Fatal miscommunication: English in aviation safety

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ABSTRACT: This paper critically analyzes the use of English in the field of aviation. International air traffic has played an increasingly important role in recent globalization, which stresses the massive movement of people. Many pilots and air-traffic controllers having a variety of Englishes, in terms of proficiency and local influence, share this communicative context. Proper use of phraseologic English is a crucial prerequisite for them to participate in the field. However, fatal accidents due to miscommunication where insufficient and improper English were contributing factors have still occurred. With particular focus on communication in air-traffic control (ATC), this paper reexamines some salient aviation accidents in order to critically analyze how communication breakdowns occurred and how various usages of Englishes account for them. It then introduces some attempts to avoid such communication breakdowns as well as analyzes limitations of those attempts. Finally, the paper proposes a few suggestions that may help aviation personnel to cooperatively achieve a better communicative context in aviation.

INTRODUCTION

The dynamic and increasing movement of people across geographical borders is one of the essential elements constituting recent globalization (e.g., Appadurai, 1996). In the past half-century, the number of international travelers per year increased from 25 million in 1950 to 664 million in 1999, an average of 7 percent annual growth. Furthermore, it is predicted that the number will reach 1.18 billion by 2020 (Griffin, 2002: 25). Air transportation plays a central role in this massive movement of people. In this field, needless to say, the most crucial requirement is always safety. Because air transportation is a highly systematic aggregation of technologies, in order to achieve safety, enormous efforts have been made to improve this system, which includes aircraft, maintenance facilities, airports, and navigation aids.

However, we still hear about tragic air accidents. One perpetual problem that contributes to accidents is miscommunication. Communication, especially between pilots and air-traffic controllers, plays a crucial role (Kanki and Palmer, 1993). An overwhelming majority of pilots and controllers agree: “good communication is as important as technical proficiency for the safety of flight” (Wulle and Zerr, 1997: 91). Modern, large, and high-speed aircraft cannot be operated only by the pilots. Such aircraft always need information, instruction, and support from the ground through air-traffic control (ATC). In addition, the amount of air traffic, especially in busy airspace around big terminals, has become far larger than it was only a few decades ago. The great flexibility of voice communication allows pilots and controllers to exchange a large amount of information promptly in busy airspace. However, the great flexibility can be a double-edged sword. The flexibility can cause ambiguity and misunderstanding, which, consequently and on rare occasions, lead to fatal results.

This paper examines various communication breakdowns in aircraft operation and focuses on aviation English and, especially, on English being used in ATC. First, it
conceptualizes ATC as a communicative context that involves numerous participants who must contend with a wide variety of Englishes, in terms of both proficiency and local influences (e.g., the influence of a non-English native language), and briefly reviews the nature of ATC communication, including the role of ATC, how English matters in ATC communication, an overview of miscommunication in aviation, and a review of previous research. Second, in its citing of several significant fatal accidents in which the failure of communication was a contributing factor, the paper attempts to critically analyze how those communication breakdowns occurred and how various Englishes (from those that involve very insufficient proficiency to those that rely on a usage that is too colloquial) account for these accidents. Third, while citing previous reports, documents, research, and personnel who have served in the field, the paper discusses some attempts to avoid miscommunication, the limitations of these attempts, and further suggestions for future improvements in this area.

OVERALL BACKGROUND: ATC, ITS MISCOMMUNICATION, AND ENGLISHES

Operating airplanes and the role of ATC communication

Kanki and Palmer (1993: 99) state, “there can be no doubt that operating modern aircraft is a high-stakes profession with lives invested in every flight. It is therefore reasonable to assume that communication plays an important part of this human activity as it does in all others where individuals are trying to accomplish common goals and integrate separate tasks.” Communication in aircraft operation takes a variety of forms, and it plays key roles in the achievement of safety. Cabin attendants must communicate effectively with passengers to instruct them in the emergency evacuation procedure. Operational crews in the flight deck constantly communicate with each other to “cross-check” hundreds of proper procedures from the checklist to maintain safe operation.

Among those various forms of aviation communication, ATC communication is the main focus of this paper. It plays crucial roles in operating aircraft safely. It provides pilots with diverse information, such as weather, airport, and other traffic reports. It instructs pilots to fly at altitudes, at speeds, with headings, and on routes, all of which are precise and inflexible. It gives various clearances all the way from pushback from the boarding gate to landing and taxiing at the destination airport. At the same time, pilots are not merely passive recipients in ATC communication. They constantly give their flight information to the controllers and request clearances. ATC communication especially plays a crucial role in managing crises. When an emergency occurs, pilots need to rely on ATC communication and instruction even more.

ATC and Englishes

Analyzing ATC communication provides us with many clues for an understanding of how miscommunication occurs and how use of various Englishes accounts for miscommunication. First, and most important, ATC communication is more likely to involve various Englishes than are other types of aviation communication simply because it often takes place in cross-cultural and multi-lingual environments. Many pilots fly not only domestically but also internationally. Merritt and Ratwatte (1997: 664) succinctly phrase the issue: “regardless of the country of origin, any international flight by its very definition is a multi-cultural experience.” Sullivan and Girginer (2002: 400) introduce a case from a
Turkish airport, which well illustrates the nature of aviation English. During a nine-hour period, 278 pilots communicated with the controllers. Among them, 160 pilots worked for Turkish airlines, 14 worked for German airlines, and the rest worked for airlines from 26 different countries. Only two pilots worked for airlines based in the United States and England, “in which English, the bases of Airspeak, is the native language.” Nonetheless, these participants, regardless of country of origin, normally use English.

Even in “domestic” ATC contexts of English-speaking countries, such as the United States, many foreign pilots using a variety of local Englishes fly into their airspace. This means that US air-traffic controllers need to handle a second-language environment (Fallon, 1997: 76) with diverse Englishes. Whenever one participates in aviation, having a decent command of English is a vital prerequisite. However, there are numerous occurrences in which pilots and air-traffic controllers, each having different Englishes, communicate with each other at any given moment and place in the world. Then, “the global expansion of travel” increases such cases, as well as subsequent “language problems” (Nordwall, 1997: 46).

Despite of its significance, or paradoxically “because of” its significance, some historical aviation accidents were primarily caused by ATC miscommunication, where insufficient and idiosyncratic use of English was a contributing factor. Probably the most notable case is the well-known “Tenerife Tragedy” in 1977 that killed 583 and injured 61 people, the largest-ever accident in aviation history in terms of death toll. Two Boeing 747 Jumbo Jets collided on the runway of Los Rodeos Airport in Tenerife, the Canary Islands. The crucial cause was a miscommunication between the Dutch-speaking KLM captain and the Spanish-speaking controller. Such accidents are not only from the distant past. For instance, in 1995, a Boeing 757 crashed in Cali, Columbia, killing all 163 on board. Although the primary cause of the accident was the American pilots’ faulty navigation, if the Spanish-speaking traffic controller had given proper instruction, the accident could have been avoided. He, however, failed to do so because of his insufficient English proficiency.

English has been the language predominantly used in aviation. It was originally established as such by the International Civil Aviation Organization (ICAO) in 1950. It is, however, important to note that English is still not the mandatory official language in ATC. Some countries, such as France and Italy and many from the former Soviet Union, still permit the use of their own languages besides English for their domestic ATC (Itokawa, 2000: 52). However, realistically speaking, if one cannot use English, one cannot participate in the field.

Many pilots and air-traffic controllers whose mother tongue is not English have to acquire English during their flight training. In addition, not only do they have to use English at a highly practical level, but they also need to do so while flawlessly performing their official tasks: the safe operation of aircraft and the safe maintenance of airspace. At the same time, pilots and controllers who speak English as their mother tongue sometimes fail to communicate, and on rare occasions, a failure in ATC communication leads to fatal accidents.

Studying communication failure in aviation

Because of its crucial role, miscommunication and its role in aviation accidents have been studied extensively. A Boeing study about the prevention of aircraft accidents found that miscommunication between pilot and controller contributed to at least 11 percent of fatal airplane crashes worldwide in the period of 1982–991 (Ritter, 1996: 7A). More broadly,
another analysis has claimed, “over 70% of aviation accidents result from crew coordination and communication as opposed to lack of individual technical skills” (Lautman et al., cited in Orasanu, 1993: 137). Similarly, Connell (1996: 20) notes that the initial five-year period of the National Aeronautics and Space Administration’s (NASA) Aviation Safety Reporting System (ASRS) reports that “over 70 per cent (out of 28,000) of the reports submitted noted problems in the transfer in information in the aviation system.” Apart from those quantitative summaries, qualitative research has also been conducted. For example, Kanki and Palmer (1993) recommended the application of field observation, simulation studies, and discourse analysis to transcripts from cockpit voice recorders (CVRs: one of the “black boxes”).

However, studies with a particular focus on cross-cultural communication and idiosyncratic uses of Englishes have been relatively underdeveloped. Typically, these are uniformly treated as “one of many causes” of miscommunication and accident. Steven Cushing’s (1994a) Fatal Words, perhaps one of the most thorough analyses of the topic (and, hence, widely cited in related literature), is a rare exception, focusing on language use in a cross-cultural context. One explanation for this structure, the relatively small emphasis on idiosyncratic uses of Englishes, is that the majority of miscommunication studies have been conducted in the United States, which is “the birthplace of aviation” and “dominate(s) the aviation industry, both as manufacturers and operators,” and the majority of its operation only involves “native speakers” of English (Merritt and Ratwatte, 1997: 663). However, this does not necessarily indicate any insignificance of problems about idiosyncratic uses of Englishes. Orasanu, Fischer, and Davison (1997: 140–2) analyze incident reports from NASA’s ASRS. When pilots report problems regarding cross-cultural communication, they identify “language/accent,” “dual-language switching [in non-English-speaking countries, speaking in English to foreign pilots, but simultaneously speaking in the local language to local pilots],” and “[different] reception across languages” as among the most frequently reported problems. NASA (1996, November) also acknowledges the problem: “25% of the reports cited language problem as a primary cause of the foreign airspace operational incidents reported to ASRS.”

Few broader theoretical concepts are noteworthy in the analysis of ATC communication. By referring to Goffman (1981), Sullivan and Girginer (2002: 400) define ATC communication “as successive one-to-one interaction with multiple ratified participants, both addressed and unaddressed.” And it is important to note that the interlocutors cannot see each other because of their reliance on the radio. If we theorize ATC as a communicative context, we can distinguish its unique characteristics from those of other contexts. It is perhaps the most extreme context where participants put their maximum effort to achieve crystal-clear communication by avoiding any ambiguity, described as “phraseologies, designed to be as simple as possible within the constraint of a very technical subject, and phrased so as to eliminate any ambiguity” (Field, cited in Johnson, 1994: 84). To do so, ATC communication removes various factors that normally give communicative context flexibility and depth, such as formality, politeness, and differences in social class, culture, age, and gender. In this regard, one may theorize ATC as a communicative context in which “contextual influences” are intentionally removed.

However, even though ATC communication is solely designed to be mistake-free, miscommunication occurs. To analyze it, Orasanu, Davison, and Fischer (1997: 674) categorize three major models of ATC miscommunication: “wrong information,” “loss of situation awareness,” and “lack of shared situation models.” And insufficient proficiency in and idiosyncratic uses of English could further deteriorate those. “Wrong
information” simply refers to situations where “wrong information [is] transmitted and received” between pilot and controller. For example, a pilot hears “two” as “to,” while the controller meant “two.” A lack of “native sense” about English prepositions can be a cause for this mistake. “Loss of situation awareness” is a particularly serious problem in non-English airspace. If local pilots in a non-English-speaking country use their own language in their ATC communication, foreign pilots in the same airspace may not understand “what’s going on.” Monitoring ATC communication in the area where a pilot is flying is crucial to understanding the situation, even if the particular line of ATC communication is not intended for his or her flight. By monitoring such “party-line information,” pilots can “visualize” the airspace, such as the number of airplanes and their altitudes, positions, and flying directions. However, non-English party-line talk likely makes it unable for foreign pilots to understand the situation if they are not familiar with the local language. Finally, “lack of shared situation models” refers to a more complex situation: “it is a failure of participants to build a shared understanding of the situation at a team level” (Orasanu, Davison, and Fischer, 1997: 674). For example, a pilot reports a mechanical trouble to a controller; however, while the former perceives it as “an emergency,” the latter may perceive the same not as an emergency, but merely as “a trouble.” Such connotations may be less adequately transmitted in a second-language-speaking environment.

Methodologically, ATC miscommunication can be analyzed through discourse analysis, in-depth interview, survey, self-reporting database, and so on. While the first two are often used to analyze actual accidents, the next two are used for preventive studies. One important consideration in the conducting of such studies is anonymity. It is important to preserve the anonymity of pilots and controllers who are contributing their experiences of miscommunication. They might have violated proper operation procedures and created dangerous situations. Nonetheless, the ultimate goal of such studies is to learn preventive means from these people’s precious experiences, but not to punish them for their mistakes. NASA’s Aviation Safety Reporting System is one such attempt. It is a voluntary and an anonymous reporting system that has successfully gathered over 400,000 reports from aviation personnel since 1976.

ANALYSIS OF COMMUNICATION BREAKDOWN

Insufficient English proficiency

Despite the crucial role of English in the field, some fundamental flaws in English skills have led to disasters in the air. The biggest accident in 1996 (November 12), a mid-air collision between Saudi Arabian Airlines’ Boeing 747 and Kazakhstan Airlines’ Ilyushin 76, killing 351 people near Deli, India, was allegedly due to a lack of English comprehension on the part of the Kazakhstan crews. Indian air traffic controllers have complained that pilots from the former Soviet Union have a poor command of English (Jenish, 1996: 113; News breaks, 1996: 17). Another report points out that those pilots’ individual flying skills might be first-rate; however, the pilots might have limited English skills (Upgrade pilot English standards, 1994: 90). The Kazakhstan pilots might not have understood the instructions given by the Indian controller, although the content of the instructions was altitude, one of the most basic instructions for whoever flies airplanes (Burns, 1996: A1; Morrocco and Singh, 1996: 35).
In terms of aviation safety, English proficiency matters not only for pilots and air-traffic controllers. When Garuda Indonesian Airways’ DC-10 jet crashed near Fukuoka International Airport in Japan on June 13, 1996, the survivors criticized the cabin attendants’ lack of English- and Japanese-language skills, a lack that led to the deaths of three passengers and the injury of 110. After taking off, the plane, which was moving at a relatively slow speed, crashed on a flat and soft rice paddy. It also took a while for the fire to break out. However, because of the crews’ insufficient language skills, the proper evacuation procedure was neither promptly nor fully communicated.

Even insufficient English proficiency of a single member of a cargo-handling crew could contribute to a fatal accident. Turkish Airlines’ DC-10 jet crashed near Paris on March 3, 1972, killing all 346 aboard. That was the largest air disaster at that time and is still listed as the fourth largest accident in terms of death toll. This accident was primarily due to the defective design of the DC-10’s cargo door. However, the manufacturer, McDonnell Douglas, had not fundamentally modified the defect by that time; rather, it put a caution sign (a small metal plate) near the door, as one of its superficial solutions. The sign instructed the proper cargo-door closing procedure, but it was only written in English. If cargo-handling crews properly followed the instruction, the door could be closed securely. Otherwise, it could open when the aircraft reached a certain altitude, thus making the aircraft depressurized and uncontrollable, which was precisely what happened to the airplane. The French cargo-handling ground worker was not able to read English and, as a result, closed the door improperly. It is probable that he did not even know the purpose of the caution sign. After the crash, McDonnell Douglas accused the cargo-handling worker of not following the sign. However, the French officials, of course, strongly opposed McDonnell Douglas (Yanagida, 1991: 46–7, 76–7). It became a political debate. This suggests the importance of mistake-free or even foolproof design, rather than language-oriented or language-based instruction.

Another accident also suggests the failure of language-based warning systems. On November 13, 1993, a McDonnell Douglas MD-82 jet crashed in Urumqi, China, while it was approaching to land, killing 12 and injuring 24. The airplane did not have enough altitude to be on the proper glide slope to reach the runway. Its ground-proximity warning system went off to notify the pilots that it was flying too low. However, unfortunately, the pilots, all native speakers of Chinese, could not understand or capture a very basic English phrase for flying airplanes: “pull-up,” the succinct caution that the warning system yielded. Later, by analyzing the aircraft’s cockpit voice recorder, the investigators heard the pilot’s last words: he asked, in his native Chinese, “What does ‘pull up, pull up’ mean?” as the warning went off (Calvert and Connet, 1997: 4; Proctor, 1996: 144). This example probably sounds like an unbelievably poor failure of communication, even for people who are unfamiliar with aviation.

One important lesson from the aforementioned accidents is the limitation of language-based warning systems. Although aircraft have such warning systems, which often utilize the latest technology, they have a great potential for failure simply because the operators of the systems may not be proficient in the language being used, predominantly English. Moreover, there is a more complex question about such systems in terms of man–machine interface design philosophy and language use. A voice warning system is actually a very effective means to warn pilots of unusual occurrences. Rather than require individual pilots – by themselves – to receive a warning, the voice warning system automatically jumps into pilots’ auditory perception. If a visual indicator, such as a lamp, notifies a pilot...
of an unusual occurrence, the pilot would, first, have to notice that the lamp was lit. There is always the possibility that the pilot would miss it because usually he or she constantly needs to pay visual attention to other things, such as other instruments and the area outside. Second, pilots have to read what the visual indicator means; this implies three further problems: (1) a pilot often has to distinguish the meaning of the particular visual indicator from numerous other visual indicators and instruments; (2) to do so, the pilot has likely to discontinue what he is doing; then, (3) such a sequence requires some amount of time. Needless to say, engineers who develop devices for notifying pilots of events must take time into consideration because time – specifically, the rapidity of a successful warning – is crucial to the design of any warning system in modern high-speed aircraft that can fly more than 250 meters (270 yards) per second. A study shows that the total time needed to execute three key actions – an initial recognition of a visual indicator, the distinguishing or interpreting of its meaning, and quick action to control the aircraft – may take more than 10 seconds, which gives enough time for the aircraft to fly 1.56 miles (2.5 kilometers) (Yanagida, 1991). On the other hand, voice warning systems can provide pilots with necessary information promptly without forcing them to actively read signs.

However, the crucial presumption of such audio-based systems is that all pilots should well understand the language being used: again, exclusively English. However, this presumption may not be true. English voice warning may “not appear so strikingly” to pilots who do not possess high proficiency in English, although they may eventually understand the meaning. They might need some seconds to translate what the warning system is telling them. This essentially means that the promptness of the voice-warning system does not work as the designer intended. This examination suggests a possible failure of this new safety system and philosophy, the voice-warning system, and ultimately the limitations of language-based instruction and warning systems in general.

English proficiency beyond phraseologic usage

Although most participants of ATC communication have English proficiency to a satisfactory extent, that may not be enough, especially when something unusual, such as an emergency, occurs. This section presents two examples illustrating this problem of limited English proficiency under unusual and emergency circumstances.

The aforementioned accident of American Airlines’ Boeing 757 in Cali, Columbia on December 20, 1995 was partly due to the lack of English proficiency of the Spanish-speaking controller. When American Airlines’ Flight 965 from Miami to Cali was about to reach its destination, the pilots lost their position. Of course, they attempted to confirm the position. Unfortunately, however, following several confusing lines of miscommunication between the pilots and the controller, the captain engaged the autopilot to steer the plane toward a wrong navigation beacon. Eventually, the plane crashed into mountainous terrain (Ladken, 1996).

The Columbian air-traffic controller later told the accident investigators in his native Spanish that the content of the radio transmission from the American pilots did not make much sense to him. However, he also acknowledged that he would have questioned the pilots or elaborated the situation if the pilots had been Spanish speakers (Ladken, 1996: 23). He said that “their request made no sense, that their request was illogical, incongruent, but I did not know how to convey those thoughts to the American flight crew … in English” (Lunsford, 1996: A1).
The other accident illustrates a complicated situation in which the lack of English proficiency might not seem to be the primary cause of the accident; however, misunderstandings based on limited English lexicon and comprehension actually deteriorated the situation and led to a fatal result. On January 25, 1990, when Colombian Avianca’s Boeing 707 was approaching its destination, New York’s J. F. Kennedy International Airport, the plane was required to remain in several holding patterns (flying around the airport awaiting further landing instructions) due to bad weather conditions. However, the plane did not have sufficient fuel left to do so, and the pilots attempted to tell the controller that. However, the first officer, who was communicating with the controller, used ambiguous expressions like “need for priority,” instead of clearly declaring “an emergency” (National Transport Safety Board, 1991: 56–7). As a result, the New York controller never realized that the airplane was in an emergency situation, and he never gave an emergency clearance for it to land prior to the others. The airplane eventually ran out of fuel and crashed near the airport, killing 72. If the pilots had explicitly declared an emergency, they would have been given a priority to land (Standard terms sought for air traffic control, 1996: A15).

One question is how well the Colombian Spanish-speaking pilots recognized the real implication of the phrases like “need for priority” and “landing priority” in English. Later the American air-traffic controller(s) argued that those phrases did not really indicate a sense of emergency for them. However, the Columbian authority counter-argued that the use of those phrases was originally suggested through the Boeing 707’s flight training manual provided by Boeing Company (NTSB investigates air traffic control flows in Avianca crash, 1990: 19; National Transport Safety Board, 1991: 56). Thus, the Columbian pilots might have believed that those phrases they uttered should mean fuel emergency. However, this interpretation and recognition did not apply to the American controller. Of course, it is reasonable that the controller did not know the flight manual of the aircraft. If the pilots had had enough proficiency in English, the accident could have been avoided because they would have known that phrases like “need for priority” did not imply emergency. This is a very clear example of the “lack of shared situation model,” where limited English proficiency is a contributing factor. However, it is unreasonable to expect pilots whose mother tongue is not English to be proficient enough to handle such a nuance-oriented or connotative, hence, ambiguous, ATC communication. Rather, clearer misunderstanding-free ATC commands should be established.

Those two analyses suggest one fundamental question about ATC communication: How well can pilots and controllers handle a situation beyond normal circumstances? Actually, ATC communication is highly “formulated” and “standardized” (Orasanu, Davison, and Fischer, 1997: 136). Under normal circumstances, pilots use a vocabulary of around 200 phraseologic English words and phrases according to English teachers and flight instructors who are specialized in the teaching of pilots, especially, ESL pilots (Brown, 1997: 25; John Hamilton, personal conversation, 1997). However, this number is clearly not enough to account for most emergency situations. In the case of the American Flight 957, it is easy to accuse the Columbian controller for possessing an insufficient grasp of English lexicon; in fact, a substantial number of American media accused him and aviation personnel throughout Central and South America for lacking adequate English skills. However, the plane was flying over a non-English-speaking country. Colombians may counter-argue that it is a one-sided and hegemonic accusation unjustifiably biased against them. If the American crews had been able to speak Spanish
even to some extent, and they had let the controller notify them about their mistake in Spanish, the accident could have been avoided. Accusing only the individual Spanish-speaking controller does not fundamentally solve the problem at all. Rather, it is important to establish error-resistant and easy ATC communication methods for emergencies.

Local English – the Tenerife tragedy

The worst accident in the aviation history was the Tenerife accident in the Canary Islands, an on-runway collision between two Boeing 747 Jumbo Jets on March 27, 1977. The sequence of this historical accident includes several important aspects of communication breakdown that this paper has already discussed. In addition, this was a case where “code-switching” (Cushing, 1994b: 50) or “code-mixing” played a crucial role. Code-switching/mixing can be seen among almost all multi-language speakers. A brief definition of code-mixing is “the embedding of various linguistic units such as affixes (bound morphemes), words (unbound morphemes), phrases and clauses from two distinct grammatical (sub-) systems within the same sentence and speech event” (Bokamba, 1989: 278).

The departing Royal Dutch Airlines (KLM) Flight 4805 was waiting at the end of a runway of the Los Rodeos Airport for takeoff, while the Pan American (PAA) Flight 1736 was attempting to turn off from the runway onto a taxiway (see figure 1). The accident occurred under unfortunate and chaotic conditions. The two planes’ pilots were unable to see each other because of the low-altitude cloud and fog. There were unexpectedly and unusually many airplanes at the airport because a bomb explosion at nearby Las Palmas Airport diverted them to Los Rodeos. Many were chartered flights and not familiar with the area and the airport. The airport was small and not quite designed for the Jumbo Jet. Because of the chaotic conditions, many planes had been forced to wait for a long time. The pilots might have been frustrated and fatigued. Under such conditions, the KLM airplane started its takeoff run while the PAA airplane was still on the runway and crashed into the latter. The KLM airplane had already reached its lift-off speed (280 km/h, 175 miles/h) and slightly lifted off the ground when it collided with the PAA airplane. The accident killed 583 and injured 61 people.

![Diagram of the Tenerife accident sequence](image)

**Figure 1.** Sequence of collision
Why did the KLM pilots start the takeoff run, and why did the controller fail to stop it? There is a key miscommunication stemming from this accident that helps us to understand this fatal sequence of events. The following is an excerpt from the transcript of their radio transmission (see also Figure 1). The KLM captain was a Dutch speaker, and the controller was a Spanish speaker.

1. 17:05:44 KLM 4805 Captain: “The KLM four eight zero five is now ready for takeoff, and we are waiting for our ATC clearance.”

2. 17:05:53 Controller (Tower): “KLM four eight zero five, you are cleared to the Papa Beacon, climb to maintain flight level niner zero, right turn after takeoff, proceed with heading four zero until intercepting the three two five radial from Las Palmas VOR.”
   –He gave some instruction for what to do after taking off. Note: NO takeoff clearance, however, was given at this point.

3. 17:06:09 KLM 4805 Captain: “Ah, roger sir, we are cleared to Papa Beacon, flight level….—repeating the instruction given by the controller. We are now at takeoff.”

4. 17:06:18 Controller: “OK. Stand by for takeoff. I call you.”

Interrupted by another radio transmission

First of all, unless simultaneously giving a takeoff clearance, the controller should not have given the KLM pilots post-takeoff instructions (2). Although this is not an unusual practice, the informing of pilots about what to do after takeoff might give the pilots the illusion that they have already obtained a takeoff clearance. Nonetheless, because no takeoff clearance had been given, the KLM pilots should not have started their takeoff run. Besides those problems, the most problematic utterance in the transcript is “We are now at takeoff,” made by the KLM captain (3). This is actually a very nonstandard phrase from the ATC English. This can be interpreted as either

5. “We are now at the takeoff position.” OR
6. “We are now (actually) taking off.”

The former indicates that the airplane is not in motion but is waiting at the end of the runway for a further takeoff clearance. The latter indicates that the airplane is in its takeoff run on the runway. Needless to say, these two are totally different situations. The controller interpreted the phrase, “We are now at takeoff,” as indicating that the airplane was not in motion and was waiting for a takeoff clearance (shown in dotted line as (A) in Figure 1). However, it had already started its takeoff run. The controller actually instructed the pilots to “stand by for takeoff” (4) (that is, to wait for a further takeoff clearance); however, very unfortunately, someone else’s radio transmission interrupted this particular instruction, and the KLM pilots missed the instruction. As a result, they kept accelerating the airplane until it collided with the PAA plane.

The most significant question is why the KLM captain uttered, “We are now at takeoff,” although this was a non-standard expression. Some analyses argue that his native language, Dutch, has a clue for an understanding of what he really meant by this unusual phrase. In Dutch, the present progressive tense of a verb is expressed by the equivalent of the preposition “at” in English plus the infinitive of the verb (Meiker and Smit, 1963: 36; Joost De Bruin, personal conversation, 2002). This is what the Captain did (Cushing, 1994b). Maybe because of the highly frustrated situation and fatigue, he unintentionally used the present progressive form of his native Dutch, although what he
spoke was still English. In other words, he did code-mixing at a syntactic level. He really meant that he was “in the process of a takeoff run.” However, the controller interpreted it differently. Again, the “lack of shared situation model” is evident here. If the controller had realized what the captain really meant, he could definitely have stopped the fatal takeoff run. The captain was one of the most experienced pilots in KLM, and in fact was the chief examiner of its Boeing 747 pilot-training program. He had been using aviation English intensively for decades, and he should have had very high English proficiency. Furthermore, the Netherlands was one of the European countries that had permitted only English for its ATC and prohibited all other languages including its native language, Dutch. Thus, it is reasonable to assume that he had been using only English during his entire pilot career. However, even such an experienced pilot, both in flying and in using ATC English, could not be totally free from the influence of his native language. The very small phrase, or even the one preposition, that he unconsciously uttered by code-mixing led to this fatal result. This example illustrates a deeply rooted problem beyond a superficial discussion of English proficiency.

Non-phraseologic and too colloquial English

In the examples above, controllers did not accurately interpret what the pilots intended to transmit. As a result, the New York controller disregarded the emergency fuel situation of the airplane, and the Tenerife controller did not realize that the KLM jet had started its takeoff run. Party 1 can first misinterpret what party 2 means; then, the misinterpretation often becomes party 1’s presupposition, which leads to further miscommunication. This is a perpetuated problem for any type of human communication. ATC communication is not an exception. Also, it is important to note that such a sequence of miscommunication holds not only among people having insufficient English proficiency or local influence, but also, or rather, among “native English speakers” who tend to rely on too colloquial, non-phraseologic, and ambiguous English. This induces misunderstanding and danger (Wulle and Zerr, 1997: 90).

Eastern 401

The Eastern Airlines’ Flight 401, a Lockheed L-1011 TriStar, from New York to Miami, crashed into the Everglades near Miami International Airport on December 29, 1972, killing 99 out of 176 on board. Although there were several factors that mutually led up to the airplane’s crash, one miscommunication played a key role. In this case, both the pilots and the controller were native speakers of English. While the plane was in the final approach to the airport, the pilots, who had lowered the landing-gear lever, noticed that the lamp normally indicating the down position of the nose gear was not lit. They were not sure whether this really indicated that the landing gear was not down or simply that the indicator’s bulb was dead. They then attempted to check the bulb. Since this would take minutes, they notified the controller about the problem and obtained a go-around clearance to terminate the initial landing and to circle around the airport. Then, they activated the autopilot, which was supposed to maintain a constant altitude of 2,000 feet, without the pilots’ having to fly the airplane.

However, while checking the bulb, the captain unconsciously pushed the control wheel, which disengaged the autopilot. As a result, the plane started a gradual descent without the pilots’ noticing it. However, the controller, who was watching the plane through the radar, noticed the descent. Then, the controller asked the pilots,
(7) 23:41:40 **Controller:** “Eastern, ah, four oh one, how are things coming there?”

Then, the Captain responded,

(8) 23:41:44 **Captain:** “Okay, we’d to turn around and come, come back in.”

23:42:12 *The plane crashed into the Everglades.*

(National Transport Safety Board, 1973: 5)

The controller intended to check the alteration of altitude (descending) in (7). However, unfortunately, that inquiry was made immediately after the pilots confirmed the nose gear was actually in the lowered position. The captain misunderstood the question: he believed that the controller had asked him about the landing gear problem; however, the question truly concerned the descent, of which the captain was unaware. In (8), what the captain meant by “okay” concerned the landing gear, while the controller mistakenly believed that the “okay” concerned the descent (Cushing, 1994a: 19; Yanagida, 1991: 118–20). They were talking about two totally different topics: the descent for the controller and the landing gear for the captain. However, as a result of the captain’s “okay” response, the controller thought that the descent was under the pilots’ intentional control, which became his wrong presupposition. However, in fact, nothing and no one was flying the airplane at that time. The autopilot had been disengaged; the pilots were not flying the airplane either. The pilots needed to follow up the landing-gear problem for a while after the radio transmission. Because of his wrong presupposition, the controller stopped paying attention to the Eastern flight on the radar screen. The aircraft kept descending. Eventually, when the pilots heard the warning alarm of the minimal ground proximity going off, it was too late for them to regain control of the airplane.

This accident clearly illustrates the danger of using ambiguous and too colloquial English. The controller should have explicitly asked the pilots something like, “Confirm you are descending” or “Report your altitude,” instead of “how are things coming there?” At the same time, when the pilots were asked ambiguously “how are things coming there,” they should have clarified what the controller meant. This is also a clear example of “lack of shared situation model.” However, in contrast to the aforementioned Avianca crash case in New York involving Spanish-speaking pilots, the use of too colloquial English among native English speakers was a contributing factor. Hypothetically and ironically, if at least one of the participants had been a non-native speaker of English who could use only phraseologic expressions, such colloquial and ambiguous uses of English might not have occurred and the accident could have been avoided (see, Sullivan and Girginer 2000: 402). Merritt and Ratwatte (1997: 664) argue that, among ESL pilots and controllers, “clear, concise verbalization of intent and requirements must take place and be undertaken ‘by text book’.”

In many cases, communication failures may not be the primary cause of accidents. Usually almost all aviation accidents are caused by multiple interacting factors. However, communication failure often plays a crucial role in aggravating the situation, and proper communication could rescue an airplane from a fatal result. If the Miami controller had confirmed the Eastern jet’s altitude properly, the crash could quite possibly have been avoided. If the KLM captain had used the proper standard expression, the controller could have easily given further instructions to stop the plane from continuing the fatal takeoff run. Proper communication has a great potential to save airplanes from problematic situations which can lead to fatal accidents.
ATTEMPTS FOR ERROR-RESISTANT AVIATION ENGLISH AND THEIR LIMITATIONS

Needless to say, a number of attempts to avoid miscommunication in ATC have been developed and practiced. Their roles can also be crucial when the communication involves people using various Englishes. Some attempts are even familiar to ordinary passengers. While an emergency evacuation procedure is instructed before takeoff, the passengers normally see printed instructions installed in the seatback pocket. If we carefully looked at these instructions, we would realize that many of them utilize universally recognizable photographs, illustrations, and icons instead of verbal language. This is especially important for international operations because it is likely that different passengers whose languages differ share the same seats over time.

Even if verbal instruction is needed in case of an emergency, using a highly simplified and universally comprehensible language is crucial. A veteran Japanese flight attendant who had exclusively flown internationally acknowledges that, because her flights could go anywhere in the world, the flight attendants are trained to use a very simplified language to instruct passengers about emergency evacuation procedures. For instance, if passengers need to evacuate from the plane by the emergency slides, the attendants must only shout “jump, jump.” Such simplified language is important not only for passengers having a variety of native languages, but also for multi-national flight attendants needing to effectively communicate with each other (Naoko Izutsu, personal conversation 1997).

Some basic linguistic attempts to avoid ATC miscommunication have been used for a long time. The most simple, but famous, example is the use of “niner” instead of “nine” for the numeral 9. It should be pronounced “niner” to avoid confusion with “nein” that means “no” in German. Pilots having a German-language background might be confused when they hear “nine.” They then might do something improper as a result. All pilots and controllers must use “niner” instead of “nine.” For instance, “29.92” has to be read “two niner point (or decimal) niner two.” Similarly, all pilots and controllers also have to use the ICAO phonetic alphabet shown in Table 1 (Cessna Pilot Center, 1996: 5–23). For example, a call sign, “N978GQ,” should be read “November niner seven eight golf Quebec.” This is especially helpful for some pilots and controllers who, largely because of their respective native languages, experience great difficulties with English. In particular, the letters in the English alphabet, such as “B” versus “V,” “M” versus “N,” and “L” versus “R,” are difficult for such pilots and controllers to hear and pronounce clearly.

When ATC communication involves the transmission of questions and answers, it requires some specific ways to avoid misunderstanding. For instance, if a pilot were asked by a controller “Confirm are you at 9,000 feet,” the pilot would have to answer either “affirmative” or “negative.” Another good example is the use of a commonly known word, roger. Strictly speaking, it only means, “I have received your transmission,” and in fact, the word was derived from “Received.” It does not necessarily mean, “I will comply with what you have asked.” Thus, for example, if a controller asked a pilot, “Climb and maintain 19,000 feet,” then, if the pilot replied “Roger,” he or she would not make any sense, technically, to the controller. This reply does not tell the controller whether or not the pilot will comply with the instruction. The pilot should either say, “Will comply,” or repeat/readback, “(I) Climb and maintain 19,000 feet,” if he intends to comply. In such contexts, the latter response – the repeating or the readbacking of what the pilot has been told – is better because it reconfirms the content of the instruction, and because the controller can verify that the pilot has correctly received the instruction (Wulle and Zerr, 1997: 91). If the pilot does not intend to comply, he
or she should say “unable.” Only when a controller gives a pilot information but not instructions, such as “Wind 240 (degree) at 5 (knot),” the pilot may reply, “Roger.” This means that the pilot has merely received the information.

Cross-cultural cockpit/cabin-resource management has become an important issue as international operations have increased (Johnson, 1993). For instance, an international flight is often operated by multi-national crews who have various Englishes. The crews, such as pilots and flight attendants, need to use written instructions and take a certain amount of time during the pre-flight briefing to clarify their duties in work environments where the participants have different native languages and have to commonly communicate through English.

However, such a multi-lingual-crew environment has a potential to alienate “language minorities.” An anonymous American flight engineer who works for a Japanese airline acknowledges that he always feels a kind of isolation and discomfort when he flies with Japanese-speaking pilots. Of course, all intra-crew conversation for flight operations uses English. However, he often feels isolated when the other Japanese crews speak something colloquial (not for flight operation) in Japanese in the cockpit. Although he has not experienced any significant failure due to this language barrier, and the English proficiency of those Japanese crews is acceptable, he acknowledges that he prefers to do his work within a team whose members are all native speakers of English.

Such “language alienation” exists in much broader, beyond intra-cockpit, communication contexts and poses a serious threat to safety. As briefly reviewed earlier, language alienation in a given airspace is often a threat to “situation awareness.” Pilots do not only communicate with their air-traffic controllers about their own flights. They constantly monitor the communication between controllers and pilots of other airplanes in the same airspace. By monitoring such “party-line” ATC information, they can build broader situation awareness about the airspace in which they are flying. A veteran captain for a US airline explains his concern with actual examples. When he flew over the countries of the former Soviet Union, although controllers spoke to him in English, they and local pilots simultaneously communicated with each other in Russian. Orasanu, Fischer, and Davison (1997: 141–2) specifically refer to this problem as “dual-language switching.” Beyond what he was told by the controllers, he could not understand any of the rest of the situation. His comprehension about the airspace was limited. As he notes, “I often don’t understand what’s really going on there.” If all party-line communication was in English, he could know information like how many planes are waiting to land, their plane types, and the order of landing prior to his plane’s. Then, he could more clearly predict what he would have to do and could be more prepared (e.g., fuel management). This problem also exists in other nations. France permits the use of French for its domestic ATC. Foreign pilots often complain about this because they find themselves confronted with a widened context that they simply cannot understand unless they understand French (Schwartz, 1997, CN1).

One simple solution for the loss of situation awareness due to language alienation may be to require all pilots, no matter where, to use only English. However, the reality is not that

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Table 1. ICAO phonetic alphabet

<table>
<thead>
<tr>
<th>Alpha</th>
<th>Bravo</th>
<th>Charlie</th>
<th>Delta</th>
<th>Echo</th>
<th>Foxtrot</th>
<th>Golf</th>
<th>Hotel</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>Julia</td>
<td>Kilo</td>
<td>Lima</td>
<td>Mike</td>
<td>November</td>
<td>Whiskey</td>
<td>Oscar</td>
<td>Papa</td>
<td>Quebec</td>
</tr>
<tr>
<td>Sierra</td>
<td>Tango</td>
<td>Uniform</td>
<td>Victor</td>
<td>Whiskey</td>
<td>X-ray</td>
<td>Yankee</td>
<td>Zulu</td>
<td></td>
</tr>
</tbody>
</table>

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simple. Enforcing them to use only English seemingly enhances the safety of foreign airplanes flying into the airspace. However, in an airspace over a region where English is not commonly spoken, local pilots are not likely to be proficient in English. Thus, to require such pilots and controllers to use only English would likely threaten the safety of such airspace.

By the end of the 1990s, English proficiency requirements for aviation personnel was determined by the licensing authority of each country (Schwartz, 1997: CN1). No international standard had been established. For instance, the Spanish-speaking Columbia controller, who did not possess sufficient English proficiency to notify the American Airlines' flight of the dangerous situation, was a qualified controller in Columbia. According to a report released by NTSB and the Colombian aviation authority, his academic performance in English was “above average with grades between 85 and 96 out of a perfect score of 100” (Language lapse cited in Colombian air crash, 1996: A9). However, as discussed, his English was not sufficient to handle the “beyond ordinary and phraseologic” circumstance.

Many foreign pilots and controllers have their training in the United States. Major airlines across the world mostly have training facilities in the United States. If an airline does not have such a facility, it normally sends its student pilots to US pilot schools. The Federal Aviation Administration (FAA) regulation regarding English proficiency was tightened in the late 1990s. The Federal Aviation Regulation (FAR) Part 61 had once permitted FAA certified examiners to issue airman’s licenses with an “English limitation” for pilots whose native language was not English. However, the new FAR Part 61 (61–141), which became effective in October 1997, eliminated the issuance of such language-limitation licenses. All student pilots and controllers have to have a certain level of English proficiency as long as they wish to receive training in the United States.

At the same time that it is used to train pilots and controllers whose native languages are not English, aviation English itself can be modified to be friendlier to them. For example, multiple fixes (location indicator for navigation: normally a five-letter code) in a given area can sound confusing to the area’s aviation personnel. A US airline pilot notes his experience regarding two fixes near Japan, NOGA_L and NOGA_R, which sound very confusing to Japanese controllers, who generally cannot, when speaking and listening, distinguish “L” from “R.” He suggests that changing those names (fixes) would be much “user friendlier,” hence enhancing safety of this particular airspace (NASA, n.d., ASRS No. 242971).

As reviewed through past accidents, to improve communication skills also matters for pilots and controllers who use English as a native language. The US airline’s captain, who has been cited earlier, stresses that English-speaking pilots have to learn to be accustomed to the idiosyncratic characters of local Englishes in non-English-speaking countries. When he started flying to Japan and China, he had experienced many difficulties and problems in his ATC communication with Japanese and Chinese controllers. However, he now experiences almost no problem in communicating with them. He feels that he has become accustomed to the ways in which the Japanese and the Chinese controllers speak English. He stresses that this includes knowing not only their peculiar pronunciation but, more importantly, their preference – due to their limited English lexicon – for words and phrases. And such preferences should vary depending on ESL speakers’ native languages. In addition, he also emphasizes the importance of using easy and comprehensible English in the presence of non-native-English-speaking controllers and pilots. He said that this strategy has tremendously helped to improve flight safety (Dan Winchelt, personal conversation, 1997).
A number of other pilots have also contributed similar suggestions in terms of what native-English-speaking aviation personnel ought to do. Referring to his experiences in Venezuela, a US airline pilot contributed one suggestion to NASA’s Aviation Safety Reporting System (ASRS):

If they just slowed down and tried to enunciate clearly it would help immensely. Of course it goes both ways, we should speak slowly and clearly to them using standard phraseology ... Bottom line: when operating in foreign airspace, do not accept anything other than absolute certainty that they know what you are doing, and you understand what they want you to do – even if it takes several confirming radio calls. (NASA, n.d., ASRS No. 431752)

Merritt and Ratwatte (1997: 665) further stress the important role of native speakers of English in this cross-cultural communication in aviation:

Language training may also be necessary. English is the official language of aviation and its practice should be mandated, however, language training is not just for the non-native speaker of English. Anglo pilots, who have been arbitrarily granted the linguistic advantage, should be taught how to communicate simply, slowly, and precisely with non-Anglo personnel as required.

Many experts in this field suggest that native-English-speaking pilots and controllers should not only speak slowly and clearly, but also use standard ATC English. In their discourse analysis of ATC communications in Turkey, Sullivan and Girginer (2002) found that Turkish air-traffic controllers were experiencing difficulty in understanding colloquial, vague, and complex English syntax used by native-English-speaking pilots flying into Turkish airspace. Connell (1996: 22) acknowledges that, generally, pilots show “lower levels of awareness of proper phraseology and weaker adherence to proper protocols” than air-traffic controllers. Thus, a similar problem likely takes place in any airspace in non-English-speaking regions of the world in which native-English-speaking pilots fly. This essentially means that those native-English-speaking pilots are endangering lives in those airspaces. Itokawa (2000: 52) also argues that non-phraseologic and fast-rate ATC communication in English-speaking countries and airspace is more problematic than phraseologic communication in non-English-speaking airspace. He refers to some extremely busy airspaces in the United States, such as New York and Los Angeles, as examples of this problem. In fact, Fegyveresi (1997: 82–3) surveyed air-traffic controllers in the New York area and found that they tend to talk rapidly under stress (e.g., extreme amounts of traffic), even though they simultaneously admit that “rate adjustment” (i.e., slowing down) is a very effective way to communicate with pilots with limited English proficiency. Thus, the fundamental problem may not be their use of language itself, but the congestion of those airspaces. At any event, the use of colloquial, non-phraseologic, and fast-rate English ATC communication alienates non-native-English-speaking pilots, just as use of a non-English language in a non-English airspace alienates English-speaking pilots flying there.

**DISCUSSION AND CONCLUSION**

Among various means that pilots and controllers utilize to operate airplanes safely, the crucial role of voice communication has remained the same or will even become greater in the future. Voice communication through the radio is a very effective way to transmit
substantial information between pilots and controllers regardless of the distance between them. It also allows them to make many decisions and carry out practices promptly within a limited amount of time. Contents in ATC communication can also change flexibly based on their contextual elements, such as weather, the airspace’s congestion, and emergency needs. The importance and the usefulness of voice communication are largely based on voice communication’s flexibility that makes the transfer of complex contents possible. However, those superior characteristics of voice communication can be a double-edged sword. While analyzing ATC miscommunication, Cushing (1989: 4) insightfully notes,

> While voice has a natural appeal as the preferred means of communication both among humans themselves and between humans and machines – as the form of communication that people find most convenient – the complexity and flexibility of natural language are problematic, because of the confusions and misunderstandings that can arise as a result of ambiguity, unclear reference, intonation peculiarities, implicit inference, and presupposition.

Those may be universal aspects of any kind of human communication and potentially cause a variety of problems in almost all fields of human activities that involve use of language. However, in terms of avoiding fatal results, communication in aviation is perhaps one of the few important fields that need critical examination. To maintain safe operation, pilots and controllers have to use voice communication at a highly practical level and heavily rely on it. Simultaneously, they are always faced with a number of problematic aspects of communication, as Cushing argues.

Since ATC is a communicative space that involves numerous people having different Englishes, in terms of both different degrees of proficiency and different local influences, how to establish a mistake-free standard English is always a crucial consideration. Often, miscommunication in aviation is simply attributed to a lack of English proficiency when the pilots or controllers are non-native speakers of English. Needless to say, pilots and controllers whose native language is not English are indeed some of the most seriously task-oriented second-language speakers around. They carry tremendous responsibility in maintaining safety through their command of English. If an accident occurs, they definitely cannot be excused from responsibility for the accident simply because their language abilities were insufficient. Their lack of English proficiency has been criticized whenever their communication failures led to a fatal accident. Then, it has been stressed that they must simply work harder to acquire higher English proficiency. Many would agree that all those non-native English speakers in aviation always need to improve their English proficiency.

However, merely and hegemonically blaming their language inabilities or limitations for preventable accidents will not fundamentally solve the problem. It is important to notice that the ultimate goal is “not to improve their English proficiency itself,” but “to avoid fatal accidents due to miscommunication.” Their effort in acquiring English proficiency may have certain limitations or will reach a “ceiling,” as it were. Although the KLM captain of the Tenerife accident had made intensive use of aviation English for decades, he was still not totally free from interference from his native language. Therefore, we should sincerely and rigorously strive to create an error-resistant and mistake-free language environment.

At the same time, pilots and controllers who have high proficiency in English still use improper English and miscommunicate, two shortcomings that can lead, and have led, to
fatal results. And importantly, they interact with pilots and controllers whose English may be limited and has local influence. Such interaction through ATC radio is taking place millions of times a day anywhere in the sky. Furthermore, because ATC should rely on phraseology and what Lippi-Green (cited in Kubota, 2001: 47) argues can be a very precise cautionary rule for Anglo-speaking pilots and controllers, “standard behavior does not come naturally, and indeed, just as natural languages are never static.” Essentially, they have to be trained to fully use ATC phraseology.

In this regard, linguistics and language educators can greatly contribute to this yet-to-be-extensively-researched area. For example, language educators having expertise in local Englishes can make a great contribution. They may develop region-specific aviation-ESL training programs. They can conduct research to analyze idiosyncratic usage and difficulties of local English in a given airspace, and their finding can be a great “safety-enhancing resource” for all pilots who fly into the airspace. Researchers of cross-cultural communication may provide meaningful suggestions for the improvement of cross-cultural crew-resource management in the cockpit. The importance of and demand for the area of aviation English will certainly increase simply because of the rapid increase of international air traffic. Their research and effort will greatly benefit the whole world by saving lives.

NOTES

1. An earlier version of this paper was presented at the 2003 annual conference of the International Communication Association, San Diego, CA. The author would like to thank Professor Jane Zuengler and the anonymous WE reviewers for their insightful comments and valuable suggestions regarding previous drafts of this essay.

2. The autopilot could be disengaged, by pushing or pulling the control wheel, with a force more than 6.5 kg/14.5 lbs, in order for the pilots to promptly regain their initiative to control the aircraft without turning the autopilot switch off.

3. The operating of some large aircraft requires flight engineers who are also in the cockpit. Rather than fly the aircraft directly, they monitor and control the instruments and the whole system of the aircraft, such as engines and cabin pressure.

4. The flight engineer refused to be named in this paper.

REFERENCES


