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Pilot–Air Traffic Control Communications: It's Not (Only) What You Say, It's How You Say It

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Flight Safety Foundation (FSF) is an international membership organization dedicated to the continuous improvement of flight safety. Nonprofit and independent, FSF was launched in 1945 in response to the aviation industry's need for a neutral clearinghouse to disseminate objective safety information, and for a credible and knowledgeable body that would identify threats to safety, analyze the problems and recommend practical solutions to them. Since its beginning, the Foundation has acted in the public interest to produce positive influence on aviation safety. Today, the Foundation provides leadership to more than 660 member organizations in 77 countries.

Pilot–Air Traffic Control Communications: It's Not (Only) What You Say, It's How You Say It

English is the international language of aviation. But even when pilots and controllers both speak English fluently, there are pitfalls in the nature of language and the ways that language is heard. Subtle miscues can subvert messages that seem clear to the sender. Pilots and controllers must be aware of, and avoid, common types of linguistic misunderstandings. Ultimately, an intelligent voice interface may cut through confusion.

Steven Cushing, Ph.D.

Miscommunication arising from spoken interaction is a fact of life experienced, in one form or another, almost daily. Even two people speaking face-to-face, ostensibly in the same language, with a common background in the subject of the communication, frequently discover that what was meant was not what was understood. In casual discussion or routine business situations, the results of such miscommunication can range from amusement to expensive errors. But in aviation, the outcome of spoken miscommunication can be deadly. In no area is this more true than in pilot–air traffic control (ATC) interaction.

Various researchers have categorized the types of errors in reports of pilot-ATC misunderstandings. Some errors were caused by technical problems such as poor microphone technique or frequency congestion. Others resulted from missteps that were not specifically linguistic, such as failure to provide necessary information or failure to monitor transmissions. These types of errors could be prevented or ameliorated through better conditions, training or discipline. More serious, because more difficult to solve, are problems that arise from characteristics of language itself and from the ways that the mind processes what is heard.

Grayson and Billings's taxonomy of pilot-ATC oral communication problems included 10 categories, of which at least three were specifically linguistic: "ambiguous phraseology," "inaccurate (transposition)" and "misinterpretable (phonetic similarity)" (Table 1, page 2).[1] Monan identified "failure modes" that included "misheard ATC clearance/instruction numerics," "cockpit mismanagement resulting in readback errors," "inadequate acknowledgments," "apparent inattention to amendments to ATC clearances/instructions," "[controller] failure to hear error in pilot readback" and "clearance amendment not acknowledged by pilot and not challenged by controller."[2]

Prinzo et al.[3] divided pilot-ATC communication phraseology errors into nine types. They included grouping of numerical information contrary to U.S. federal air traffic control regulations[4]; failure to group numbers as specified in regulations; transposition, or using numbers or words in the wrong order; and dysfluency, including unwarranted pauses.

More than 200 communication-related aviation incidents, some of which resulted in disastrous accidents and the rest of which easily could have, have been analyzed by the author.[5] The

Table 1

Categorization of Pilot-ATC Oral Communication Problems Grayson and Billings (1981)1

Category	Number of Reports	Definition
Other inaccuracies in content	792	1) Erroneous data (formulation errors) 2) Errors in judgment 3) Conflicting interpretation
Ambiguous phraseology	529	Message composition, phraseology, or presentation could lead to a misinterpretation or misunderstanding by the recipient
Incomplete content	296	Originator failed to provide all the necessary information to the recipient to understand the communication
Inaccurate (transposition)	85	Misunderstanding caused by the sequence of numerals within a message
Misinterpretable (phonetic similarity)	71	Similar-sounding names or numerics led to confusion in meaning or in the identity of the intended recipient
Absent (not sent)	1 ,991	Failure to originate or transmit a required or appropriate message
Untimely transmission	710	Message not useful to the recipient because it arrived too early or too late
Garbled phraseology	171	Content of the message lost or severely distorted to the point where the recipient could not understand the intended message
Absent (equipment failure)	153	Equipment malfunction resulting in a complete loss of a message
Recipient not monitoring	553	Failure to maintain listening watch, proper lookout, or read available correct information

Source: U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS)

incidents were taken from U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) reports, U.S. National Transportation Safety Board (NTSB) accident reports and from audio recordings of ATC exchanges with pilots. Many of these incidents were linguistic-based, perhaps exacerbated by nonlinguistic factors such as distractions, fatigue, impatience, obstinacy, frivolousness or conflict.

Language is replete with *ambiguity*, the presence in a word or phrase of more than one possible meaning or interpretation. In a study of 6,527 reports submitted by pilots and controllers to ASRS, there were 529 reported incidents that the authors, Grayson and Billings,[6] classified as representing “ambiguous phraseology.”

On March 27, 1977, the pilot of a KLM Boeing 747 radioed, “We are now at takeoff,” as his plane began rolling down the runway in Tenerife, the Canary Islands. The air traffic controller mistook this statement to mean that the plane was at the takeoff point, waiting for further instructions, and so did not warn the pilot that another plane, a Pan American Airways B-747 that was invisible in the thick fog, was already on the runway. The resulting crash killed 583 people in what is still the most destructive accident in aviation history.

The KLM pilot’s otherwise perplexing use of the nonstandard phrase *at takeoff*, rather than a clearer phrase such as *taking off*, can be explained as a subtle form of what linguists refer to as “code switching.” Careful studies of bilingual and multilingual speakers have shown that they habitually switch back and forth from one of their languages to another in the course of a conversation, not because of laziness or lack of attention, but because of inherent social and cognitive features of how language works that are still poorly understood.

In the KLM pilot’s case, the form of a verb that is expressed in English by the suffix-*ing* happens to be expressed in Dutch by the equivalent of *at* plus the infinitive (the uninflected form of the verb, e.g., “fly” as contrasted with “flies,” “flying” or “flew”). For whatever reason, perhaps because of fatigue or the stress of having to work in conditions of low visibility, the normally

Dutch-speaking pilot inadvertently switched into the Dutch grammatical construction while keeping the English words. The Spanish-speaking controller, proficient in English but not in Dutch, and unattuned to subtle linguistic phenomena, had no clue that this shift was going on. He interpreted the *at* in a literal way, indicating a place, the takeoff point.

The controller at Tenerife had, a few seconds earlier, inserted another kind of ambiguity into the control tower–KLM pilot exchange. The controller had said, "KLM eight seven zero five you are cleared to the Papa Beacon, climb to and maintain flight level nine zero, right turn after takeoff … ." The tower intended the instruction only to mean that the KLM airplane was vectored to the Papa Beacon following a takeoff clearance that was still to come, rather than that the pilot was given permission to take off. But that was not how the KLM pilot understood *you are cleared*.[7]

Code switching can take place even when speakers have the same native language, when different dialects or variants are available. One example occurred in the accident at John Wayne Orange County Airport in Santa Ana, California, U.S., on Feb. 17, 1981 (see box at right for transcript). Air California Flight 336, a Boeing 737, was cleared to land at the same time as Air California Flight 931 (another B-737) was cleared to taxi into position for takeoff, but the controller decided that more time was needed between the two scheduled events and so told the Flight 336 captain to go around.

Flight 336's captain chose to have his first officer radio for permission to continue landing, but the pilot used the word *hold* to express the requested continuation, inadvertently switching from technical aviation jargon to ordinary English vernacular while speaking to the first officer. The first officer then radioed: "Can we land tower?"

In aviation parlance, *hold* always means to *stop* what you are now doing. But in ordinary English *hold* can also mean to *continue* what you are now doing (as in "hold your course"). The controller's seemingly self-contradictory instruction to Flight 931 to *go ahead and hold* at almost exactly the same time further exacerbated the situation, especially in view of the similarity of the two airplanes' identifying call signs and the consequent uncertainty as to just who was being addressed with that instruction. The resulting confusion led to 34 injuries, four of them classified as serious. The Flight 336 aircraft was destroyed by impact and postimpact fire when it landed with its gear retracted, the pilot having finally decided to follow instructions to go around, but too late actually to do so.[8]

Problems can also arise from *homophony*, the occurrence of different words that sound almost alike, such as *left* and *west*, or exactly alike, such as *to* and *two*. The latter misunderstanding actually led to a fatal accident at a southeast Asian airport.

Partial Transcript of Pilot-ATC Communications in Landing Accident: John Wayne Orange County Airport, Santa Ana, California, U.S., Feb. 17, 1981

0133:11	**Tower:** Air California three thirty six, you're cleared to land.
0133:33	**Tower:** Air California nine thirty one let's do it taxi into position and hold, be ready.
0133:37	**AC 931:** Nine thirty one's ready.
0133:52	**Tower:** Air Cal nine thirty one traffic clearing at the end, clear for takeoff sir, Boeing seven thirty seven a mile and a half final.
0133:57	**AC 931:** In sight we're rolling.
0134:13	**Tower:** Okay Air Cal three thirty six, go around three thirty six, go around.
(**0134:16**	**AC 336 Captain:** Can we hold, ask him if we can —– hold.)
0134:18	**Tower:** Air Cal nine thirty one if you can just go ahead and hold —–.
0134:21	**AC 336:** Can we land tower?
0134:22	**Tower:** Behind you Air Cal nine thirty one just abort.
0134:25	**Tower:** Air Cal three thirty six, please go around sir traffic is going to abort on the departure.
(**0134:27**	**AC 336 Captain:** Gear up.)
0134:36:	**IMPACT:** Aircraft lands with gear retracted.

Source: U.S. National Transportation Safety Board (NTSB)

ATC cleared the aircraft to descend "two four zero zero." The pilot read back the clearance as, "OK. Four zero zero." The aircraft then descended to 400 feet (122 meters) rather than what the controller had meant, which was 2,400 feet (732 meters).[9]

In another case a captain, who was the pilot flying, heard his copilot say, "Cleared to seven." He began a descent to 7,000 feet (2,135 meters), but at 9,500 feet (2,898 meters) the copilot advised the captain that 10,000 feet (3,050 meters) was the correct altitude. The copilot's communication, which the captain had heard as *cleared to seven*, was in fact *cleared two seven* — meaning, the assigned runway for landing was 27L.[10]

In written language, tiny differences in punctuation can drastically change the meaning of a sentence. (Compare these: "The flight attendant called the passengers' names as they boarded" vs. "The flight attendant called the passengers names as they boarded." That little apostrophe after *passengers* represents the difference between an action likely to evoke a smile from the passengers and one resulting in shock and outrage.)

Similarly, in spoken language, subtle differences in intonation and placement of pauses provide clues about how the words are to be interpreted. A simple, one-word exclamation — "right!" — can be understood as enthusiasm, resignation or sarcasm, depending on the intonation. But when a speaker is distracted, stressed or careless, these verbal "keys" can be omitted or displaced, resulting in an important component of the communication being lost or distorted.

A flight instructor giving a check ride noticed that the pilot of the small airplane added power just before touching down, contrary to the instructor's order. The instructor (thought he) had said, "Back … [pause] … on the power." What the pilot heard was, "Back on … [pause] … the power."[11]

Excessive pauses within a transmission can lead to what Monan[12] called "the delayed dangling phrase," which he defined as "the add-on of an explanatory phrase or sentence to a transmission that sound[s], tonally and in contents, to have been already terminated." On a congested frequency, he noted, such afterthoughts run the risk of covering, or being covered by, another transmission. Monan reported this example from the ASRS data base:

The expectation of an instruction can prime a pilot to mistake a different communication for the anticipated instruction.

An air carrier pilot radioed: "[Call sign] is maintaining zero nine zero … [pause] … as assigned." The pilot then heard the approach controller transmit: " … turn to one eight zero degrees." The pilot responded, "Roger, [call sign], turning to one eight zero."

Thirty seconds later, the approach controller radioed: "[Call sign], where are you going! You were given zero nine zero. Turn immediately and climb … ." It was some time before the pilot comprehended what had happened. The 180-degree heading had been for another aircraft; *as assigned* had blocked the other aircraft's call sign.

Further complexity results from the variety of *functions* — what linguists call "speech acts" — that any sentence can represent, including statement, question, request, promise and so forth. In spoken English, the structure or grammar of a phrase (especially if given in an abbreviated, shorthand form) does not necessarily indicate its function, and this can wreak havoc in even the simplest of situations. For example, a pilot misconstrued the phrase "traffic … level at 6,000 [feet (1,830 meters)]" to be an *instruction* for himself, meaning *[descend to and remain] level at 6,000 [because of traffic]*, rather than an *assertion* about his traffic, meaning *[the traffic is] level at 6,000*, as the controller intended.[13]

Words with uncertain reference, such as the pronouns *him* or *it* or indefinite nouns such as *things*, can cause considerable confusion in aviation communications. For example, in an accident that occurred at the Florida Everglades, U.S., on Dec. 29, 1972, the pilot and crew of an Eastern Airlines Lockheed Martin L-1011 had been preoccupied with a nose-gear problem that they had informed several controllers about during their trip. When the Miami [Florida] International Airport approach controller noticed on radar that their altitude was decreasing, he radioed, "How are things comin' along up there?" and the flight crew responded "OK." The crew was referring to the nose-gear problem, which, as it happens, they had just managed to fix, entirely unaware that there was any problem with altitude. But the controller interpreted *OK* as referring to the altitude problem, because that is what he had had in mind when he radioed the question. The crash killed 101 people.[14]

To clarify the time frame of an instruction, and thus to avoid the kind of confusion that apparently occurred in the Tenerife accident when an instruction about what to do *after a takeoff for which permission had not yet been given* seemed to imply takeoff clearance, controllers use the words *anticipate* or *expect*. Such modifiers are helpful, but they are not without dangers of their own.

The expectation of an instruction can prime a pilot to mistake a different communication for the anticipated instruction. In their study of more than 6,000 ASRS reports, Grayson and Billings[15] observed that "many instances of misunderstanding can be attributed to the expectation factor; that is, the recipient (or listener) perceives that he heard what he expected to hear in the message transmitted. Pilots and controllers alike tend to hear what they expect to hear. Deviations from routine are not noted and the readback is heard as [being the same as] the transmitted message, whether correct[ly] or incorrect[ly]."

This was demonstrated as recently as May 1995 at Heathrow Airport, London, England, when a Lufthansa Airbus A300 took off without ATC clearance. (It was the sixth such incident at major U.K. airports since 1990.) Investigators said that "having lined up, [the crew expected that] their next instruction would be to take off. … In a fast-moving queue for takeoff, the crew were further primed when they had lined up by seeing the aircraft ahead of them lift off."[16]

In another incident, an aircraft cruising at flight level (FL) 310 (31,000 feet [9,455 meters]) asked for a descent clearance to FL 240 (24,000 feet [7,320 meters]) and was told to expect the clearance in 20 miles. After a flight attendant came to the cockpit to discuss a recurring temperature problem, the captain mistook the first officer's readback of a clearance for a 280 degree *heading* as a clearance to *FL* 280 (28,000 feet [8,540 meters]), and began a premature descent. The similarity of 240 and 280, and the force of expectation, combined to give a false impression.[17]

Failure to make a clear distinction between a conditional statement and an instruction can put one or more aircraft in peril.

During cruise at FL 230 (23,000 feet [7,015 meters]) a copilot, who was the pilot flying, asked ATC for permission to climb to FL 310 (31,000 feet [9,455 meters]). The controller replied, "[FL] 310 is the wrong altitude for your direction of flight; I can give you [FL] 290 [29,000 feet (8,845 meters)]… ." The copilot replied, "Roger, cleared to 290, leaving 230." The controller did not challenge the readback. When the airplane reached 24,000 feet (7,320 meters), the controller queried the airplane's altitude and said, "I did not clear you to climb; *descend immediately to FL 230*. You have traffic at eleven o'clock, 15 or 20 miles." The pilot had understood *I can give you 290* to mean *You are cleared to climb to 290*.[18]

Failure to make a clear distinction between a conditional statement and an instruction can put one or more aircraft in peril.

Misunderstanding can derive from the overlapping number ranges that are shared by multiple aviation parameters. For example, *240* can be a flight level, a heading, an air speed or the airline's flight number. Aircraft call signs are particularly apt to be confused with one another.[19] Incidents in which one aircraft accepted an instruction meant for another have included pairs with only mild similarities: for instance, "TWA 232" vs. "United 692" and "Air Cal 127" vs. "Air Cal 337."[20]

An aircraft was flying on a heading of 300 degrees at FL 270 (27,000 feet [8,235 meters]). ATC vectored the aircraft to "three one zero." The airplane's first officer acknowledged "three one zero" and then climbed to FL 310 (31,000 feet [9,455 meters]) instead of turning to a course of 310 degrees.[21]

Another aircraft *was* in fact cleared to FL 310. At about FL 260 (26,000 feet [7,930 meters]), the controller asked about the aircraft's airspeed. The pilot answered, "315 knots." The controller said, "Maintain 280." The pilot answered "280 knots," slowed to 280 knots, and continued the climb to FL 310. At about FL 295 (29,500 feet [8,998 meters]), the controller asked for the airplane's altitude and the pilot replied, "295." The controller said that the aircraft was cleared only to FL 280 (28,000 feet [8,540 meters]).[22]

In this case, the controller had established a context of airspeed through his first question and failed to indicate that the subject had changed for his next question. The pilot had then given a readback that combined what the controller actually said ("280") with the presumed context ("knots"), and the controller had not taken notice of the extra word.

Researchers have suggested that the possibility of confusion about the sequence or meaning of numbers is enhanced when two or more sets of numbers are given in the same transmission. Especially in a high-pressure, high-workload cockpit or tower, it would require no more than a momentary slip of attention to transpose a three-digit flight level and a three-digit heading.

Grayson and Billings[23] wrote that number-sequence errors "[seem] to occur most often when ATC gives assigned headings or distances in conjunction with changes in assigned altitudes in the same clearance." Monan,[24] in his study of ASRS incident reports, said that "one error pattern could be clearly identified: mishearing of the numbers occurred most frequently when single, one-sentence clearance messages called for two or more separate pilot actions. Thus, 'cross XYZ at one one thousand, descend and maintain one zero thousand, reduce speed to 250 knots … .'"

Salzinger et al.[25] noted that "it is well known that saying a number after another number that is supposed to be remembered creates the classic condition for confusing the numbers. Yet this is precisely what happens when the pilot states an understood numeric command (such as an assigned altitude) and then states the flight identification, which is itself a number."

To make the problem worse, extensive repetition of instructions in essentially the same format, such as *cleared to — feet; expedite*, can have a dulling effect on a pilot's consciousness. Such an effect, especially during a heavy-workload phase of flight, can encourage language-based mistakes.

The primary responsibility for clear, comprehensible radio communication is on pilots and controllers. Pilot-ATC communications technique has evolved into a four-step system that involves a "confirmation/correction loop." The steps are: (1) Sender transmits message; (2) Recipient actively listens to message; (3) Recipient repeats the message back to sender; and (4) Sender actively listens for a correct readback. The system's built-in safety margin depends on all four elements of a communication being performed correctly.

Linguistic errors generally represent an aberration in step (1): the transmission falls victim to one of the kinds of anomalies discussed in this article. Awareness of linguistic traps may help to avoid introducing them into the communication in the first place, but under workload pressures it will be the rare person who can completely avoid them. Therefore, strict adherence to steps (2) through (4) becomes the next line of defense against errors.

In his 1988 ASRS report study, Monan wrote that "perhaps the most important … pattern emerging among the findings of this study was a strong indication that an essential redundancy — the fail-operational, double-check procedure elements recently termed 'hearback' — frequently is missing from controller-pilot-controller dialogues." Among the ways that the absence of a confirmation/monitoring step manifests, Monan said, are:

- A controller does not hear — or does not listen to — a pilot's incorrect readback. The pilot accepts the lack of response as silent confirmation that the readback was correct.
- After receiving an instruction, the pilot signs off with an inadequate "Roger" or "okay" or "so long," which precludes any controller double-check of the exchange.

The ASRS reports in Monan's 1988 study contained a number of complaints by pilots of controllers' failure to correct mistaken readbacks. Among the comments he quoted were these:

- "My impression is that controllers are not in a listening mode. As soon as they issue a clearance, they start talking to other aircraft and pay no attention to the readbacks."
- "It is my opinion that I could read back my Social Security number and most controllers would not question it!"

… research does suggest some ways that pilot-ATC linguistic problems can be alleviated.

Monan pointed out, however, that "the airmen tended to downgrade the significance of their own listening errors as less critical than the monitoring role of the controller." Moreover, he suggested that flight crews relied too much on controllers' active listening. "Half-heard, doubtful, sometimes guessed-at numbers for headings, altitudes, taxi hold points, or Victor airway routings — IF their readbacks passed unchallenged — were accepted by the airmen as validated, double-checked instructions as to where to fly their airplanes. Accepting heard clearances for descents to low altitudes while well outside normal distance-to-destination range, climbs above usual altitudes, turns 180 degrees away from desired track, wrong-direction flight levels, descents in clouds down through tiers of aircraft in a holding stack, IMC descents below known mountainous terrain — the airmen subordinated commonsense judgment and operational practicality to an assumption from a controller's silent 'confirmation' of their readbacks."

Morrison and Wright,[26] in their review of ASRS records from January 1986 to September 1988, found that "*too rapid issuance of instructions* ('speed feed') was the most common delivery technique problem cited."

In a 1983 study, Monan discussed the related problem of "nonstop ATC transmissions." He wrote, "Run-on ATC messages — instructions to one aircraft continuing without a break in transmission into multiple instructions to numerous other aircraft — evoked a series of pilot protest reports to the ASRS. 'The controller issued instructions to 12 different aircraft, all in one, nonstop transmission … .' 'The controller was so busy that he had to talk continuously for up to 45 seconds [at] a time … .'"

Although recognizing the realities of congested traffic conditions approaching major terminals during peak periods, and often complimenting controllers for doing a good job under difficult circumstances, pilots nevertheless pointed out a double danger from "nonstop transmissions." First, it makes it easier to miss one's own aircraft's call sign in the jumbled messages, and second, there is no opportunity for readback acknowledgment and the controller will not know of any missed instructions.

Pilot-ATC communications difficulties have been extensively studied; in their survey of the research literature, Prinzo and Britten reviewed 43 reports.[27] But the problem will not be easy to eliminate. In the 1988–1989 period, ASRS reports citing faulty readback or hearback technique increased by 2 percent.[28] As the Airbus A300 incident at Heathrow (page 4) suggests, pilot-ATC communications problems still occur, even at major airports with highly experienced controllers and pilots.

Nevertheless, research does suggest some ways that pilot-ATC linguistic problems can be alleviated.

Prinzo and Britten, in their survey of research in the field, wrote that "taken as a whole, the studies presented here indicated that

- "Only a few speech acts should make up a single transmission; [and,]
- "The speech acts making up a transmitted message should be topically related … ."

Citing a particular group of studies, Prinzo added that "this research suggests that

- "Pauses between messages should be of sufficient duration so the message can be completely understood before more information is transmitted."
- Some research suggests that the technique of "chunking" orally transmitted information into smaller units makes it easier to comprehend.[29] For instance, a four-digit transponder code ("two seven seven two") may be easier to understand and retain if presented as two two-digit numbers ("twenty-seven seventy-two").

- Flight crews should not assume that a routine readback of a questionable clearance or instruction is adequate for confirmation. They should *call attention* to their uncertainty by prefacing their readback with the word "Verify … ."[30]

Another approach would involve intensive efforts to develop a heightened awareness in pilots and controllers of the nuances of language and of the dependence of both their own and other people's safety on their willingness to use language more mindfully. For example, NASA's ASRS program, based at Ames Research Center in Mountain View, California, U.S., issues alerts on threats to aviation safety that it finds to be particularly prevalent, many of which involve issues of language and communication. The Centre de Linguistique Appliquée of the Université de Franche-Comté in Besançon, France, develops linguistically sophisticated training materials for pilots and controllers and sponsors a triennial International Aviation English Forum.

Much more needs to be done in this area, especially in the United States, where English is taken for granted as a language that everyone is expected to speak correctly in a standard way, in contrast to Europe or Asia, where the coexistence of multiple languages forces people to take linguistic issues more seriously. As the Tenerife and John Wayne accidents reveal, a clearer understanding of linguistic processes and mechanisms such as code switching would help speakers in pilot-ATC communications to avoid potentially problematic formulations.

Another path is the development of technological communication tools. Although such tools would probably be of limited use in emergency situations, which require split-second decisions by human beings, technology can reduce the number of emergency situations that arise.

A close-to-ideal solution to at least some of the sorts of problems discussed in this article would be the development of an intelligent voice interface for aviation communication.

Such a device would monitor communications and filter out potential linguistic confusions, if necessary checking with the speaker for clarification before conveying messages, and monitoring the aircraft's state, providing needed callouts automatically. The system would be valuable on line, as a safety device in real time, but would also be useful as a training device, an aid to developing an awareness in both pilots and controllers of the kinds of linguistic constructions they ought to avoid, while conditioning them, to some extent, to do so. It might also be helpful in furthering our understanding of phenomena such as code switching, as basic linguistic research reveals more clearly the mechanisms and triggering factors that bring such phenomena about.[31]

Developing such a system would require extensive further research to solve many still open questions of scientific linguistics, such as the problem of speech recognition, that is, how to extract a meaningful message from an acoustic wave. This problem has become tractable technologically for individual words but still resists solution for more extended conversational utterances.

There are also many unsolved problems of what linguists call *pragmatics*, that is, the ways in which *context* can effect the meaning of an utterance. For example, the sentence *I have some free time* means one thing when uttered during a discussion of one's work schedule, but means something quite different when uttered after just having driven one's car up to a parking meter. People routinely distinguish such meanings in real conversations with very little effort, but exactly how they do that, and how what they do can be implemented in workable tools, will only be discovered as basic research in linguistics progresses. The only certainty is that a workable intelligent voice interface is a very long-term goal, not likely to be developed for this or the next generation of aviation.

In the meantime and in parallel with that research, it may be more fruitful to develop more limited systems, in which a *visual* interface for processing a more restricted English-*like* language is used.

One system that offers hope of overcoming problems in radio-frequency voice communications for ATC is the Aeronautical Data Link System (ADLS), now being developed by the FAA in coordination with the International Civil Aviation Organization (ICAO). ADLS enables digital transmission of messages between pilots and controllers through a two-way data link (TWDL). Coded messages, modeled after existing ATC phraseology, will be transmitted by this alternative to radio, and the digital data can be decoded at the receiving end as text, graphics or speech. With a TWDL system, more information can be exchanged in less time and with less demand on voice channels.[32]

A prototype version of another such system, the Aviation Interface Research (AIR) System, was developed by graduate students under the author's supervision at Boston (Massachusetts, U.S.) University.

AIR uses a system of nested menus (in which choosing a menu item brings up another menu) to send messages back and forth between two Macintosh computers, which simulate pilot and controller interfaces (Figure 1, page 8). When a message is entered from one of these two user interfaces, a program called a *parser* checks that it is correctly formed with respect to the restricted English-like language that is used by the system, before permitting it to be transmitted to the other interface, where it appears at the top of the screen. If necessary, an error message is returned to the sender instead.

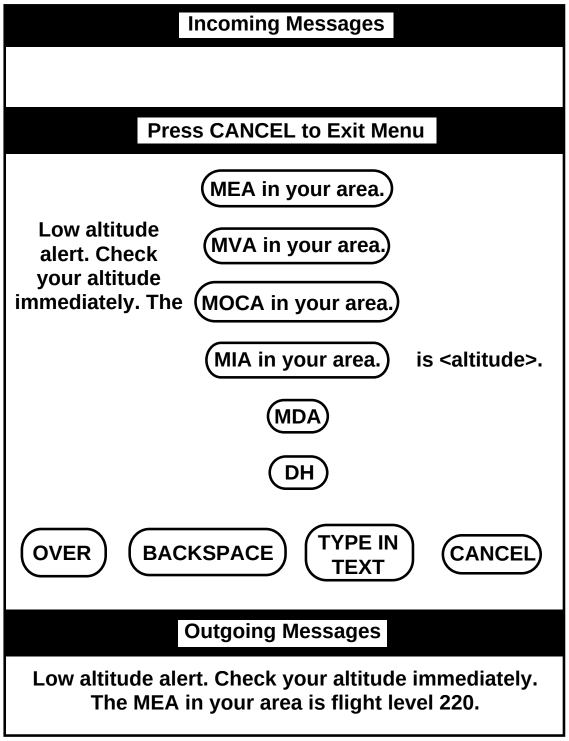
Menu screens are invoked by selecting symbolic *icons* and messages are constructed by selecting *buttons* (such as "MEA [minimum en route IFR altitude] in your area" in Figure 1) that contain actual words or phrases, which are echoed at the bottom of the sending screen. On the prototype system the selections are made by mouse, but they could just as well be made, more conveniently in a pilot-ATC communication situation, by touch-screen. Figure 2 shows a sample of the sorts of messages that the present parser will recognize as well formed and will permit to be sent.

As it now stands, AIR serves mainly to illustrate the concept and demonstrate the feasibility of an error-resistant visual message-sending and -receiving system for pilot-controller communication. A second version is envisioned as having further features that will improve on the current system in several ways.

For example, it will be possible to provide bilingual screens, in English and in the user's own language, to enable the crew or controller to check the correctness of messages they want to send or to test their understanding of messages they receive (Figure 3). It will also be possible to have the system choose randomly from a set of synonymous *alternative formulations* of an instruction in order to pre-empt the semi-hypnotic boredom that is induced by repeatedly receiving instructions of exactly the same form (Figure 4, page 9).

Further research and development of intelligent error-resistant voice and visual systems such as AIR can reasonably be expected to offer substantive progress toward technological

Typical Pilot-ATC AIR System Screen Interface



Incoming Messages

Press CANCEL to Exit Menu

Low altitude alert. Check your altitude immediately. The

MEA in your area.

MVA in your area.

MOCA in your area.

MIA in your area.

is <altitude>.

MDA

DH

Outgoing Messages

Low altitude alert. Check your altitude immediately. The MEA in your area is flight level 220.

Source: Steven Cushing, Ph.D.

Figure 1

Examples of Messages Accepted for Transmission by the AIR System

Weather area between 1 o'clock and 3 o'clock 7 miles.

Traffic alert 9 o'clock, 5 miles, eastbound, converging. Advise you turn right heading 045 and climb to flight level 190 immediately.

Hold short of runway.

Flock of geese, 6 o'clock 4 miles northbound, last reported at altitude 15 thousand 7 hundred.

Contact Logan ground 131.1.

Wind shear alerts all quadrants. Centerfield wind north at 30 knots varying to northeast at 20 knots.

Maintain flight level 203 10 miles past Chicago VORTAC.

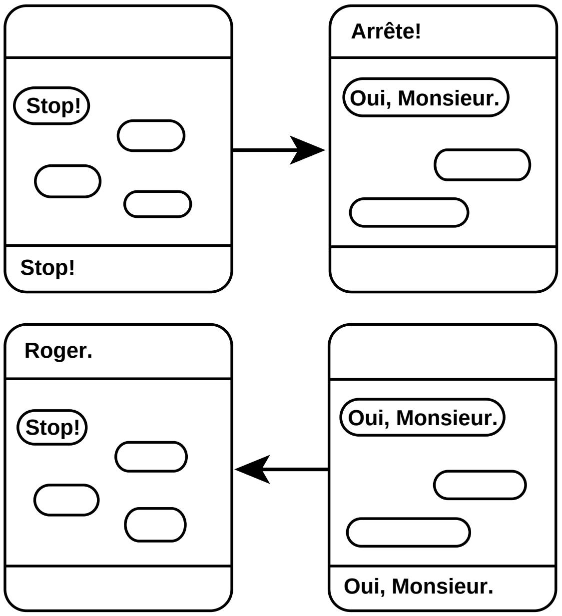
Reduce speed by 30 knots.

Descend and maintain altitude 16 thousand 3 hundred. Then reduce speed by 10 knots.

Source: Steven Cushing, Ph.D.

Figure 2

Bilingual AIR System Screens for Sending and Receiving Messages in Different Languages

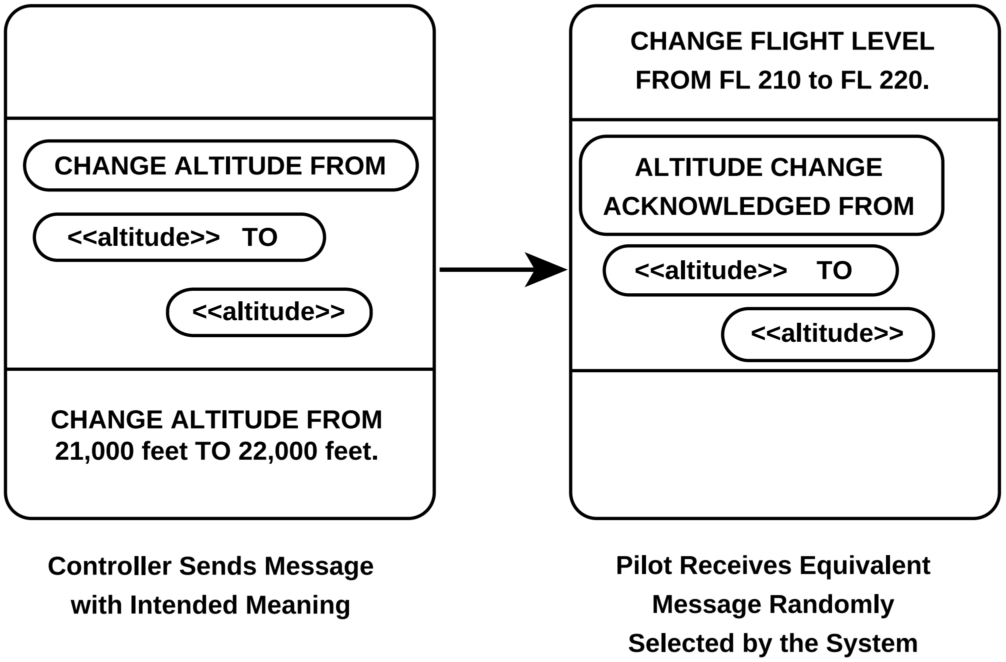


Messages Sent from and Received at English-based Screen. (Controller)

Messages Sent from and Received at French-based Screen. (Pilot)

Source: Steven Cushing, Ph.D.

Figure 3



AIR System Conversion to Alternative Formulations of Instructions

Source: Steven Cushing, Ph.D.

Figure 4

mediation in communication for the aviation setting. In the meantime, explicit instructions by controllers, complete readbacks by pilots and active listening by controllers to pilots' readbacks are the best defense against miscommunication … which, at worst, can mean fatal words.♦

Editorial note: This article is based in part on Steven Cushing's book *Fatal Words: Communication Clashes and Aircraft Crashes*. University of Chicago Press, 1994.

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About the Author

Steven Cushing, Ph.D., is a computational and cognitive linguist currently specializing in technical communication. He was a summer faculty research fellow in human factors at NASA-Ames Research Center, Mountain View, California, U.S., in 1987 and 1988, and in flight management at NASA-Langley Research Center, Hampton, Virginia, U.S., in 1989. Also in 1989 he served on a delegation sponsored by the Soviet Academy of Sciences to help evaluate Soviet uses of computers in education and training. He currently works at InterSystems Corp. in Cambridge, Massachusetts, U.S., and is an adjunct professor at the Union Institute Graduate School in Cincinnati, Ohio.

Flight-crew Error Declined As Causal Factor in Accidents with Known Causes in Recent 10-year Period

But flight crews were cited as primary causal factor far more often than the airplane, maintenance or any other factor.

Editorial Staff

Flight crew errors, airplane mechanical failures, weather and airport/air traffic control (ATC) anomalies all declined as primary causal factors in accidents with known causes in the worldwide commercial jet fleet in the 1985–1994 period compared with the 1959–1994 period, according to Boeing's *Statistical Summary of Commercial Jet Aircraft Accidents: Worldwide Operations 1959–1994.* Only maintenance and "miscellaneous/other" were the primary causal factor in a larger percentage of accidents during the 10-year period compared with 1959–1994 (Figure 1, page 12).

Errors involving flight crew were primary causal factors in a majority of accidents during both periods under review, comprising 64.4 percent of accidents with known causes in 1959–1994 and 58.1 percent of those in 1985–1994. Airplane failures (including the airframe, systems and engines) were the primary causal factor in 15.6 percent of accidents with known causes in the longer period and 13.7 percent in the 10-year period.

Maintenance displaced airport/ATC as the third most frequent primary causal factor during 1985–1994, compared with 1959–1994.

Half of all worldwide commercial jet accidents between 1959 and 1994 with known causes occurred during final approach and landing, a phase representing only 4 percent of total flight time (Figure 2, page 13). Of the 439 final-approach-and-landing accidents with known causes, 383 (78.1 percent) included flight crew as a primary causal factor. This percentage was far in excess of any other primary causal factor: airplane failures represented 8.4 percent of the final-approach-and-landing accidents with known causes, followed by weather (5.2 percent), airport/ATC (4.6 percent), maintenance (2.1 percent) and miscellaneous/other (1.6 percent).

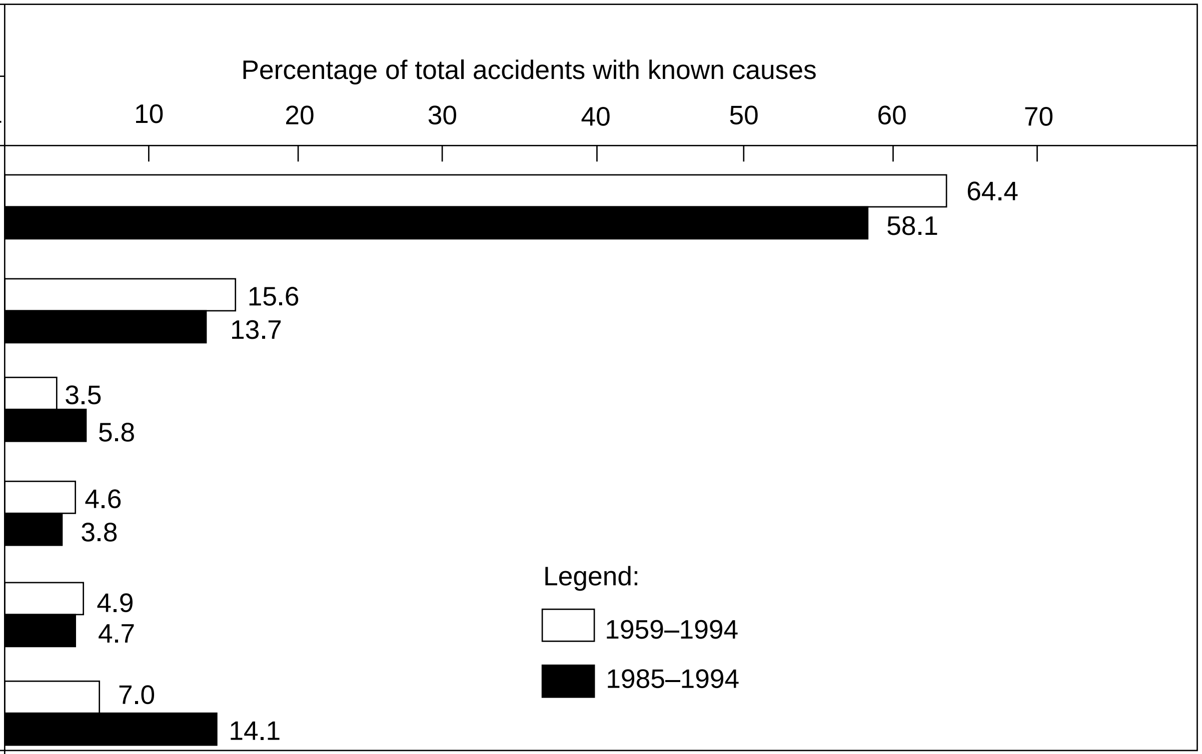
The publication correlated phase of flight with primary causal factor in worldwide jet fleet accidents during the 1959–1994 period, subdividing each comparison into Boeing and non-Boeing aircraft (Figure 3, page 14). Although flight crews were the primary causal factor in a majority (51 percent) of takeoff accidents whose causes were known, airplane malfunctions represented a larger proportion (27 percent) of takeoff-accident primary causal factors than they did in final-approach-and-landing accidents.

The study defined "accident" as "an occurrence associated with the operation of an aircraft … in which any person suffers death or serious injury as a result of being in or upon the aircraft or by direct contact with the aircraft or anything attached thereto, or the aircraft receives substantial damage."

The brochure is updated annually Boeing Commercial Airplane Group, P.O. Box 3707, Seattle, WA 98124-2207 U.S.

Worldwide Commercial Jet Fleet: All Accidents, by Primary Causal Factors

Primary causal factor	Number of accidents	
	Total	1985–1994
Flight crew	569	136
Airplane*	138	32
Maintenance	31	13
Weather	41	9
Airport/ATC	43	11
Miscellaneous/other	62	33
Total with known causes	884	234
Unknown or awaiting reports	133	76
Total	1,017	310



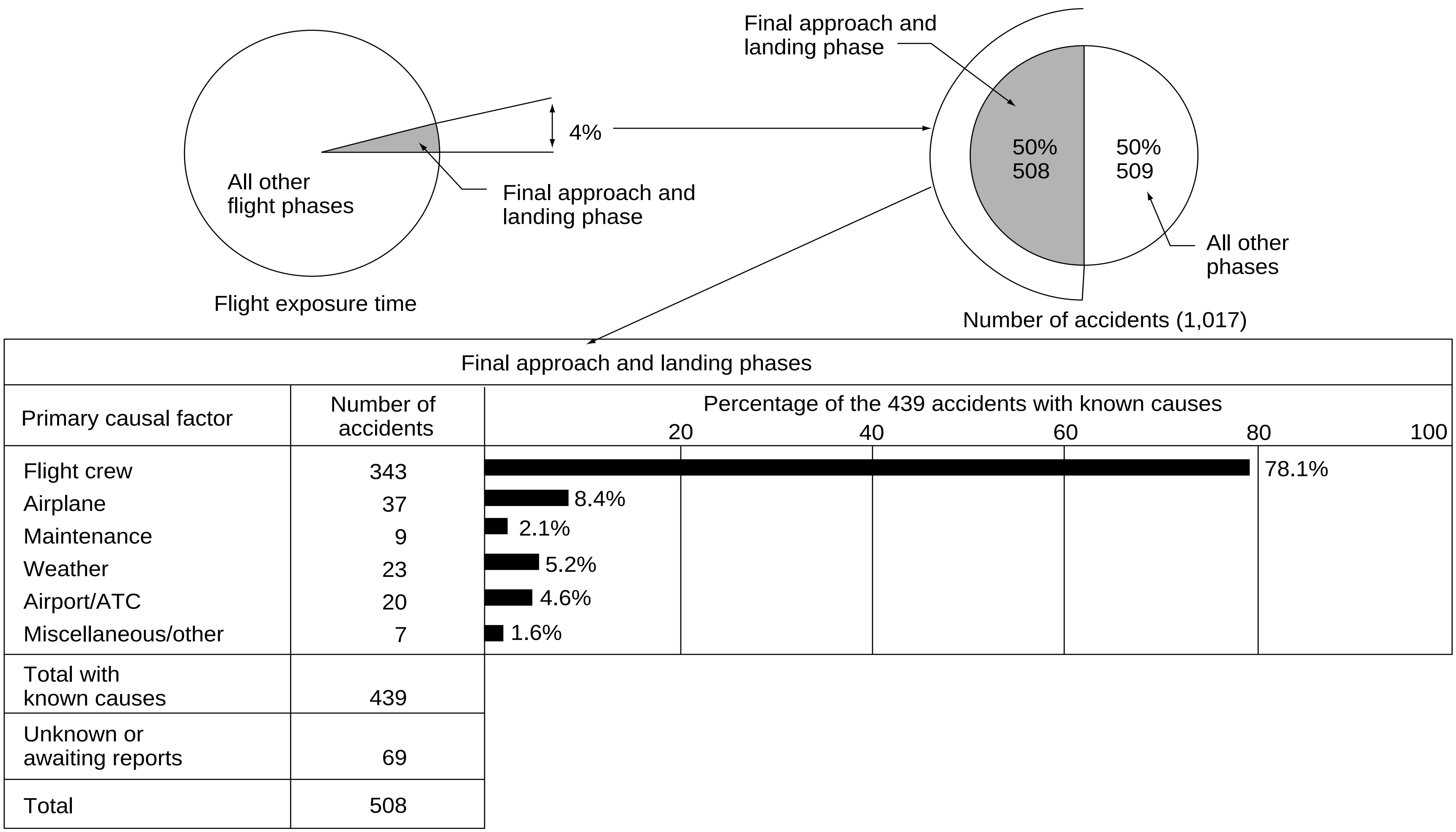
Excludes:
- Sabotage
- Military action
- Turbulence injury
- Evacuation injury
- Servicing injury

* Includes:
- Airframe
- Aircraft systems
- Powerplant

Source: Boeing Commercial Airplane Group

Figure 1

Worldwide Commercial Jet Fleet 1959–1994: All Accidents, by Critical Time and Cause, Final Approach and Landing



Primary causal factor	Number of accidents	Percentage of the 439 accidents with known causes
Flight crew	343	78.1%
Airplane	37	8.4%
Maintenance	9	2.1%
Weather	23	5.2%
Airport/ATC	20	4.6%
Miscellaneous/other	7	1.6%
Total with known causes	439	
Unknown or awaiting reports	69	
Total	508	

Source: Boeing Commercial Airplane Group

Figure 2

Worldwide Commercial Jet Fleet 1959–1994: All Accidents, by Primary Causal Factors

Primary causal factor	Boeing Non-Boeing	Number of Accidents							
	Total	Takeoff	Initial Climb	Climb	Cruise	Descent	Initial Approach	Final Approach	Landing	Taxi, Load
Flight crew	306 263	31 26	17 24	9 4	9 5	19 20	28 26	83 86	108 66	2 6
Airplane	62 76	12 18	7 8	12 17	6 7	2 3	0 0	3 0	16 18	4 5
Maintenance	15 16	1 5	1 1	2 5	4 1	0 1	0 0	0 1	6 2	1 0
Weather	22 19	1 0	2 2	4 0	2 3	1 1	0 1	4 4	7 8	1 0
Airport/ATC	19 24	3 1	2 1	1 1	0 5	1 2	0 1	0 4	9 7	3 2
Miscellaneous	39 23	5 8	1 2	3 1	4 3	7 1	1 0	1 0	5 1	12 7
Unknown	52 81	5 14	6 3	3 3	6 3	2 3	4 6	7 7	15 40	4 2
Total 1,017	515 502	58 72	36 41	34 31	31 27	32 31	33 34	98 102	166 142	27 22

Excludes:
- Sabotage
- Military action
- Turbulence injury
- Evacuation injury
- Servicing injury

	Accidents	Flight time	Departures
Boeing	51%	58%	55%
Non-Boeing	49%	42%	45%

Source: Boeing Commercial Airplane Group

Figure 3

Report Analyzes Progress of U.S. National Weather Service Modernization

U.K. Civil Aviation Authority reviews helicopter offshore safety and sea survival.

Editorial Staff

Advisory Circulars (ACs)

General Aviation Airworthiness Alerts: Improve Reliability-Interchange Service Experience. U.S. Federal Aviation Administration (FAA). Advisory Circular (AC) No. 43-16. July 1995. 17 p.; illustrations. Available through FAA Flight Standards Service, Safety Data Analysis Section (AFS-643), P.O. Box 25082, Oklahoma City, OK 73125-5029 U.S.

General Aviation Airworthiness Alerts contain notices of faulty products and system failures, contributed by civil aviation mechanics and safety inspectors via Malfunction or Defect Reports to the FAA Service Difficulty Reporting (SDR) Program. By exchanging service experiences, members of the aviation community can increase general awareness of the durability, reliability and safety of aeronautical products. Damaged part- and system-failure information published in these alerts include such items as corroded fuselage tubing, a defective nose-gear actuator retraction arm, battery-box leakage and several cracked main and nose landing-gear wheel assemblies reported by one repair station operator.

Announcement of Availability — Aviation Weather Services. U.S. Federal Aviation Administration (FAA). Advisory Circular (AC) No. 00-45D. February 1995. 1 p. Available through GPO.**

This AC announces the availability of the newly revised advisory circular *Aviation Weather Services*, which provides information on current products and services of the U.S. National Weather Service (NWS). Major changes have occurred in the following NWS services and products: area forecasts; in-flight advisories; terminal forecasts; weather depiction charts; and severe weather outlook charts. Further additions to the revised AC include automated surface weather observation and center weather service unit products as well as the new METAR/TAF formats. Instructions for ordering the revised AC are included with this announcement.

Reports

National Implementation Plan for Modernization of the National Weather Service for Fiscal Year 1996. U.S. Department of Commerce. Report No. Trans-95-2. April 1995. 186 p.; figures; tables; appendices. Available through GPO.**

In 1989, the National Weather Service (NWS), which is part of the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce, initiated a program to modernize its systems with the ultimate goal of improving weather services and reducing weather-related fatalities.

This report analyzes the progress of this extensive modernization plan, currently at its midpoint. The success of newly implemented systems such as next-generation weather radar (NEXRAD) and the automated surface observing system (ASOS) are examined, and the potential impact of changes made to the plan since its inception are discussed.

A Study of the Human Factors Influencing the Reliability of Aircraft Inspection. Murgatroyd, R.A.; Worrall, G.M.; Waites, C. U.K. Civil Aviation Authority (CAA). Paper No. 95005. July 1995. 26 p.; tables; figures. Available through U.K. CAA.*

As part of the joint U.S. Federal Aviation Administration (FAA)/CAA Aging Aircraft Inspection Program, the U.K. CAA has initiated a research project to investigate the reliability of airframe inspectors. Test subjects, 11 professionally qualified inspectors from airline and maintenance facilities in the United States and Europe, were asked to perform a typical inspection task — the examination of a section of fuselage — under controlled conditions. The main task assigned to each subject was a simulated lap-joint inspection using the sliding eddy-current probe technique, but a small number of ultrasonic inspections were also included to assess the subjects' level of alertness. A computer-based inspection simulator allowed crack signals to be presented to the subjects over a wide range of frequencies and distributions. To determine the influence of normal working conditions on inspector reliability, selected environmental variables were also introduced to the test situation; these included shift working, interruptions, inspection position, ambient temperature and humidity, and task duration.

The results revealed that a small number of cracks were overlooked because of mistakes in the scanning technique employed; misalignment of the straight edge during scanning was a particular problem. Other errors were made in miscounting the number of cracks in a cluster. The majority of inspectors were unable to detect low-amplitude signals, typical of scans conducted over areas of thick paint. Some inspectors, however, did not miss any cracks.

The study found no evidence of the influence of work environment, task length or inspection position, but concluded that the failure to detect crack signals could be attributed to boredom and fatigue. A tendency to concentrate on the primary task at the expense of other reporting requirements was also cited as a cause of inspector error. The study also concluded that simple human errors are often the result of inadequately defined inspection procedures.

Review of Helicopter Offshore Safety and Survival. U.K. Civil Aviation Authority (CAA). Report No. CAP 641. February 1995. 76 p.; glossary; annexes. Available through U.K. CAA.*

This review, which was commissioned by the CAA after the crash of an AS 332L Super Puma helicopter at the Cormorant Alpha platform in 1992, addresses all aspects of offshore helicopter safety and survival. The report is based on an event tree, a diagram that outlines the course of an offshore helicopter flight and explores all possible points during flight when an emergency situation might occur. Procedures for coping with each type of emergency are presented in seven phases: preflight; postflight; before ditching or crashing; ditching; crash; sea survival; and rescue. Each of these phases is assessed individually. The procedures outlined in the first four phases are found to be satisfactory, though a need for improvement remains. Nevertheless, safety measures related to crash situations as well as to sea survival and rescue following a crash require greater attention.

The review concludes with 17 recommendations. The annexes include evidence from the survivors of the Cormorant Alpha accident, summaries of fatal accidents involving U.K.-operated offshore helicopters since 1976, a review of relevant accident data, a graphic representation of the event tree, and a safety and survival system table.

Safety Standards at Unlicensed Aerodromes, fourth edition. U.K. Civil Aviation Authority (CAA). Report No. CAP 428. July 1991. 25 p.; figures; appendices. Available through CAA.*

This Civil Aviation Publication (CAP) provides safety guidelines for owners and operators of unlicensed aerodromes. The CAA suggests that the physical characteristics of unlicensed aerodromes and the facilities provided there should comply as much as possible with CAP 168, *The Licensing of Aerodromes*, to ensure safe aircraft operations. Fueling of aircraft must be conducted in accordance with CAP 74, *Aircraft Fuelling — Fire Prevention and Safety Measures for the Fuelling of Aerodromes and Helicopters* [sic] and fuel storage with CAP 434, *Aviation Fuel at Aerodromes.* If an unlicensed aerodrome is near a civil or military airfield, air traffic co-ordination procedures are essential. Other standards for acceptable aerodrome features described in these guidelines are ground signals and markings, airfield lighting, the provision of a duty officer, aircraft parking and emergency services. The appendices cite the pertinent CAA regulations.

Books

World Encyclopedia of Aero Engines, third edition. Gunston, Bill. Sparkford, Somerset, U.K.: Haynes Publishing, 1995. 192 p.; illustrations; glossary; index.

This updated third edition of the *World Encyclopedia of Aero Engines* has been expanded and revised to include engine designs from every major manufacturer from the Wright brothers to Eurojet. The highlight of the third edition, however, is its new entries featuring previously unavailable information on engines of Chinese and Russian design. The Chinese aero-engine industry is covered by a single entry; Soviet manufacturers and bureaus such as Bessenov, Tumansky and VOKBM are presented individually.

The author places his information in a historical context. As he traces the most significant aero-engine manufacturers from the early days of flight through two world wars and into the jet age, Gunston's accounts of their struggles to develop and sell their engines gives the longer entries a narrative quality that is engaging as well as highly informative. Gunston also provides detailed descriptions and critical evaluations of the various engines. Black and white photographs, some of them rare, accompany the text.

The Turbine Pilot's Flight Manual. Brown, Gregory N.; Holt, Mark J. Ames, Iowa, U.S.: Iowa State University Press, 1995. 195 p.; figures; appendix; glossary; index.

Keywords:
1. Aircraft —Turbine Engines
2. Jet planes — Piloting
3. Handbooks, Manuals, etc.

This manual covers the fundamental principles of the systems and procedures necessary to pilots operating high-performance turbine aircraft. It is designed to be used as a comprehensive source of information for ground-school students, military pilots making the transition to careers in commercial aviation or seasoned turbine-aircraft professionals refreshing their basic training. Chapter titles follow the format of standard pilot operating manuals: "General preparations"; "Turbine engine and propeller systems"; "Turbine aircraft power systems"; "Major aircraft systems"; "Dedicated aircraft systems"; "Limitations"; "Normal procedures"; and "Emergency and abnormal procedures."

In addition to its descriptions of turbine engines and systems, this manual also addresses issues particular to turbine aircraft operation, such as high-speed aerodynamics, multipilot crew coordination, wake turbulence and high-altitude weather navigation with state-of-the-art avionics. Throughout the manual, the differences between turbine and piston aircraft are explained.

Numerous figures and tables supplement the text. An original spotter's guide to regional, corporate and airline aircraft is included in the appendix, and the glossary covers commonly used airline and corporate aviation terms. ♦

*U.K. Civil Aviation Authority
Printing and Publication Services
Greville House
37 Gratton Road
Cheltenham, GL50 2BN England

**Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402 U.S.

U.S. Federal Aviation Administration (FAA) Regulations and Reference Materials

Federal Aviation Regulations (FARs)

Part	Date	Subject
Part 1	4/23/95	*Definitions and Abbreviations* (incorporates Amendment 1-39, "Public Aircraft Definition and Exemption Authority," adopted 1/6/95).
Part 25	3/6/95	*Airworthiness Standards: Transport Category Airplanes* (incorporates Amendment 25-38, "Improved Flammability Standards for Materials Used in the Interiors of Transport Category Airplane Cabins," adopted 1/24/95).
Part 61	3/27/95	*Certification: Pilots and Flight Instructors* (adds new Special Federal Aviation Regulation [SFAR] 73, "Robinson R-22/R-44 Special Training and Experience").
Part 121	8/25/95	*Certification and Operations: Domestic, Flag, and Supplemental Air Carriers and Commercial Operators of Large Aircraft* (incorporates Amendment 121-248, "Pilot Operating and Experience Requirements," adopted 4/25/95).

Advisory Circulars (ACs)

AC No.	Date	Title
150/5210-17	4/6/95	*Programs for Training of Aircraft Rescue and Firefighting Personnel* (change pages to 150/5210-17, *Programs for Training of Aircraft Rescue and Firefighting Personnel*, dated 3/9/94).
00-7C	4/14/95	*State and Regional Disaster Airlift (SARDA) Planning* (cancels *State and Regional Disaster Airlift (SARDA) Planning*, dated 8/31/87).

Accident/Incident Briefs

Boeing 727 Rotates Early on Takeoff to Avoid Dornier 228 on Runway

Heavy rain, severe turbulence cause double engine flameout in Learjet.

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

Lack of Coordination Leads to Ground Collision

Boeing 747. Minor damage. No injuries.

The aircraft was pushed back from the gate for a night flight. The engines had been started, checklists completed and ground crew release had been given.

When the aircraft began to taxi, a warning light illuminated and the aircraft was stopped. The flight crew contacted company maintenance on the radio. During the conversation with maintenance, a pickup truck was driven into position next to the fuselage inboard of the No. 2 engine. The ground technician plugged in his communications set but did not chime the cockpit. The flight crew was not aware that the truck had been parked near the aircraft.

After the flight crew resolved the problem with maintenance, the aircraft began to taxi again. The technician plugged into the aircraft ran clear as the B-747 began to taxi. The left main gear struck the truck, pivoting it into the No. 2 engine nacelle. Although damage to the aircraft was minor, some cowl and flap repairs were required. The truck was substantially damaged but there were no injuries.

After an investigation, it was recommended that ground personnel training stress the importance of communication and coordination between flight crews and ground crews.

Runway Collision Narrowly Avoided

Boeing 727-200. Minor damage. No injuries.

The tower controller cleared the Boeing 727 for a night takeoff on Runway 22R and then cleared a twin-turboprop Dornier Do-228 to position and hold on 22R. The tower controller did not realize that the Dornier was at an intersection 4,200 feet (1,281 meters) down the runway and had not noticed that the takeoff strip was marked with a red "T" indicating an intersection takeoff.

The ground controller had not coordinated with the tower when he cleared the Dornier to taxi to the intersection. During the takeoff roll, the Boeing crew saw the Dornier move onto the runway and executed an early rotation.

There was no contact between the aircraft, but the B-727 crew returned the aircraft to the airport to check the engines, which had been overboosted after maximum power was applied to clear the Dornier.

An investigation determined that air traffic control coordination and decisions had been inadequate.

Air Taxi
Commuter

Service Truck Rocks Commuter Jet

Canadair Challenger 600. Substantial damage. No injuries.

The pilot and first officer were completing preflight checks and the aircraft had been refueled for a daylight flight. As the fuel truck moved away, a lavatory service truck began positioning to service the aircraft.

The lavatory service truck struck the aircraft, throwing the first officer into the captain's seat, and the captain against the cockpit wall. The right rear corner of the truck struck the aircraft fuselage and penetrated about one foot (0.3 meter) into the cabin. Nose-gear tire marks on the tarmac indicated that the aircraft moved about six feet (1.8 meters) during impact.

Emergency Evacuation Follows Uncontained Engine Failure

Saab 340. Minor damage. Three minor injuries.

A loud bang followed by heavy smoke occurred after touchdown when propeller reverse thrust was selected. After the bang, the left-engine fire-warning bell sounded and the crew completed the engine-fire drill checklist.

The aircraft was stopped safely on a taxiway and an emergency evacuation was carried out. Three of the 20 passengers on board received minor injuries during the evacuation.

An investigation determined that an uncontained failure of the left-engine power turbine had occurred. A "B" nut on the stage 4 compressor bleed-tube coupling was disconnected, which caused a loss of cooling air to the power-turbine rotor cavity and overheating of the stage 4 turbine disk.

Corporate
Executive

Severe Turbulence Encounter Sets Stage for Emergency Landing

Learjet 25. Substantial damage. No injuries.

The aircraft collided with terrain and crops while executing an emergency night landing in a wheat field following a double engine failure.

The Learjet was in cruise at 41,000 feet (12,505 meters) over a thunderstorm when it encountered severe turbulence and the No. 2 engine flamed out. The aircraft began to descend and the flight crew decided to divert to a nearby airport.

During the descent, the aircraft encountered large hail, heavy rain and severe turbulence and lightning. The second engine flamed out from hail and water ingestion as the aircraft was descending through 33,000 feet (10,065 meters). Attempts to restart the engines were unsuccessful.

An investigation determined that the flight crew had not obtained a weather briefing before the flight, although a convective SIGMET [significant meteorological information about weather hazardous to all aircraft] and weather warnings were issued for the route of flight.

The aircraft sustained moderate to severe hail damage. None of the seven passengers on board were injured. The two pilots also escaped injury.

Air Conditioning Anomaly Plays Havoc with Controls

Cessna Citation II. Minor damage. No injuries.

During a daylight descent through 14,000 feet (4,270 meters), the pilot turned on the air conditioning unit and immediately experienced uncommanded aircraft excursions.

The pilot managed to land the aircraft safely at its destination. An investigation determined that the air conditioning unit had shorted out and damaged the elevator control cable. It was the first time the air conditioning unit had been used after its installation, which was found to be improper. The two pilots and two passengers were not injured.

Other General Aviation

Attention-getting Maneuver Ends in Fatal Dive

Beech 55 Baron. Aircraft destroyed. One fatality.

Witnesses observed the Baron flying erratically near a lake and said it appeared the pilot was attempting to get their attention for a greeting.

The aircraft entered a sudden dive and impacted the ground at high speed. No preimpact malfunctions were found, but a toxicology examination of the pilot's remains determined that the pilot had been drinking alcohol before the flight.

Engine Failure Puts Single in Trees

Cessna 172. Substantial damage. Two minor injuries.

The Cessna had just taken off from a small private airport when the engine lost power at about 100 feet (31 meters) above ground level. The pilot lowered the nose but saw trees ahead and pulled up.

The aircraft struck the trees and came to a stop hanging from tree limbs about 20 feet (six meters) off the ground. The pilot and a passenger managed to exit the aircraft with minor injuries. Fuel tanks were reported to be about one-fourth full at the time of the accident.

Rotorcraft

Tail-rotor Problem Blamed for Water Crash

Bell 206B. Aircraft destroyed. One serious injury. One minor injury.

The helicopter was attempting a ship takeoff when the pilot reported that the Bell 206 was experiencing an unspecified tail-rotor problem. The pilot reduced the throttle and collective to control yaw, but the helicopter's main rotor blade struck the ship.

The helicopter landed hard on the water and sank. Both the pilot and a passenger were able to escape the sinking aircraft. The pilot received minor injuries and the passenger sustained serious injuries. The helicopter was destroyed. Weather at the time of the accident was reported as visual meteorological conditions with scattered clouds at 2,000 feet (610 meters) and 20 miles (32 kilometers) visibility.

Down Draft Cuts Short Sightseeing Flight

Enstrom F28C2. Aircraft destroyed. No injuries.

The helicopter was flying upslope above a waterfall when it encountered a downdraft and began to settle. The pilot attempted to fly out of the downdraft but the aircraft continued to descend.

The pilot flared the helicopter and the main rotor blades struck trees. The left skid contacted the ground and the helicopter rolled to the right, downslope. The right skid then collapsed and the helicopter came to rest on its side.

The pilot and two passengers evacuated the helicopter and were not injured. They were rescued two hours later after the pilot contacted a nearby air traffic control tower, which dispatched police to the accident scene.

Weather at the time of the accident was reported as visual meteorological conditions, 18,000 feet (5,490 meters) broken and visibility seven miles (11.3 kilometers).

Rotor Mast Fails During Log Lifting Operation

Sikorsky S58-JT. Substantial damage. One serious injury.

The helicopter was picking up logs on a 150-foot (46-meter) line when the pilot heard a loud bang. The pilot said he attempted to move the load downhill away from a ground crew before he released the load but the aircraft turned downslope and impacted terrain.

An investigation determined that the main rotor shaft had separated through the shaft-to-flange radius. The shaft had 952 total hours on a 2,500 hour TBO (time between overhauls). The pilot received serious injuries in the crash.

Weather at the time of the accident was reported as visual meteorological conditions, with clear skies and 75 miles (121 kilometers) visibility.♦

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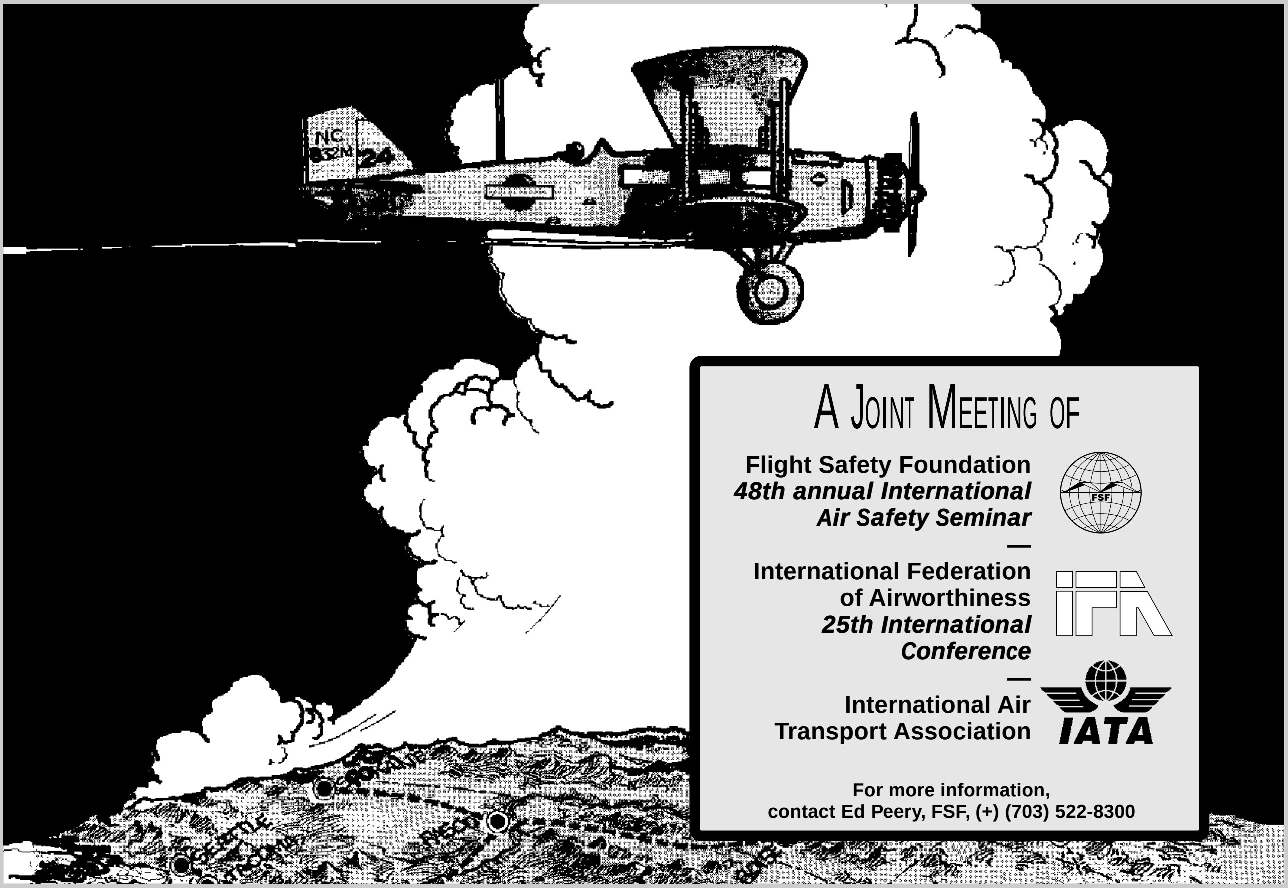
Westin Hotel, Seattle, Washington, U.S.
November 6–9, 1995



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contact Ed Peery, FSF, (+) (703) 522-8300

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