Pilot and controller "incident reports" were developed and, to prompt responses, participants were "offered corrective action in lieu of certificate action" as long as the actions did not constitute a gross violation of FAA regulations or create a significant safety hazard.

The following summarizes the FAA study and concentrates on those altitude deviation factors deemed most important to pilots.

Altitude Awareness Program Outlined

In 1990, USAir was scheduling some 3,000 flights per day, the most of any U.S. airline, and, along with other major airlines, was experiencing an increasing number of altitude deviations. Figure 2 illustrates the estimated number of altitude deviation opportunities for USAir during 1990. The final number — 100 million — was derived from estimating the number of altitude deviation opportunities per altitude clearance, the number of altitude clearances per flight (10, which is probably a conservative figure for flights in the highly complex U.S. Northeast region airspace) and the number of flights per year.

The U.S. Altitude Awareness Program began in the fall of 1990 with three primary objectives: creating and implementing stan-

Estimated Number of Altitude Deviation Opportunities for USAir During 1990

$$\frac{\text{Altitude Deviation Opportunities}}{\text{Year}} = \frac{\text{Altitude Deviation Opportunities}}{\text{Altitude Clearance}} \times \frac{\text{Number of Altitude Clearances}}{\text{Flight}} \times \frac{\text{Number of Flights}}{\text{Year}}$$

$$\frac{\text{Altitude Deviation Opportunities}}{\text{Year}} = 10 \times 10 \times 1{,}000{,}000$$

$$\frac{\text{Altitude Deviation Opportunities}}{\text{Year}} = 100{,}000{,}000$$

Source: U.S. Federal Aviation Administration

Figure 2

dardized cockpit procedures to use with altitude clearances; generating heightened USAir pilot altitude awareness and introducing the altitude awareness procedures; and analyzing altitude deviation incidents to evaluate the altitude awareness procedures and to explore the potential causal factors of altitude deviations from a pilot'sperspective.

The USAir altitude awareness procedures addressed four issues:

1. **Accepting the ATC clearance**. This called for the pilot not flying (PNF) to accept the altitude clearance from ATC. The rationale was that the PNF typically was assigned the responsibility for communicating with ATC and that the PNF's workload was less than the workload of the pilot flying (PF), especially during the initial climb, descent and approach phases of flight.

2. **Setting the altitude alerter or MCP**. This required that the pilot in direct contact with ATC, usually the PNF, set the altitude alerter or MCP because the pilot in direct contact with ATC and not burdened by flying duties was less likely to err in setting the altitude alerter or MCP.

3. **Having the second pilot verify the assigned altitude**. The PNF, usually the pilot communicating (PC), announced the assigned altitude while simultaneously pointing to the assigned altitude set in the altitude alerter or MCP until the other pilot repeated the assigned altitude. This vertified the altitude assignment and the rationale was that, in most cases, the PF was also giving attention to the ATC clearance. By going through the verification process, the probability of entering the wrong altitude was reduced.

4. **Making a "1,000 feet-to-go" callout**. The PF was responsible for verbalizing that the aircraft was leaving the altitude that was 1,000 feet (303 meters) from the assigned altitude. The pilot might say "six thousand for seven thousand," or "three zero zero for two niner zero." The rationale was twofold. First, making the callout lessened the probability of an altitude deviation. Second, given that a callout was to be made, it was thought that the altitude awareness of the PF was enhanced by requiring that pilot to make the altitude callout.

By going through the verification process, the probability of entering the wrong altitude was reduced.

In September 1990, pilot incident data forms were distributed to each of the approximately 6,000 USAir pilots and when a pilot was involved in an altitude deviation incident, a form would be completed and submitted for analysis. Pilots were encouraged to report the incidents promptly so that the ATC communication tape (saved by the FAA for 15 days) could be reviewed if more information was needed or if there were questions about an ATC clearance assignment and pilot readbacks.

Educated Guesses Identified Causal Factors

As with most post hoc studies, determination of who caused the error and why was, at best, an educated guess based on the available information, which may have been incomplete or inaccurate. In the study, analysts based their analyses primarily on the written narratives supplied by the pilots and the controllers. ATC tapes and transcripts and pilot interviews were other sources of information.

After the data were collected, experts developed error categories and assigned them to individual incidents. During the error classification process, a conceptual framework was needed to accommodate error types that were being identified. Because the altitude assigned by ATC and the actual altitude of the aircraft were the bases for determining whether an altitude deviation occurred, the pilot and controller tasks involved in issuing, processing and implementing altitude clearances provided a common framework for discussing deviations and errors.

Figure 3 shows a simplified flow of the tasks that involve the issuance, processing and implementation of an altitude clearance and incorporates the USAir altitude awareness procedures. Usually, three individuals were involved in altitude clearances: the controller, the PC and the PF (sometimes the PC and PF were the same person). The PC listened for the call sign, received the clearance and then read back the clearance. At the same time, or within seconds, the PC also set the assigned altitude in the altitude alerter or MCP. The assigned altitude was then verified by both pilots verbally acknowledging and pointing at the newly

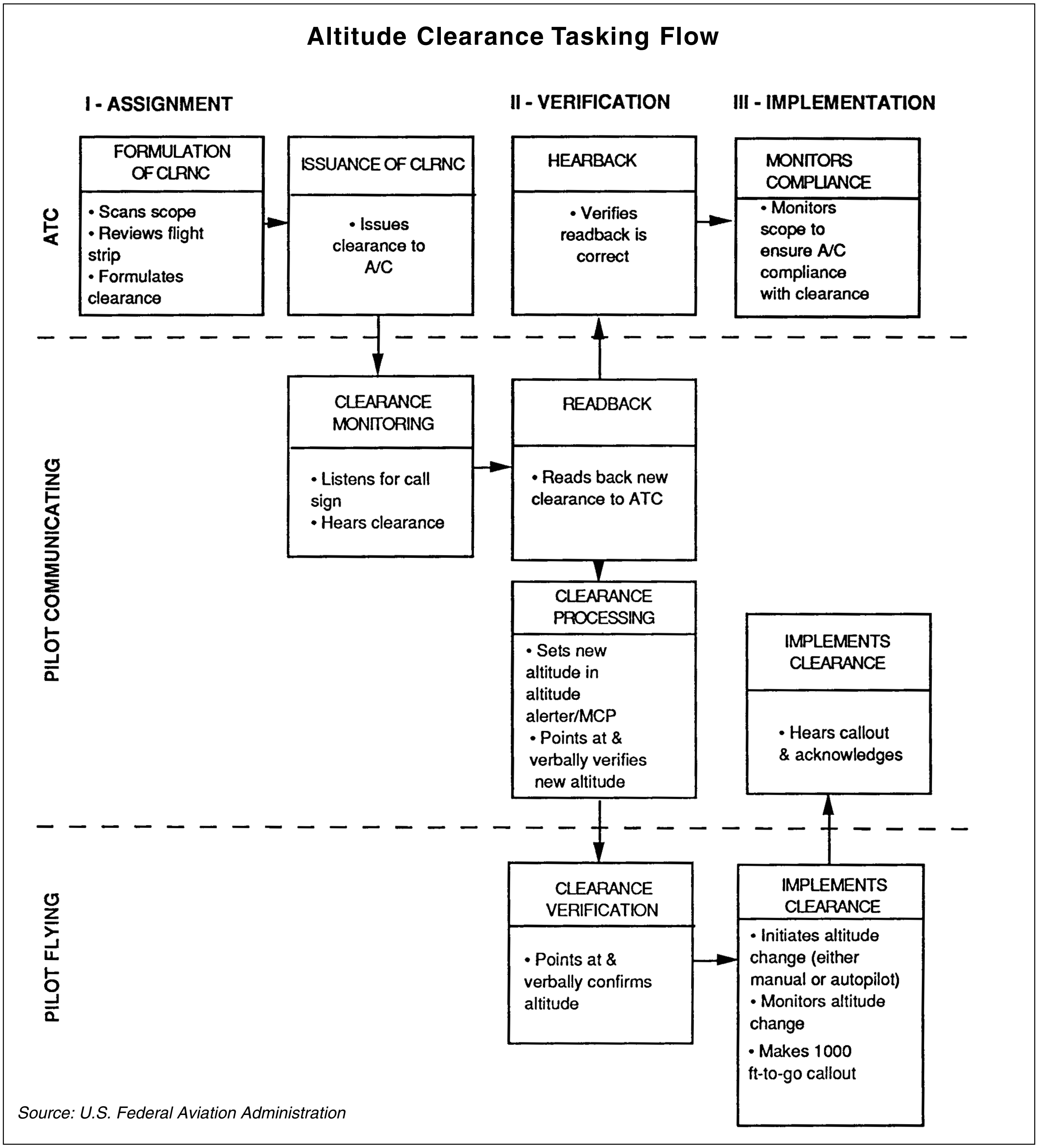


Figure 3

assigned altitude. The PF initiated the altitude change and monitored the aircraft climb or descent. At 1,000 feet, prior to the newly assigned altitude, the PF made the callout, which the other pilot acknowledged. During this time, the controller monitored the radar scope to ensure that the aircraft was complying with the altitude clearance.

Errors could occur at any point in the sequence, but because checks and balances were built into the system, the errors did not necessarily result in altitude deviations. However, if an error was followed by another error at one of the check points, an altitude deviation was likely. For example, the controller issues an altitude clearance to USA123 using the correct call sign. USA213 responds to the clearance and reads it back. USA123 does not respond. The controller, who is already planning the next control instruction, does not recognize the incorrect call sign and does not correct the improper readback. USA213 then deviates from its assigned altitude.

Mistakes are likely to occur when the decision requires the simultaneous consideration of more than two or three variables ...

Another way the built-in checks and balances can fail is illustrated in the following example. The controller issues an instruction to cross 10 DME [distance-measuring equipment] from a VOR [very high frequency omnidirectional radio range] at a specific altitude. The PC reads back the clearance correctly but transposes the DME numbers and altitude numbers when setting the MCP. The PF is performing other duties and does not hear the audio portion of the clearance. When the PF completes the other duties and directs attention to the altitude instructions, the PF accepts what is set in the MCP, resulting in an altitude deviation.

Taking another aircraft's clearance and transposing DME numbers and altitude numbers are examples of errors in information processing known as "slips." Slips are errors of action (as opposed to errors of intention) and occur in relatively familiar environments during automatic, well-learned behaviors, and are associated with some level of distraction. Slips are the results of actions that are not consciously monitored and are likely to occur when salient environmental cues are not relevant to the current action; features of the environment have changed but the task has not changed; the intended routine has changed but the environment has not changed; environmental cues are unusual or ambiguous; a long series of actions is required to accomplish a goal; the time period between related actions is long and/or filled with other activity; and procedures required to achieve different goals are similar. From a strict information processing point of view, slips often result when the environment causes interference during the initial processing of information.

Mistakes are errors of intention and are the result of an inappropriate choice of alternatives. Mistakes occur because of errors in recall, problem oversimplifications, decision biases and failures to consider all relevant variables. Mistakes are likely to occur when the decision requires the simultaneous consideration of more than two or three variables; salient environmental cues suggest a solution that is inappropriate; a method that is inappropriate for the current situation has been used successfully many times in similar situations; and choice of a solution requires dealing with the problem in a novel way. Mistakes are also information processing errors but occur at a higher cognitive level in which environmental characteristics and personal biases influence the accuracy of decision making.

Cockpit resource management (CRM) errors are less obvious than information processing errors and usually occur at a later stage in the altitude clearance sequence (e.g., implementation of the altitude change). CRM-type errors also can be contributory factors in altitude deviations; that is, poor task allocation or prioritization can contribute to, but is not usually the primary reason for, the altitude deviation. In the study model, CRM errors consisted of poor task allocation and task prioritization decisions, both of which could increase the probability of an altitude deviation. Task prioritization errors occurred during the last thousand feet of climb or descent, when both pilots became preoccupied with a problem or task and failed to monitor the climb or descent and to level the aircraft at the assigned altitude.

Table 1

Pilot-reported Altitude Deviations By Error Source and Task

	ERROR SOURCE				
TASK	PILOT	ATC	DOC	EQUIP	TOTALS
FORMULATE & ISSUE CLEARANCE	N/A	10	1	0	11
MONITOR/PROCESS CLEARANCE	47	N/A	1	2	50
HEARBACK	N/A	6	0	0	6
IMPLEMENT CLEARANCE & VERIFY	31	1	0	10	42
TOTALS:	78	17	2	12	109

Source: U.S. Federal Aviation Administration

The last error type results from equipment malfunctions rather than human error. Unexpected malfunctions of the autopilot or MCP can cause altitude deviations. These do not include malfunctions caused by human operation of the equipment (i.e., incorrect programming of the autopilot); rather, equipment malfunctions are the direct result of electrical and/or mechanical problems in the system or equipment. Equipment operating errors are errors of information processing.

Thus, primary errors can be categorized into one of four types: information processing errors (slips), decision making errors (mistakes), task prioritization allocation errors (CRM-type errors) and equipment malfunctions. The first three types are considered human errors, while the last is equipment-related. "Contributory factors" are another element of the error classification scheme. Depending on the amount of information available for each incident, contributory factors such as fatigue, workload, weather, etc., were identified.

Pilot-reported Errors Summarized

For each pilot-reported altitude deviation and altitude error in the data base, the following items were determined:

- The altitude clearance task in which the primary error occurred (Table 1);
- The source of the error (pilot, controller, documentation or equipment);
- The primary error category (information processing, decision making, task prioritization or malfunction) with explanatory information; and,
- The contributory factors, if any could be identified.

Each incident could have more than one primary error type and more than one source. A review of Table 1 shows that if the PC made a readback error and the controller made a hearback error, an altitude deviation could result. In other incidents, an equipment problem and pilot error were the primary error sources and, in several incidents, the pilots made more than one primary error. Thus, the total number of primary error sources and primary error categories equals 109, although 88 unique incidents were reported.

Table 1 shows the primary error sources by altitude clearance task. For these purposes, the PC's task of clearance monitoring, readback and processing were compressed into one cell (called monitor/process clearance) because, in most cases, an error was believed to have occurred during all three tasks or during two of the three tasks. As seen in the table, the task at which the primary error occurred corresponded with an error source.

Table 2 (page 7) shows the pilot-reported deviations by their primary error categories and error sources. Information processing errors were the most frequent error type, then decision making errors and task prioritization errors, which were almost the same, and finally equipment malfunction errors, which were the least frequent.

Table 3 shows that 58 information processing errors occurred across all the altitude clearance tasks but took place primarily during the monitor clearance/readback/processing tasks that were the PC's responsibility when that pilot pointed at and verified the newly assigned altitude set in the altitude alerter or MCP. Information processing errors at these steps accounted for about 69 percent of all the information processing type errors.

Table 4 (page 8) lists the incidents which account for the 40 information processing errors during clearance monitoring/processing and indicates the steps at which an error occurred. The 29 incidents break down as follows:

- The PC responded to the wrong call sign, and the controller did not recognize the error. (There were three additional incidents where the altitude deviation may have resulted from taking another aircraft's clearance but the information was incomplete);
- The PC heard the newly assigned altitude but set the wrong number in the altitude alerter/MCP, and the other pilot did not recognize the error.
- The PC heard a crossing restriction clearance and either transposed the DME number with the altitude or entered the wrong DME number in the flight management computer (FMC), resulting in an incorrectly set altitude alerter, MCP or FMC. The other pilot did not recognize the error;
- The PNF did not set the new altitude in the alerter/MCP; and,
- The error involved a misunderstanding of an amended clearance.

Table 2

Pilot-reported Altitude Deviations by Primary Error Category and Error Source

	ERROR SOURCE				
PRIMARY ERROR	PILOT	ATC	DCC	EQUIP	TOTALS:
INFORMATION PROCESSING	48	7	2	1	58
DECISION MAKING	11	10	0	0	21
TASK PRIORITIZATION	19	0	0	0	19
MALFUNCTION	N/A	N/A	N/A	11	11
TOTALS:	78	17	2	12	109

Source: U.S. Federal Aviation Administration

Table 3

Pilot-reported Altitude Deviations By Error Type and Task

	PRIMARY ERROR				
TASK	INFO PROCESS	DECISION MAKING	TASK PRIORIT	MALFUNC-TION	TOTALS
Formulate & issue clearance	2	9	0	0	11
Monitor/process clearance	40	7	2	1	50
Hearback	6	0	0	0	6
Implement clearance & monitor compliance	10	5	17	10	42
TOTALS:	58	21	19	11	109

Source: U.S. Federal Aviation Administration

Table 4

Incidents Involving Information Processing Errors During Clearance Monitoring and Processing

INCIDENT NUMBER	MONITOR/PROCESS CLEARANCE TASKS			
	MONITOR FREQUENCY	READBACK	SET ALERTER (PC)	VERIFY ALTITUDE (PF)
0000-003-P	✓	?	✓	?
0000-011-P	✓	?	✓	✓
0000-019-P	✓	✓	✓	✓
0000-025-P	✓			✓
0000-026-P	✓	?	✓	✓
0000-028-P			✓	
0000-029-P	✓	?	✓	✓
0000-034-P			✓	
0000-037-P	✓	✓	✓	✓
0000-039-P	✓	✓	✓	✓
0000-044-P	✓	✓	✓	✓
0000-046-P	✓	✓	✓	✓
0000-047-P			✓	
0000-052-P	✓	✓	✓	✓
0000-061-P	✓	✓	✓	✓
0000-070-P	✓	?	✓	✓
0000-074-P	✓	✓	✓	✓
0000-082-P			✓	✓
0000-088-P	✓	✓	✓	✓
0691-150-P	✓	✓	✓	✓
0691-151-P		✓	✓	✓
0691-198-P	✓	✓	✓	✓
0691-199-P		✓	✓	✓
0791-280-P	✓	✓	✓	✓
0891-342-P		✓		
0991-403-P	✓	?	✓	✓
0991-412-P	✓		✓	✓
0991-413-P			✓	✓
0991-439-P			✓	✓

PF=Pilot Flying; PC=Pilot Communicating

Source: U.S. Federal Aviation Administration

Crews Took Clearances Meant for Other Aircraft

This error type accounted for four of the 29 incidents involving clearance monitoring/processing. In only one of the four incidents was it determined that there were similar call signs. A second incident involved another USAir aircraft, but the call sign was unknown. There was not enough information in the other two incidents to determine if similar call signs were a factor. In all four incidents, the pilots reported that they read back the clearances as assigned (although in one case the pilot did not use his call sign), thus, controller hearback error was also a primary factor. In three of the four incidents, all USAir altitude awareness procedures were used, and in each incident both pilots apparently made the same error — "mishearing" their call sign. If, indeed, similar call signs were involved in all four incidents, the situation would be conducive to this kind of information processing/perceptual error.

The problem of communicating when several aircraft with similar call signs share the same frequency is well documented.

Pilots and Controllers Misheard Altitudes

In these incidents, the PC either misheard the altitude, or heard the correct altitude but later set the alerter incorrectly. This error type accounted for about 38 percent of the 29 incidents. For none of these incidents was it definitely determined that the PC also read back the wrong altitude and the controller did not recognize it (either information regarding the readback was unavailable or it was determined that the readback was correct). The altitude issued by ATC and the number set in the altitude alerter or MCP are listed in Table 5 (page 9). In five of the 11 incidents, 10,000 feet (3,030 meters) and 11,000 feet (3,333 meters) were the altitudes involved. Table 5 also shows the PC who set the alerter and whether cross-cockpit verification took place.

Of the eight incidents involving a misheard altitude, five involved the PC mishearing "10,000 feet" instead of "11,000 feet." The confusion between 10,000 feet and 11,000 feet is well known but it is not always clear why this confusion exists. When the 10,000/11,000 problem originally was discovered, the FAA instructed controllers to say 10,000 feet as "one zero thousand" and 11,000 feet as "one one thousand" to make the two numbers sound less alike. Unfortunately, the confusion persisted despite this change, and 10,000 feet and 11,000 feet are common altitude assignments when aircraft are descending and approaching terminal areas.

To determine why the 10,000/11,000 problem still persists, the study researchers asked pilots for their opinions; two findings emerged. When getting ready for approach, the pilot expects that the flight will be given either 10,000 feet or 11,000 feet at particular points on a standard terminal arrival route (STAR). However, the altitude and location varies from terminal to terminal and from STAR to STAR for that airport. Thus, the pilot's expectation interferes with what the pilot actually hears. This phenomenon is called proactive interference, in which a previously processed piece of information (e.g., 10,000 feet) interferes with the processing of new information (11,000 feet). Thus, 11,000 feet can be heard and/or recalled as 10,000 feet.

Table 5

Communication Pilot, Pilot Who Set Alerter, Cross-cockpit Verification and Altitudes Involved for Incidents Involving Altitude Confusions

	INCIDENT INFORMATION					
INCIDENT NO.	ASSIGNED ALTITUDE	(MIS)SET ALTITUDE	REASON	COMMUNICATING PILOT	WHO SET ALERTER	CROSS COCKPIT VERIF
0000-003-P	11,000	10,000	misheard altitude	PNF (F/O)	PNF (F/O)	Yes
0000-011-P	FL200	FL270	misheard altitude	PNF (C)	PF (F/O)	Yes
0000-025-P	FL220	FL200	misheard altitude	PNF (F/O)	PF (C)	No
0000-029-P	??	11,000	misheard altitude	PF (F/O)	PF (F/O)	Yes
0000-070-P	11,000	10,000	misheard altitude	PNF (C)	PF (F/O)	Yes
0000-082-P	8000	7000	misset alerter	PNF (C)	PF (F/O)	No
0000-088-P	7000	6000	misset alerter	PF (F/O)	PF (F/O)	No
0691-198-P	11,000	10,000	misheard altitude	PNF (C)	PF (F/O)	No
0691-199-P	FL230	FL330	misset alerter	PNF (C)	PF (F/O)	Yes
0991-403-P	11,000	10,000	misheard altitude	PNF (F/O)	PNF (F/O)	Yes
0991-412-P	11,000	10,000	misheard altitude	PF (C)	PF (C)	No

(PNF=pilot not flying; PF=pilot flying; F/O=First Officer; C=Captain)

Source: U.S. Federal Aviation Administration

The second finding was given by one pilot who mentioned that, in his particular case, a speed restriction of 250 knots was also given and the 250 knots triggered an association with 10,000 feet even though 11,000 feet was the assigned altitude. This is also an example of proactive interference. Of the five incidents of 10,000/11,000 confusion, the available information indicated that 250 knots was also given in the clearances for two incidents.

In the other three incidents involving misheard altitudes, the altitudes varied and may have been because of phonetic similarities between the two sets of numbers (i.e., "flight level two two zero" and "flight level two zero zero"). In the eight mishearing incidents, the PC was the PF in two incidents; the PF set the altitude alerter in six incidents; and there was no cross-cockpit verification in three incidents. There is a strong probability that a misheard altitude will be recognized and corrected if proper radio communication procedures (readback/hearback) and USAir's altitude awareness procedures are used by all (both pilots monitor ATC, PNF communicates, PF verifies new altitude). Nevertheless, as seen in Table 5, the system of checks and balances failed at one or more points during these mishearing incidents, and the errors were not recognized and corrected. In each of the eight incidents, although the act of cross-cockpit verification may have occurred, in fact, one of the pilots was not listening to the radio during the ATC communication and, therefore, the verification of an assigned altitude was actually a mere acknowledgment of what the PC reported to the other pilot.

Similar explanations account for incorrectly set altitude alerter incidents in which the PC heard and understood the altitude as assigned but set the altitude alerter or MCP with an incorrect number. In two of the three incidents, the PC was not the person who set the altitude alerter and in two incidents, no cross-cockpit verification took place. Thus, there was an information transfer problem in the cockpit and the lack of independent verification of the newly assigned altitude by the PF and PNF.

Errors Made in FMC Data Entry

This error type accounts for four of the 29 incidents that involved either transposition of DME numbers with altitude numbers when setting the FMC or other types of FMC data entry errors. In both incidents where the DME numbers were transposed with altitude numbers, the clearances involved 10 miles DME and 11,000 feet. Again, the similarity between the numbers 10 and 11 compounded with the usual confusion between 10,000 feet and 11,000 feet allowed for information processing errors to occur. In the other two incidents, a crossing restriction was programmed for the wrong waypoint (the FMC did not have two crossing restrictions in the data base. Therefore, they were computed manually and labeled as Waypoint 1 and Waypoint 2) and the incorrect DME numbers were entered in the FMC. In three of the four incidents, USAir altitude awareness procedures were used as prescribed.

Four incidents involved both pilots forgetting to set the new altitude in the alerter, MCP or FMC.

Pilots Forgot to Set Altitude Alerter, MCP or FMC

Four incidents involved both pilots forgetting to set the new altitude in the alerter, MCP or FMC. This type of information processing error is analogous to what human error theorists call a "place-losing error" in which the individual forgets to perform an action in a sequence of steps. In three of the four incidents, ATC-pilot communications occurred without any problems, but the pilots became distracted and forgot about the assigned altitude. In one incident involving a Boeing 737-400, the pilot was flying on autopilot and forgot to set the new altitude in the FMC cruise page. In another incident, the pilots were issued a profile descent clearance and both forgot about the crossing restriction in the profile descent. In a third incident, the PC neglected to set the departure clearance altitude in the MCP, but it was not noticed because the MCP defaulted to 10,000 feet (a normally assigned departure altitude) during a power transfer before takeoff. In the final incident, the PF did not hear the new altitude clearance, which was given between two turn clearances, and altitude awareness procedures were not used (PF was setting FMC, no verification).

Errors Involved Amended Clearances

The three remaining clearance monitoring/process information processing incidents involved a misunderstanding of amended clearances. In one incident, the pilot set the alerter prior to departure with the standard instrument departure (SID) altitude rather than the amended clearance altitude. The second incident involved a misunderstanding of a previously issued clearance that was amended to an "expect" clearance. The pilots complied with the previously issued clearance because they did not understand that it had been canceled. The third incident also involved a misunderstanding of an amended clearance because part of the transmission was blocked by radio frequency congestion. In this incident, the first clearance was to descend from Flight Level (FL) 270 to cross an intersection at FL190. The controller then gave an amended clearance: "Descend and maintain FL260 now." The pilots only heard, "descend now to FL260," which they interpreted as hurry through FL260 on your way to FL190. The result of this miscommunication was an altitude deviation involving loss of separation that triggered two additional operational errors for the controller.

While all the amended clearances technically complied with phraseology requirements in the *Air Traffic Control* handbook, it seemed because the problem was continuing to occur, that there was some ambiguity for pilots about when a clearance was amended and when it was not amended.

Other Processing Errors Occurred

Table 3 (page 7) shows 18 information processing errors also occurred during formulate/issue clearance, hearback and implement clearance.

The two information processing errors occurring during formulate and issue clearance involved ambiguous clearances. In one incident, the controller gave a time-based clearance (i.e., "Be at FL350 in three minutes") but did not give an absolute time reference in the clearance (i.e., "Center time is now 2145:30"). Thus, the time by which the altitude should have been reached was open to interpretation. Did the three-minute countdown start from the time that the controller issued the clearance or the time that the pilot accepted the clearance?

In the second incident, the clearance involved turning while maintaining a specific altitude until "established on the localizer," followed by a descent. Interviews with the pilots and controller revealed that the phrase "established on the localizer" was interpreted differently by the pilots and by the controller. The pilots believed that it meant that their equipment indicated they had contacted the localizer beam, but the controller believed that it meant that the aircraft was fixed and tracking on the localizer centerline. The error source was considered to be documentation (the *Airman's Information Manual* and the *Air Traffic Control* handbook) in which ATC terminology is published. Phraseology should be defined in these manuals so that pilots and controllers can interpret the same meaning from the same phrase.

In all six hearback errors, the controllers failed to recognize incorrect readbacks: the wrong aircraft readback, or the wrong altitude or other information was read back incorrectly.

The 10 errors that occurred during altitude changes all involved some error in information processing subsequent to accepting the clearance. Three incidents involved navigation errors (i.e., misread approach plates). Three incidents involved incorrectly set altimeters. In all three cases, one or both altimeters were incorrect by 1,000 feet because the pilots only checked the last two digits when resetting at the FL180 transition altitude and the actual pressure difference called for checking three digits rather than two (e.g., 29.92 and 28.92). Another incident involved a misread drum-pointer altimeter that combined with pilot fatigue as a contributing factor. The last three incidents involved other information processing problems, including incorrect operation of the autopilot altitude hold control, failure to note the altitude alert warning and failure to level off in time because the pilot's attention was elsewhere.

Decision Making Errors

Table 6 shows 21 decision making errors that tended to occur during the controller's task of

Table 6

Decision-making Errors by Source and Task

	ERROR SOURCE		
TASK	PILOT	ATC	TOTAL
Formulate & issue clearance	N/A	9	9
Monitor/process clearance	7	N/A	7
Hearback	N/A	0	0
Implement clearance	4	N/A	4
Verify clearance	N/A	1	1
TOTALS:	11	10	21

Source: U.S. Federal Aviation Administration formulating and issuing an altitude clearance, the pilot's task of processing the clearance, and then implementing the clearance. One decision making error also occurred during the controller's task of monitoring compliance with the clearance.

Formulating/Issuing Clearance Decision Errors

Because these incidents were reported by pilots, it is not known what circumstances or situations led the controllers to issue incorrect altitude clearances or to fail to issue one in a timely manner. Of the nine errors, four incidents also involved pilot error when the pilot should not have accepted a late clearance.

Clearance Processing Decision Errors

Of the seven incidents involving clearance processing, four involved the pilots accepting and attempting to comply with questionable altitude clearances. In these incidents, the clearances were either given late or crossing restrictions were impossible to meet. The pilots should have had sufficient situational awareness to inform the controllers that they were unable to comply with the clearances. In another incident, the pilots did not inform ATC that they were on a maintenance test flight that warranted a request for a block altitude. In another incident, the clearance involved two altitudes; the less restrictive of the two altitudes was set in the altitude alerter and led to a deviation. (USAir recommends setting the more restrictive altitude when two are given). In the last incident, the pilot did not ask the controller to verify before descending because the pilot believed that he had been cleared for the approach.

Implementing/Verifying Clearance Decision Errors

The last group of decision making errors involved five incidents. In the first incident, both the pilots and the controller were at fault for failing to establish whether an approach (subsequent to a descent clearance) was going to be a visual approach or an instrument approach. The controller was apparently waiting for the pilots to call the airport "in sight" for a visual approach while the PF descended to the initial approach altitude for the instrument landing system (ILS). If the pilot had asked for an ILS approach or if the controller had asked the pilot to report the airport in sight, the incident would not have happened. In the other four incidents, each of the pilots was expecting a certain descent clearance and initiated the descent or approach prematurely.

Task Prioritization/ Allocation Errors

Of these 19 errors, 17 occurred while conducting the implement-altitude-change task and two occurred during clearance processing. Of the 17, all but three involved both pilots not giving attention to the last 1,000 feet of climb or descent and resulted in altitude deviations. In the remaining three of the 17, the deviations occurred because of failing to reset altimeters during FL180 transitions. Various reasons were given for not giving attention to the climb or descent, but most said that both pilots became preoccupied with another activity (such as resolving a navigation problem or attending to an equipment problem). Common to all incidents was that the pilot in command did not properly prioritize tasks so that the climb or descent would be completed satisfactorily before turning attention to other tasks. Alternatively, the pilot in command could have allocated tasks among the

Common to all incidents was that the pilot in command did not properly prioritize tasks so that the climb or descent would be completed satisfactorily before turning attention to other tasks.

crew such that one person concentrated on the altitude change while the other addressed the navigation or equipment problem. Both concepts are important elements in CRM and are addressed in CRM training and evaluations. Failure to reset the altimeter at FL180 occurred in three incidents and in all three, the pilots became distracted by other problems and simply forgot to reset the altimeters.

Equipment Malfunctions

Eleven incidents involved equipment malfunctions. In two, a transponder caused an erroneous Mode C altitude readout, leading the controller to believe that the aircraft was at a different altitude than the assigned altitude. Various problems with autopilots caused the aircraft to overshoot the assigned altitudes in four incidents. In two incidents, the MCP apparently "jumped" or somehow changed settings. Other electro-mechanical problems were described in another two incidents. Finally, in one incident, the pilot received a time-based clearance ("Be at FL350 in three-and-a-half-minutes") and checked the performance management system (PMS) to see if the aircraft could comply. The PMS feedback indicated that the clearance could be implemented in three minutes. Subsequent investigation revealed that the PMS estimate had a margin of 59 seconds (i.e., the feedback of 3:00 could mean 3:00 to 3:59). Thus, the incomplete feedback provided by the equipment misled the pilot. In each of these incidents (with the possible exception of the MCP jump), the errors can be traced to equipment malfunctions rather than human errors. ♦

Reference

MiTech Inc. and Carlow International Inc. *Altitude Deviation Study: A Descriptive Analysis of Pilot and Controller Incidents*. A special report prepared at the request of the U.S. Federal Aviation Administration Research and Development Service. October 1992.

About the Author

John A. Pope established John A. Pope & Associates, an aviation consulting firm located in Arlington, Virginia, U.S., after retiring in 1984 as vice president of the U.S. National Business Aircraft Association. He specializes in developing operations manuals for corporate flight departments.

He served as a command pilot in the U.S. Air Force and the U.S. Air National Guard. He retired as a colonel from the U.S. Air Force Reserve after 33 years of service.

Canadian Bird-strike Data Reviewed

by
Editorial Staff

Minutes from the Seventeenth Meeting of Bird Strike Committee Canada (BSCC) provide statistical data from several different sources on aircraft bird strikes in Canada.

In the published minutes, members of the BSCC (Transport Canada, Canadian Department of National Defence (DND), Air Canada and Canadian Airlines International) each gave bird-strike report summaries based on bird-strike statistics recorded under varying conditions. The minutes reflect each member's bird-strike data.

A summary of the DND's 1991 data indicated that the overall number of bird strikes continued to decrease; a total of 186 were recorded in 1991, of which 20 percent resulted in some kind of damage to aircraft engines (Figure 1).

Training-type aircraft had the most bird strikes in 1991 (Figure 2, page 15), with 30 percent (57 of 186 bird strikes), followed by transport-type aircraft with 23 percent of the total bird strikes. For 1992, the DND reported a total of 101 bird strikes, with transport aircraft having the most strikes with 34.65 percent (35 of 101 bird strikes), closely followed by trainers with 32.67 percent. Fighter aircraft and maritime patrol aircraft each comprised 13.86 percent, with helicopters recording 4.95 percent of the bird-strike incidents.

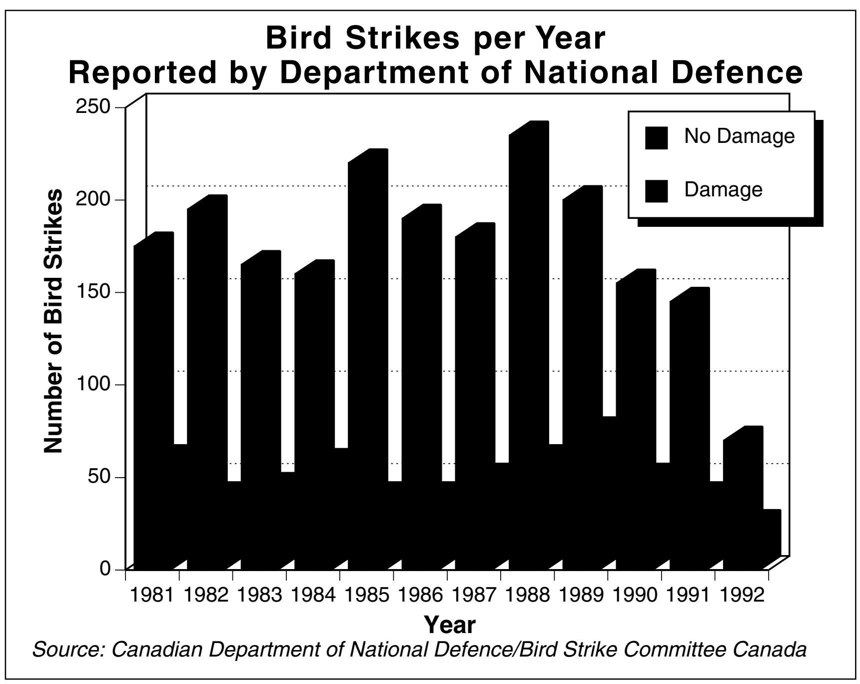
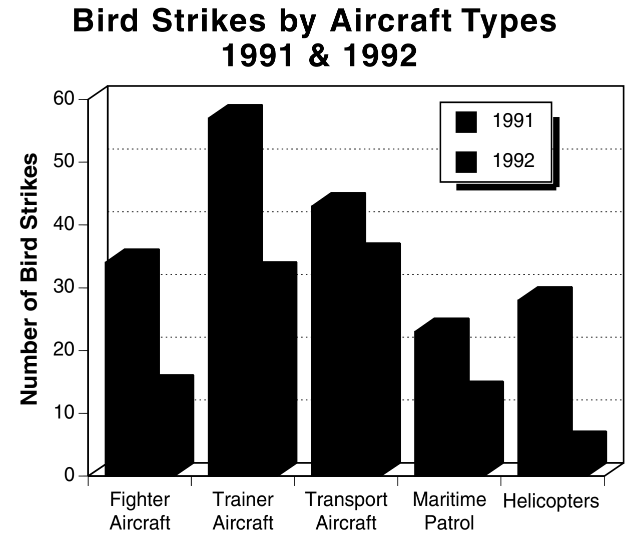
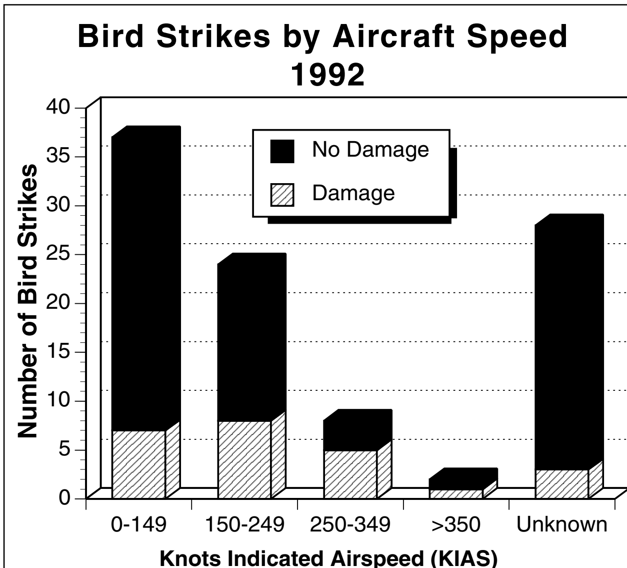


Figure 1



Source: Canadian Department of National Defence/Bird Strike Committee Canada

Figure 2



Source: Canadian Department of National Defence/Bird Strike Committee Canada

Figure 3

For Canadian military aircraft in 1992, most of the bird strikes occurred at speeds up to 149 knots. Nevertheless, a higher number of damaging strikes was observed at aircraft speeds between 150 knots and 249 knots (Figure 3).

The "Bird Strike Statistics — Interim Report," prepared by Air Canada, covered the period from January 1992 to October 1992. The number of reported bird strikes at 13 of Canada's major airports are shown in Table 1.

Four of the 53 reported bird strikes with Air Canada's fleet resulted in minor damage and three of them resulted in substantial engine damage:

- Engine No. 1 of an Airbus A320 was damaged on takeoff at Calgary Airport on Sept. 5, 1992;

- Substantial damage resulted from bird ingestion in engine No. 1 of an A320 at St. John's Airport, Sept. 19, 1992; and,

- Substantial damage occurred to engine No. 1 of a Boeing 747-300 when the aircraft struck a number of ducks on approach to Calgary Airport on Oct. 26, 1992.

According to the Air Canada summary, the aircraft most often struck by birds during 1992 was the McDonnell Douglas DC-9, followed by the A320 and finally the B-767. The phase of flight with the most bird strikes continued to be takeoff, and the month of the year with the highest incidence of bird strikes was August (Table 2, page 16).

The Operations Safety Division of Canadian Airlines International provided bird-strike statistics for Aug. 1, 1991, to Aug. 31, 1992.

Table 1

Reported Bird Strikes at 13 of Canada's Major Airports

	1992	1991
Winnipeg	10	8
Toronto	9	14
Ottawa	6	11
Montreal-Dorval	6	11
Calgary	5	3
Edmonton	3	2
Vancouver	3	6
Moncton	3	0
Regina	3	2
Mirabel	2	1
Fredericton	1	1
Halifax	1	0
St. John's	1	1

Source: Air Canada/Bird Strike Committee Canada

Eighty-nine bird strikes with Canadian Airline's fleet were reported during this interval, with the airport at Vancouver reporting the most — 18 incidents. The eight most affected airports (listed below) reported 75 percent of the 89 strikes.

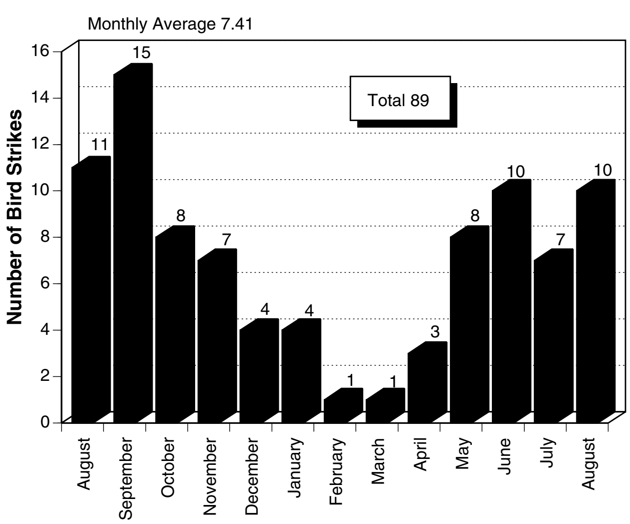
Toronto	12
Vancouver	18
Calgary	10
Dorval	10
Edmonton	7
Ottawa	5
Winnipeg	3
Prince George	2

Boeing 737s encountered 80 percent of the reported strikes, followed by the B-767 with 10 percent and the A320 with 6 percent. The most strikes occurred in September, followed by August and June (Figure 4).

According to the Canadian Airline International summary, the approach phase of flight was most affected at 43 percent, followed by the landing phase with 26 percent and takeoff with 20 percent (Figure 5, page 17).

Transport Canada compiled bird-strike statistics for the period Jan. 1, 1992, to Nov. 18, 1992.Bird strikes for this period totaled 327 with the Ontario region registering the most at 31 percent (103 bird strikes). In addition, there were 62 strikes reported in the Central Region (19 percent); 58 strikes in the Atlantic Region (18 percent); 50 strikes in the Pacific Region (15 percent); 29 strikes in the Western Region (9 percent) and 25 strikes in the Quebec Region (8 percent).

Bird Strikes by Month Reported
Aug. 1, 1991 to Aug. 31, 1992



Source: Canadian Airlines International/Bird Strike Committee Canada

Figure 4

Table 2

Bird Strikes Reported January 1992 to October 1992

Comparison January-October:		1992	1991
	Totals	62	72
By aircraft type:	A320	17	7
	B-727*	6	15
	B-747	2	2
	B-767	12	11
	DC-8	4	0
	DC-9	21	34
	L1011	0**	3
By phase of flight:	Descent	2	1
	Approach	15	21
	Landing roll	11	12
	Takeoff	27	23
	Climb	5	6
	Parked	1 ***	0
	Unknown	1	9
By month:	January	3	3+
	February	2	3
	March	0	2
	April	5	5
	May	7	7
	June	8	11
	July	7	9
	August	15	14
	September	7	12
	October	8	7

Notes:

+ 1991 data by month totals 73 not 72.

* Aircraft withdrawn from service effective October 25, 1992.

** L1011 aircraft withdrawn from service.

*** Bird strike was found on walkaround.

Source: Air Canada "Bird Strike Statistics — Interim Report"/ Bird Strike Committee Canada

According to Transport Canada, bird-strike totals for 11 airports were:

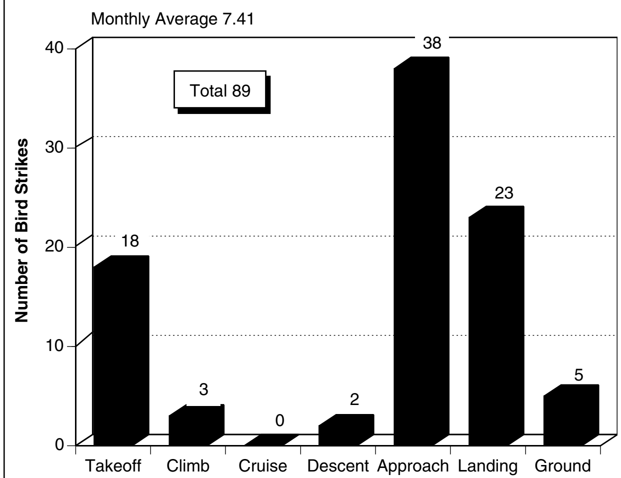
Toronto	61
Winnipeg	31
Thunder Bay	21
Ottawa	20
Moncton	17
Victoria	11
Sandspit	8
Dorval	7
Fredericton	7
St. John	7
Quebec	7

The BCCS agreed there was a need to standardize the collecting, inputting and reporting of bird-strike statistics. The report said one way to standardize data collection would be to adopt standard operating definitions and a standard reporting form such as the International Civil Aviation Organization (ICAO) form used by civilian pilots. Thus, data can be collected from various regions of aviation activity and more meaningful comparisons can be made between them.

In addition, a member of the U.S. Department of Agriculture (USDA) presented an update on bird-strike incidents at John F. Kennedy (JFK) International Airport in New York for the period 1979 to 1992. The total number of bird strikes at JFK for this period was 3,414 strikes and included those birds found dead on the runway. A total of 54 species were identified; gulls constituted 70 percent of the involved birds. The number of aborted takeoffs was 45, and the number of engines replaced was 14.

The USDA, the U.S. Federal Aviation Administration and the U.S. Air Force are co-sponsoring the next meeting of the Bird Strike Committee-USA, Aug. 2-6, 1993, at Seattle-Tacoma International Airport, Seattle, Washington. Although the proceedings will not be printed, the committee is accepting papers dealing with any aspect of bird hazard control for presentation. For information, contact James E. Forbes, USDA/APHIS/ADC, P.O. Box 97, Albany, New York 12201-0097 U.S. Telephone: (518) 472-6492.♦

Bird Strikes by Phase of Flight for the Period August 1, 1991 to August 31, 1992



Source: Canadian Airlines International/Bird Strike Committee Canada

Figure 5

Reference

Transport Canada/Department of National Defence. *Minutes of the Seventeenth Meeting of Bird Strike Committee Canada, November 17-18, 1992, Tyndall [U.S.] Airforce [sic] Base, Panama City, Florida*. File No. AKP 5158-36-22-51. December 1992.

Publications Received at FSF Jerry Lederer Aviation Safety Library

by
Editorial Staff

New Reference Materials

U.S. Federal Aviation Administration. *Advisory Circular 21-33, Quality Assurance of Software Used in Aircraft or Related Products.* February 1993. 4p.

This advisory circular (AC) describes compliance with the quality assurance requirements of Federal Aviation Regulations (FAR) Part 21, Certification Procedures for Products and Parts, as applicable to the production of software used in type certificated aircraft or related products (airborne software). This AC also provides supplemental guidance for the establishment of a quality control inspection system to control the development and production of software used in type certificated aircraft.

U.S. Federal Aviation Administration. *Advisory Circular 23-12, Structural Substantiation of Part 23 Airplane Modifications Involving Increased Engine Power.* January 1993. 6p.

This AC provides information and guidance for demonstrating compliance with the requirements of Part 23 of the FAR applicable to the structural substantiation of modifications involving increased engine power.

U.S. Federal Aviation Administration. *Advisory Circular 23.1521-2, Type Certification of Oxygenates and Oxygenated Gasoline Fuels in Part 23 Airplanes with Reciprocating Engines.* January 1993. 16p. Includes appendices.

This AC provides information and guidance for compliance with Part 3 of the Civil Air Regulations (CAR) and Part 23 of the FAR, applicable to approval procedures for certification of alternative fuels. These procedures also apply to those airplanes approved under Part 4a of the CAR and Aeronautics Bulletin 7A.

U.S. Federal Aviation Administration. *Advisory Circular 25.703-1, Takeoff Configuration Warning Systems.* March 1993. 6p.

This AC provides guidance for the certification of takeoff configuration warning systems installed in transport category airplanes. A list of related reading material is also included.

Reports

Kilgore, W.A.; Seth, S.; Crabill, N.L.; Shipley, S.T.; Graffman, I.; O'Neill, J. *Pilot Weather Advisor*, Contract No. NAS1-19250. A special report prepared at the request of the U.S. National Aeronautics and Space Administration, Langley Research Center. November 1992. iii, 38p.; ill.

Keywords
1. Aeronautics — Weather, Reporting and Forecasting.
2. Airplanes — Climatic Factors.
3. Aeronautics — Safety Measures.
4. Weather — Forecasting — Satellite Communications.

Summary: This report gives the results of work to demonstrate the use of a pilot weather advisor (PWxA) cockpit weather data system using a broadcast satellite communication system. The PWxA, developed under the NASA Langley Research Center Small Business

Innovation Research Program, demonstrated that the technical problems involved with transmitting significant amounts of weather data to an aircraft in flight or on the ground via satellite are solvable with today's technology.

The PWxA system provides near real-time graphic depictions of weather information via satellite communications. According to the report, the PWxA appears to be a viable solution for providing accurate and timely weather information for general aviation aircraft.

Antuñano, Melchor J. *Index of International Publications in Aerospace Medicine*, Report No. DOT/FAA/AM-93/3. A special report prepared for the Office of Aviation Medicine, U.S. Federal Aviation Administration. February 1993. v, 21p. Available through the National Technical Information Service*.

Keywords
1. Aviation Medicine — Bibliography.
2. Transportation Medicine — Bibliography.
3. Space Medicine — Bibliography.

Summary: This international bibliographic index provides a comprehensive listing of publications in clinical aerospace medicine, operational aerospace medicine, aerospace physiology, environmental medicine/physiology, diving medicine/physiology, aerospace human factors and other topics related to aerospace medicine.

The index is divided into six major sections: 1) Open Publications in General Aerospace Medicine; 2) Government Publications in General Aerospace Medicine; 3) Publications in other Topics Related to Aerospace Medicine; 4) Proceedings from Scientific Meetings, Conferences, and Symposiums in Aerospace Medicine; 5) Journals, Newsletters and Bulletins in Aerospace Medicine; and 6) Online Computerized Data Bases Containing Bibliographic Information in Aerospace Medicine and Related Disciplines. Section entries are arranged alphabetically. The primary source for this index are books because they offer a comprehensive coverage of a general area of interest, and represent excellent tools for structured learning and consultation.

U.S. National Transportation Safety Board. *Aircraft Accident Report: Air Transport International, Inc., Flight 805, Douglas DC-8-63, N794AL, Loss of Control and Crash, Swanton, Ohio, February 15, 1992.* November 1992. 115 p.; ill. Available through National Technical Information Service*.

Keywords
1. Aeronautics — Accidents — 1992.
2. Aeronautics — Ohio — Swanton — Accidents.

Summary: This report documents the accident on February 15, 1992, of an Air Transport International Inc. Douglas DC-8-63 near Toledo Express Airport.

Flight 805 crashed at 0326 eastern standard time, after executing a second missed approach at Toledo. The airplane was destroyed. Three flight crew members and one passenger were fatally injured.

The flight history of 805 into the Toledo terminal area was without incident; the airplane was vectored for an instrument landing system approach and the first officer was the pilot flying.

The cockpit voice recorder (CVR) revealed instructions from the captain to the first officer on the approach. The CVR also recorded the expressed difficulty the first officer and captain experienced in positioning the plane for the approach. The captain took control of the airplane and performed a second missed approach.

In the 22 seconds before the crash, the CVR recorded the sounds of an altitude-alert warning ground proximity warning system (GPWS) warnings. The first officer was the pilot flying when the aircraft crashed approximately three miles north of the runway.

The NTSB determined that the probable cause of this accident was the failure of the flight crew to properly recognize or recover in a timely manner from the unusual aircraft attitude that resulted from the captain's apparent spatial disorientation, resulting from the physiological factors and/or a failed attitude director indicator.

Books

Hawkins, Frank H. *Human Factors in Flight*. Edited by Orlady, Harry W. Brookfield, Vermont, U.S.: Ashgate Publishing Co. Inc., 1992. 384 p.; ill. Includes index and bibliography.

<u>Keywords</u>
1. Airplanes — Design and Construction.
2. Human Engineering.
3. Aircraft — Operation — Human Factors.

Summary: This second edition of *Human Factors in Flight* serves as a general introductory volume to human factors in aviation. It is designed primarily for industry and aims to bridge the gap between academic knowledge and the practical operation of aircraft.

Early chapters define human factors by exploring the history of human factors research and developing a conceptual model of human factors that is used throughout the book. Given the close association of human factors with human error and performance, the next few chapters deal with physiological issues such as stress, fitness, vision, fatigue and biological rhythms. Continuing its emphasis on human performance, the book shifts from physiological issues to psychological and cognitive aspects, emphasizing the vitally important theme of communication.

Close attention is given to issues such as training, proficiency, motivation and documentation. The last chapters of the book deal with the design of the work place, displays and controls, space and layout, and the aircraft cabin and its human payload. The book includes appendices recommended for further research, abbreviations used in the text, references and an index. ♦

*U.S. Department Of Commerce
National Technical Information Service (NTIS)
Springfield, VA 22161 U.S.
Telephone: (703) 487-4780

Updated Reference Materials (FAA Advisory Circulars):

AC Number	Month/Year	Subject
21.17-2A	2/10/93	*Type Certification—Fixed-Wing Gliders (Sailplanes), Powered Gliders* (cancels AC 21.17-2, dated July 13, 1989).
90-23E	10/1/91	*Aircraft Wake Turbulence* (cancels AC 90-23D, dated 12/15/72).
120-51A	2/10/93	*Crew Resource Management Training* (cancels AC 120-51, dated 12/1/89).

Accident/Incident Briefs

by

Editorial Staff

This information provides an awareness of problem areas 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.

Off Centerline Landing Leaves Boeing 747 in Mud

Boeing 747. Substantial damage. No injuries.

The Boeing 747 crew had executed a missed approach to a European airport in foggy instrument meteorological conditions (IMC).

On the second approach, the aircraft touched down right of the runway centerline with the right main landing gear in the grass. The right gear and No. 4 engine nacelle scraped the runway on touchdown. The No. 4 nacelle separated at the forward engine mount. The aircraft was subsequently brought back onto the runway.

A fire broke out on the No. 4 strut when the engine separated, but was quickly extinguished by airport fire crews.

Runway Overrun Follows Aborted Takeoff

Boeing 737. Aircraft destroyed. One minor injury.

The Boeing 737 was about 1,320 feet (400 meters) into the takeoff roll when the outboard tire blew on the right main landing gear. Takeoff was aborted, but the flight crew was unable to stop the aircraft before it rolled off the end of the 9,900-foot (3,000-meter) runway.

The aircraft came to rest in a deep depression about 198 feet (60 meters) from the end of the runway. Both engines had separated from the aircraft.

All 107 passengers and six crew members were able to evacuate the aircraft without serious injury. After the evacuation, a fire started that destroyed the aircraft. Weather was reported to be clear, with a dry runway.

Strong Gust Results in Hard Landing

McDonnell Douglas DC-9. Substantial damage. Two serious injuries.

The aircraft was on a short daylight passenger flight. High winds were causing turbulence at all altitudes.

The approach to landing was normal, with winds reported at 310 degrees, gusting to 30 knots. The flight was cleared to land on runway 24.

During the flare, a strong gust raised the aircraft's tail and the DC-9 then dropped to the runway. The impact at touchdown bent the fuselage about seven degrees just aft of the wing flaps. Two passengers seated in the area of the bend suffered serious injuries.

Air Taxi
Commuter

Training Check Ride Ends in Tragedy

BAe 31 Jetstream. Aircraft destroyed. Two fatalities.

The twin-turboprop Jetstream was on a night training check flight when it was cleared for a touch-and-go landing on runway 23.

After the landing flare, the pilot reported that the propellers had struck the runway and the pilot declared an emergency. The landing gear was extended on climb out after the near wheels-up landing. The pilot established a right turn for a teardrop approach to runway 05 and the flight was cleared for an emergency landing. However, the pilot lost control of the aircraft and it impacted the ground. The Jetstream was destroyed by the impact and post-crash fire.

An investigation determined that the right propeller had been feathered.

Collision With Mountain Ridge Destroys Islander

Britten-Norman Islander. Aircraft destroyed. Nine fatalities.

The aircraft had embarked on a daylight flight with forestry officials on board. After departure, the flight route was changed to allow the specialists to study trees.

The aircraft collided with tree tops on a mountain ridge and crashed into a forest. Weather at the time of the accident was clear with light winds. The pilot and eight passengers were killed in the crash.

An investigation determined that terrain and vegetation in the area of the crash site were conducive to spatial disorientation with a strong illusion of a false horizon possible. The pilot was not experienced in low-altitude flying or mountain flying.

Ground Handler Struck by Propeller

DHC-6 Twin Otter. No damage. One fatality.

After a night arrival, the Twin Otter with 20 passengers on board was maneuvered to the apron and the engines were shut down.

Ground personnel then approached the aircraft and one worker walked from the rear of the aircraft under the left wing toward the cockpit door, where he was struck in the head and killed by a propeller that was still turning.

An inquiry determined that apron floodlights caused a shadow on the left side of the aircraft, impairing the capability to see the moving propeller. Following the accident, airline and airport ground personnel were given additional safety training and flight crews were instructed to park aircraft in ways that optimized illumination. The airport authority was also ordered to improve apron lighting.

Corporate Executive

Engine Failure, Pattern Traffic Contribute to Control Loss

Cessna 402. Aircraft destroyed. One fatality.

While on a daylight flight, the left engine of the twin-engine Cessna lost power. The pilot secured the engine and feathered the propeller.

On single-engine approach to the airport, the pilot followed too closely behind another aircraft. As he maneuvered to maintain distance, the pilot lost control of the aircraft. The aircraft rolled to the left and descended nose down, impacting the ground.

Disorientation Sends Commander into Ridge

Commander 690. Aircraft destroyed. One fatality. Five serious injuries.

The aircraft made a departure in night instrument meteorological conditions and entered a left turn.

About one mile from the airport, the aircraft struck rising terrain in a left bank and in a slightly nose-high attitude while descending.

The aircraft became airborne again after initial impact and struck the ridge slope about 600 feet (181 meters) away. Weather at the time of the accident was reported 500 feet (151 meters) overcast.

An investigation suggested that the pilot likely suffered from spatial disorientation during the initial climb and turn.

Other General Aviation

Turbulence Pounds Cessna on Final

Cessna 310. Substantial damage. No injuries.

The twin-engine Cessna was on final behind a military helicopter at night. On short final, vortex turbulence from the helicopter caused the pilot to lose control of the Cessna.

The aircraft impacted the runway in an upright attitude, but the main gear sheared off and both main spars were damaged. The pilot evacuated the aircraft without injury.

Faulty Lever Choice Cripples Apache

Piper PA-23 Apache. Substantial damage. No injuries.

After landing, the aircraft was taxied to the ramp and stopped while the pilot carried out the after-landing checks.

During the checks, the pilot inadvertently selected the gear retraction lever instead of the flap retraction lever. The right main gear leg retracted, causing the right propeller to strike the ground and stop the engine. The airframe was also damaged. There was no fire, and the pilot and three passengers evacuated the aircraft safely.

Rotorcraft

Lack of Situational Awareness Sinks Helicopter

Hughes 369-D. Aircraft destroyed. Two minor injuries.

The Hughes was on a daylight flight with four people on board when it crashed in the ocean about 100 yards (91 meters) from shore.

The pilot said that he was maneuvering to reverse direction when he misjudged the altitude and struck the water. None of the occupants were wearing water survival equipment or flotation devices. The three passengers said after the accident that they were either unable to locate or to put on life vests that were in the helicopter.

The pilot and two passengers swam to shore and one passenger was picked up by a small boat. The helicopter sank in 200 feet (61 meters) of water.

Tail-rotor Strike Downs Bell 206

Bell 206B. Aircraft destroyed. One fatality.

The helicopter was landing on an offshore helideck when its tail rotor contacted a fence guard while the aircraft was in a nose-high landing attitude.

The tail-rotor assembly and gearbox separated from the helicopter, and the aircraft spun to the left and across the landing platform, striking a lower deck before impacting in the ocean.

The pilot, the sole occupant of the helicopter, was killed. Weather at the time of the accident was 2,500 feet (758 meters) scattered, seven miles (11 kilometers) visibility and winds at nine knots.

Dual Engine Flameout Has Predictable Cause

MBB BO-105S. Aircraft destroyed. No injuries.

The twin-engine helicopter was on a flight from an offshore oil platform to a land-based site when both engines flamed out.

The pilot initiated an autorotation, and the helicopter's tail boom struck the water during the flare. The pilot and three passengers were able to evacuate the aircraft without injury before it sank. A passenger reported that the fuel-low warning light on the caution panel had been on for about 20 minutes before the accident. An investigation determined that the fuel transfer pump switches were in the "off" positions and that about 80 gallons of fuel remained in the fuel cells. ♦