

○ ZAGREB AND TENERIFE

AIRLINE ACCIDENTS INVOLVING LINGUISTIC FACTORS

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The International Civil Aviation Organization (ICAO) is currently implementing a program to improve the language proficiency of pilots and air traffic controllers worldwide. In justifying the program, ICAO has cited a number of airline accidents that were at least partly caused by language factors. Two accidents cited by ICAO are analysed in this paper: the mid-air collision above Zagreb in 1976, and the runway collision at Tenerife in 1977. The paper examines the linguistic factors involved in each accident, such as code switching and L1 interference, and uses the 'Swiss cheese' model of accident causation developed by Reason (1990) and adapted by Wiegmann and Shappell (2003) to put these factors into a broader aviation context. It is shown that, while linguistic factors were in each case significant, both accidents occurred as the result of multiple causal factors, many of which were non-linguistic. Furthermore, stress and fatigue played a decisive role in exacerbating the linguistic factors in each accident. Finally, the paper suggests lessons that may be drawn from the analysis for the training of pilots and air traffic controllers, both native-speaker and non native-speaker.

INTRODUCTION

Over the last decade the International Civil Aviation Organization (ICAO) has been implementing a program to improve the language proficiency of pilots and air traffic controllers around the world. This program has seen the development of language proficiency requirements (LPRs) and a 6-level language proficiency rating scale which member states are required to comply with by 5 March 2011. ICAO initially intended that all pilots and controllers involved in international flights demonstrate proficiency at level 4 or higher on this scale from 2008, but difficulties in implementing the changes resulted in a 3-year transition period being adopted, and the deadline for compliance was put back to 2011.

To justify the new requirements, ICAO has cited a number of airline accidents that were at least partly caused by language factors. Seven such accidents, which occurred

between 1976 and 2001 and which resulted in the deaths of 1,460 people, were listed under the heading ‘The Case for LPRs’ at the Language Proficiency Implementation Plan Workshop held at the ICAO Asia and Pacific Office in January 2008.¹ An analysis of all seven accidents is beyond the scope of this paper. Instead the first two accidents cited by ICAO are examined: Zagreb and Tenerife. Table 1 summarises these two accidents, which feature several different linguistic factors and which also exemplify the important point that airline accidents are invariably caused by ‘a complex interplay of multiple factors’ (Dismukes et al., 2007, p. 5).

Accident	Date & location	Aircraft involved (operator & flight number)	L1 of flight crew	L1 of air traffic controllers	Type of accident	Number of fatalities
Zagreb 1976	10 September 1976 Zagreb, Yugoslavia	McDonnell Douglas DC-9-32 (Inex Adria Airways Flight 550)	Serbocroatian	Serbocroatian	Mid-air collision	176
		Trident 3B (British Airways Flight 476)	English			
Tenerife 1977	27 March 1977 Tenerife, Canary Islands, Spain	Boeing B-747-206B (KLM Flight 4805)	English	Spanish	Runway collision	583
		Boeing B-747-121 (Pan Am Flight 1736)	Dutch			

Table 1. Summary of the accidents analysed in this paper.²

A variant of the ‘Swiss cheese’ model of accident causation is used to show how the linguistic factors fit into the broader aviation contexts at Zagreb and Tenerife. The next section of the paper describes the ‘Swiss cheese’ model, and the following sections examine each accident in turn, with a brief description followed by a listing of the causes and contributing factors, and an analysis of the linguistic factors. Sources of data for the analysis include official accident reports, air traffic control (ATC) transcripts, cockpit

voice recorder (CVR) transcripts and ICAO documents. The paper concludes by suggesting lessons that can be drawn for the training of pilots and air traffic controllers.

THE ‘SWISS CHEESE’ MODEL AND HFACS

It is an axiom of modern accident analysis that airline accidents are not usually caused by a single factor, but rather by a combination of multiple factors (Dismukes et al., 2007, p. 279). In the accident causation model developed by Reason (1990, pp. 199–212) the factors are visualised as gaps, or weaknesses, in the defensive layers of a system. Thus if one defensive layer represents the actions of pilots, then a gap in this layer – an ‘unsafe act’ – could be caused by a pilot initiating a takeoff roll before receiving takeoff clearance from the control tower. The gaps are continually changing position and size, and when gaps in all the layers are aligned, as shown in Figure 1, it is possible for an accident trajectory to pass through all the defences, like a skewer passing through the holes in slices of Swiss cheese. When this happens, an accident results. Because of the obvious visual similarity, this type of framework is commonly known as the ‘Swiss cheese’ model.

While acknowledging the importance of Reason’s work to aviation safety, Wiegmann and Shappell (2003, pp. 45–50) criticise this model for being too theoretical and not suitable for use by accident investigators. Taking the Reason framework as a base, they developed the Human Factors Analysis and Classification System (HFACS), a tool for analysing and investigating accidents (Wiegmann and Shappell, 2003, pp. 50–71). HFACS focuses on defining the types of failure that may occur, and consists of the following four levels, or defensive layers:

- unsafe acts (eg: a pilot starts to take off without receiving clearance from the control tower)
- preconditions for unsafe acts (eg: a pilot or controller is suffering from mental or physical fatigue)
- unsafe supervision (eg: an airline pairs an inappropriate captain and first officer for a flight)
- organizational influences (eg: an air traffic control centre has insufficient manpower)

In addition, the HFACS model also allows for the effect of outside influences, such as loopholes in national regulations. This version of the ‘Swiss cheese’ model is used in Figures 2 and 3 to depict the causes and contributory factors of the accidents at Zagreb and Tenerife.

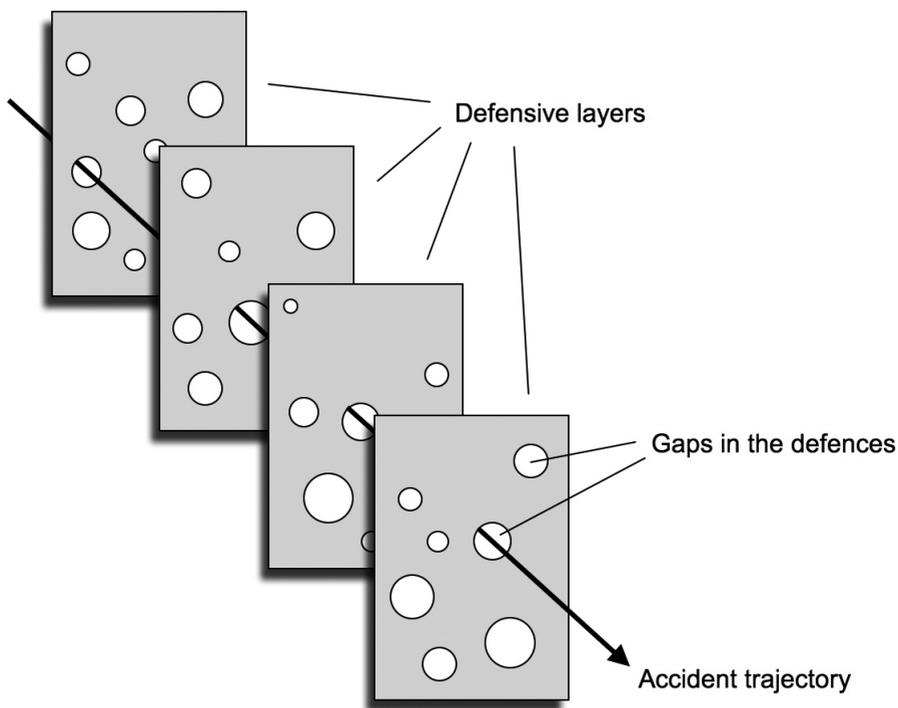


Figure 1. The 'Swiss cheese' model of accident causation (adapted from Maurino et al., 1995, p. 25).

ACCIDENT 1: ZAGREB 1976

On 10 September 1976 British Airways Flight 476 was flying from London Heathrow to Istanbul when it collided in mid-air with Inex-Adria Airways Flight 550, en route from Split to Cologne. The crash occurred at approximately 10:15 GMT in favourable weather conditions at an altitude of 33,000 feet. All 176 passengers and crew on board the two aircraft died.

The first report produced by the Aircraft Accident Investigation Committee of the Yugoslav Federal Civil Aviation Administration found two broad causes of the accident and nine contributory factors. The first cause was that air traffic controllers in the Zagreb Area Control Centre had not provided adequate separation between the aircraft, nor realised in time that a conflict was inevitable, nor taken effective measures to prevent a collision. Secondly, 'a series of circumstances contributed to the collision of the aircraft

which were flying in the conditions of great visibility' (AAIB, 1977, pp. 38–39). Figure 2 depicts these causes and factors in the form of the 'Swiss cheese' model. The figure indicates that the accident was caused by the co-occurrence of multiple factors, involving several air traffic controllers as well as the flight crews of both aircraft.

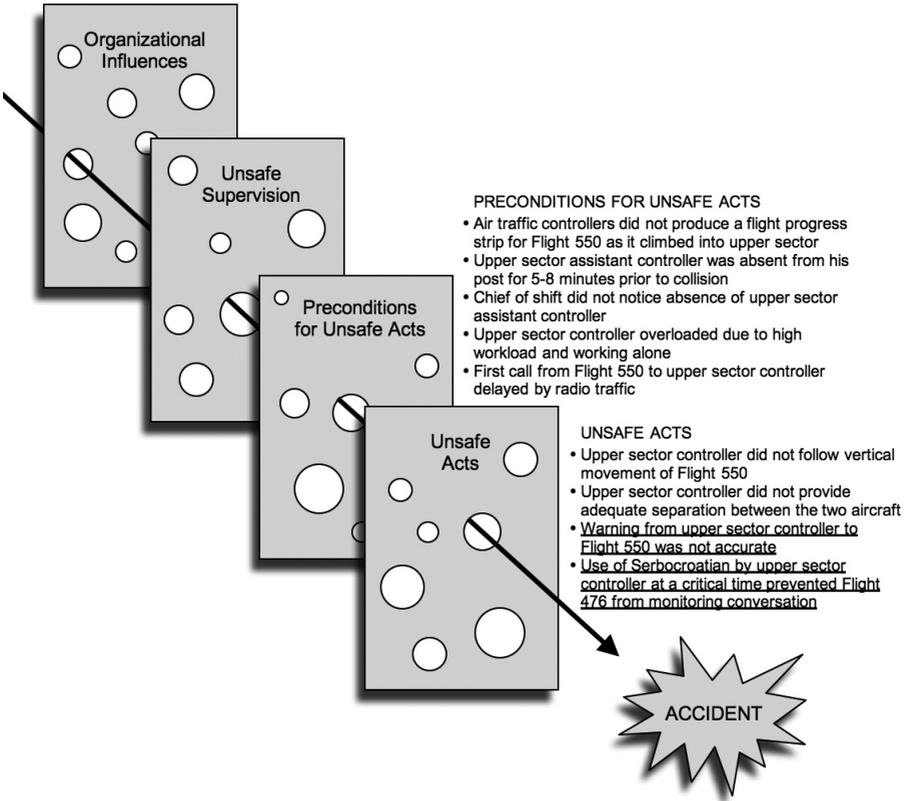


Figure 2. Causes and contributing factors of the Zagreb collision (AAIB, 1977, pp.38–39).³

A second report by the same agency published more than five years after the accident found the cause to be a combination of 'improper ATC operation' and the failure of the flight crews to maintain an effective lookout (AAIB, 1982, p. 55). The lookout finding was, however, challenged by the UK representative in an addendum to the English language reprint of the report. This addendum stated that the accident was caused by 'the

failure of the ATC system to provide the required separation’, which is in line with the findings of the first report (AAIB, 1982, p. 57).

The final two contributory factors shown in Figure 2 have been underlined because they are linguistic. They refer to a short exchange between the Zagreb upper sector controller and Flight 550 as the aircraft climbed towards its intended cruise altitude. This exchange is reproduced in Transcript 1. With the exception of greetings, the dialogue between controller and flight crew had been entirely in English, when – at 10:14:22 – the controller suddenly switched to Serbocroatian⁴ and told Flight 550 to stop climbing. The flight crew replied in Serbocroatian at 10:14:27 to ask what altitude they should maintain, and the controller instructed them to hold their current altitude because another aircraft was approaching at flight level 335 (= 33,500 feet). The other aircraft, British Airways Flight 476, was actually at flight level 330 (= 33,000 feet), its assigned altitude. Still speaking Serbocroatian, the crew of Flight 550 stated their intention to ‘maintain precisely 330’. Moments later the two aircraft collided.

Time (GMT)	Source	Content
10:14:04	JP550:	<i>Good morning Zagreb, Adria 550.</i>
10:14:07	Zagreb:	<i>Adria 550, Zagreb good morning. Go ahead.</i>
10:14:10	JP550:	325 crossing, Zagreb at 14.
10:14:14	Zagreb:	What is your present level?
10:14:17	JP550:	327.
10:14:22	Zagreb:	[Stuttering] ... e ... <i>maintain now that level and report passing Zagreb.</i>
10:14:27	JP550:	<i>What level?</i>
10:14:29	Zagreb:	<i>At which you are now climbing, because e ... you have an aircraft in front of you at ... [unintelligible] 335 from left to right.</i>
10:14:38	JP550:	<i>OK, maintain precisely 330.</i>

Transcript 1. Excerpt from the ATC transcript for the Zagreb collision (AAIB 1977, p. 4, with italics added to show sections that were originally in Serbocroatian).

The first point to note about this exchange is the code switching. It is not clear why the controller switched from English to Serbocroatian, but perhaps he realised that a collision was imminent and deliberately switched to his L1 (and that of the crew of Flight 550) to ensure his message would be immediately understood. Or perhaps the code

switching was not deliberate, but brought about by a combination of time and workload pressure. Ganushchak and Schiller (2009) note that unintentional code switching may occur under conditions of psychological stress. They go on to suggest that when speakers using L2 are subjected to time pressure there may be intrusions from the ‘dominant native language’, on account of the higher cognitive workload required to speak a second language. The controller was under time pressure to resolve the situation he now faced, and workload pressure from handling the upper sector alone for most of the previous ten minutes, when two or three controllers should have been assigned to each sector. In addition, he was quite possibly suffering from fatigue as a result of working three twelve-hour shifts in three days (Stokes and Kite, 1994, pp. 113–115, 303).

Whatever the reason for the code switching, it had the unfortunate consequence of preventing the pilots of British Airways Flight 476 from monitoring this critical part of the dialogue as they could not understand Serbocroatian. With hindsight it has been suggested that had the controller spoken English throughout the exchange, the British Airways flight crew might have realised that the two aircraft were at the same altitude and tried to prevent the collision (Beaty, 1995, p. 42). However, the accident report points out that even if this had happened there may not have been enough time for the pilots to take avoiding action (AAIB, 1977, p. 37). Furthermore, the suggestion that only English should have been used fails to take account of all the causal factors shown in Figure 2; specifically, it ignores the pressure the controller was evidently under, which may have rendered him incapable of accurately communicating the vital message in English, his L2.

The second point about the exchange in Transcript 1 is that at 10:14:29 the controller gave the incorrect flight level for Flight 476. In the subsequent trial he claimed that his radar system indicated flight level 335, but only ten minutes previously he had spoken with the British Airways crew and confirmed they were at flight level 330 (Weston and Hurst, 1982, p. 172). There has been speculation that the controller, believing that disaster was inevitable, ‘may have attempted to mask the terrible reality by “adding” that extra 500 feet to the flight level’ (Weston and Hurst, 1982, p. 172). The mistake may, though, have been attributable to other factors. As Dismukes et al. (2007, p. 49) point out, high workload can cause recently acquired information to be forgotten or not remembered correctly, and both Cushing (1994, pp. 51–62) and Monan (1986) list numerous examples of miscommunication between pilots and controllers involving numbers. In fact, the upper sector controller had made two other numerical slips in the previous two minutes: at 10:12:24 he gave an incorrect radio frequency, which he immediately corrected, and at 10:13:34 he incorrectly read back a flight number (Weston and Hurst, 1982, p. 52).

Those two mistakes were of no consequence, but the third was catastrophic as it directed two aircraft to the same flight level just as their flight paths crossed.

ACCIDENT 2: TENERIFE 1977

On 27 March 1977, KLM Flight 4805, flying from Amsterdam, and Pan Am Flight 1736, from Los Angeles via New York, were bound for Las Palmas Airport in the Canary Islands when a bomb explosion in the terminal building caused the airport to be closed. The aircraft, both Boeing 747s, were diverted to Los Rodeos Airport on the island of Tenerife. After Las Palmas Airport reopened, the Pan Am crew wanted to leave Los Rodeos as soon as possible, but had to wait until the KLM aircraft, which was blocking access to the runway, had finished refuelling. Meanwhile weather conditions were deteriorating as thick cloud enveloped the airport. Finally both aircraft were instructed to taxi along the active runway, part of the taxiway being blocked by other diverted aircraft. Flight 4805 reached the end of the runway, turned around, and then began its takeoff roll without receiving clearance from the control tower, and with Flight 1736 still taxiing on the runway. The KLM aircraft had just started to lift off when it struck the other plane. A total of 583 people were killed in the collision and subsequent fires and explosions, making this the worst accident in aviation history.

The report produced by Spain's Civil Aviation Accidents and Incidents Investigation Commission (CIAIAC) cited four actions by the KLM captain that caused the accident, together with nine other contributory factors (see Figure 3). This accident, like the Zagreb collision, was the result of multiple factors and featured communication problems between a controller and pilots. However, unlike Zagreb, it was preceded by a bomb attack causing diversions and delays. Moreover, Los Rodeos was a small regional airport located at an elevation of more than 2,000 feet, subject to rapidly changing visibility caused by wind-blown clouds, and not used to handling international air traffic or aircraft as large as the Boeing 747.

The Spanish report was reprinted in English by ICAO with comments appended by the Dutch investigation authorities. While accepting the facts presented in the original report, the Netherlands Department of Civil Aviation interpreted them differently, stressing that the accident 'was not due to a single cause' and playing down the culpability of the KLM crew, noting instead that 'a non-optimal functioning can be recognized with all parties' (ICAO, 1980, p. 66). These comments were not endorsed by the Netherlands Aircraft Accident Inquiry Board, which confined itself to making recommendations intended to prevent a recurrence of the accident (ICAO, 1980, p. 57).

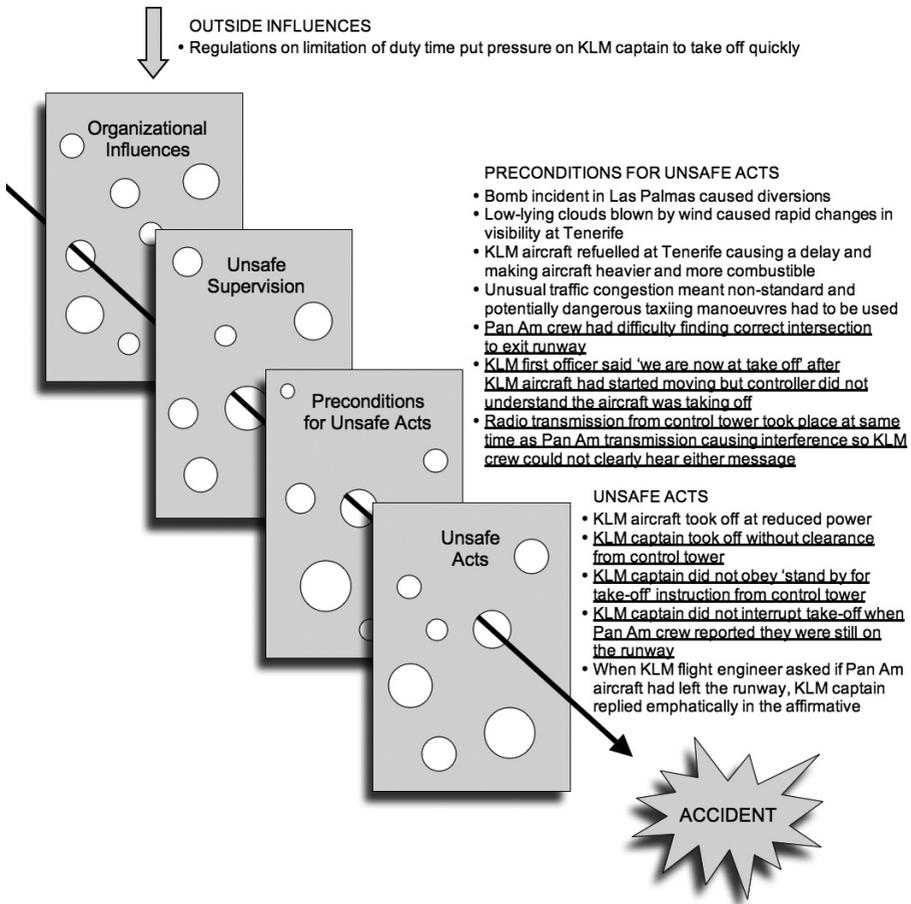


Figure 3. Causes and contributing factors of the Tenerife collision (CIAIAC, 1978, pp. 58–60).

The factors underlined in Figure 3 relate to communication issues that arose between the pilots and control tower, all of them occurring in the final five minutes before the collision. The first issue concerns problems the Pan Am crew had in locating the correct exit as they taxied down the runway: there were no signs marking taxiway exits; visibility was poor; and the crew were not familiar with the airport. Furthermore, according to a report by the Air Line Pilots Association (ALPA), it was difficult to understand instructions

from the control tower 'because of the heavy Spanish accent of the controller as he spoke English' (Roitsch et al., 1978, p. 11). At 17:02:08 GMT the controller said, 'Affirmative, taxi into the runway and – ah - leave the runway third, third to your left.' The Pan Am captain thought the controller had said 'first', so the first officer asked for confirmation and another controller replied, 'The third one Sir, one, two, three, third third one.' Instead of clarifying the situation, this created another problem because the third exit had two 148-degree turns which the ALPA report determined would have been 'a practical impossibility' for a Boeing 747 to negotiate (Roitsch et al., 1978, p. 19). In the event, either by mistake or because they thought it easier, the Pan Am crew continued towards the fourth exit, which they were approaching at the time of impact (CIAIAC, 1978, p. 57).

Meanwhile, the KLM aircraft had reached the end of the runway and was preparing for takeoff. At 17:05:41 the aircraft rolled forward slightly and the first officer warned the captain that they had not yet received ATC clearance. The tower issued ATC clearance at 17:05:53, giving permission to fly the first part of the route. This was not takeoff clearance, but confusingly it included the word 'takeoff'. The first officer then repeated the clearance to the tower: 'Ah- Roger sir, we are cleared to the Papa beacon flight level nine zero, right turn out zero four zero until intercepting the three two five. We are now at take off.' Just after the first officer had started this read-back, the KLM captain released the brakes and began the takeoff roll.

The last sentence in the first officer's read-back, underlined above, has been the subject of a lot of debate since the accident. Some commentators have posited linguistic interference from the first officer's L1: in Dutch a preposition may be used with the infinitive form of a verb to indicate an action currently being performed (ICAO, 2004, p. 30). Hence, the first officer may have meant the phrase 'at take off' to mean 'in the process of taking off' (Cushing, 1994, p. 1). His words, though, were 'hurried and the voice tremulous', indicating that he was under stress and making transcription of the voice recorder tapes so difficult that the ALPA study suggested that he might actually have said, 'We are, uh, taking off' (Roitsch et al., 1978, p. 23).

According to the Spanish report, the controller interpreted the first officer's final sentence as meaning 'We are now at take-off position' (CIAIAC, 1978, p. 47). In other words, the controller assumed an elliptical construction and, from the context available to him, inferred the missing element was 'position'. He believed, after all, that the KLM aircraft was still waiting for takeoff clearance. The controller replied at 17:06:18, saying, 'O.K.', and approximately two seconds later he continued, 'Stand by for take-off ... I will call you.' The Pan Am first officer made a radio transmission at almost the same time, saying, 'and we are still taxiing down the runway, the Clipper one seven three six.'

Either of these messages could have alerted the KLM crew to the imminent disaster, but unfortunately the near-simultaneous transmission caused interference so that neither could be heard clearly by the KLM crew.

The controller then requested the Pan Am aircraft to report when they were clear of the runway. This message could be heard in the KLM cockpit, but instead of referring to the Pan Am plane as 'Clipper' the controller used the phrase 'Papa Alpha', which was less likely to catch the attention of the pilots. The KLM flight engineer presumably heard this message, for he twice asked his colleagues whether the Pan Am plane had cleared the runway. The KLM captain replied emphatically, 'Oh, yes.' Seconds later the collision occurred.

The Tenerife accident involved the tragic co-incidence of many factors, and the ALPA accident report, which focused on human factor issues, highlighted the effects of stress and fatigue on those involved. In the tower, the two controllers had been on duty since 10:00 and had to handle three frequencies and an unusually large amount of traffic on account of diversions from Las Palmas, compounded by the fear of a possible bomb attack at Tenerife (Roitsch et al., 1978, p. 6). Workload pressure and fatigue may explain why one controller used the wrong flight number three times, saying KLM 8705 instead of KLM 4805, and it may also have prevented the controllers from realising that a Boeing 747 would not be able to negotiate the third taxiway.

The Pan Am crew had been on duty for over 11 hours, having to deal with the frustration of diverting to Tenerife when they wanted to hold at altitude, and then being delayed on the ground as they waited for the KLM aircraft to finish refuelling. The KLM crew, meanwhile, after more than 9 hours on duty, knew that if they did not leave soon they would be unable to return to Amsterdam on account of strict regulations on duty time limits introduced by the Dutch Government the previous year. Within the KLM cockpit there was an additional problem caused by a steep 'trans-cockpit authority gradient'. As Wiegmann and Shappell (2003, pp. 64–65) observe, 'when very senior, dictatorial captains are paired with very junior, weak co-pilots, communication and co-ordination problems are likely to occur.' The KLM captain was the Head of the Flight Training Department, while the first officer was a junior pilot who had in fact received his type qualification check from the captain earlier that year. This made it very difficult for the first officer to question or challenge any of the captain's decisions.

A final point to note about the KLM captain is that, due to his work as an instructor, he had not flown as a line pilot for 12 weeks before the accident. He had instead spent much of his time as a simulator instructor, in which role he would have issued ATC and

takeoff clearances to training crews. As Roitsch et al., (1978, p. 17) point out, ‘There is never a need for the crew to hold the simulator in position awaiting takeoff clearance.’

CONCLUSION

The two accidents analysed in this paper happened more than 30 years ago, but still serve as valuable lessons of what can happen when all the defensive layers of a system are breached. The first point arising from the analysis is that airline accidents are often highly complex events involving multiple causal factors, not single causes. The second point is that it can be extremely difficult to piece together the precise combination of events and factors that caused an accident, and even the publication of the official report may leave important matters unresolved. Following the Zagreb collision, for instance, there was a widespread belief that the upper sector controller had been treated as a scapegoat, with the International Federation of Air Traffic Controllers’ Associations (IFATCA) protesting until he was released from prison in 1978.

The disasters at Zagreb and Tenerife have been used to justify the ICAO language proficiency program, which is intended to improve the language proficiency of pilots and controllers worldwide. However, while both disasters involved significant linguistic factors – such as code switching, numerical slips, pronunciation problems and possible L1 interference – it should not be forgotten that they also involved many non-linguistic factors. It should also be noted that steps were taken following both accidents to prevent the recurrence of such tragedies. In the case of Tenerife these included: the introduction of ground radar at Tenerife Airport and the opening of a new airport on the island; changes to radiotelephony phraseology so that instructions are clearly confirmed and the word ‘takeoff’ is only used for takeoff clearance; and the introduction of Crew Resource Management (CRM) training to improve decision-making in the cockpit.

Finally, two areas that might warrant inclusion in future language training programs have been highlighted in this paper. One area concerns workload pressure, stress and fatigue, which played a role in both accidents. Pilots and controllers should be made aware of how these factors can hinder effective communication by causing, for example, unintentional code switching or the forgetting of recently acquired information. The other area concerns the interaction of native English speakers with non-native speakers, which again was a feature of both accidents. Although it is vital to ensure that non-native speakers have a suitable level of English proficiency, there would undoubtedly also be value in language awareness training for native speakers that taught, for instance, strategies for dealing with non-native speakers whose pronunciation is heavily influenced

by their L1. Language training in these two areas could conceivably be integrated with the use of inexpensive flight training devices (FTDs) that are increasingly common in flight training programs.

ENDNOTES

- ¹ The seven accidents cited by ICAO were: the Zagreb mid-air collision (1976); the Tenerife runway collision (1977); the Cove Neck fuel exhaustion crash (1990); the Cali, Columbia, controlled flight into terrain (1995); the New Delhi mid-air collision (1996); the Paris runway collision (2000); and the Milan runway collision (2001) (Lamy, 2008).
- ² A figure of 175 fatalities was given for the Zagreb accident at the ICAO Workshop in January 2008 but the official reports state that 176 people died (AAIB, 1977, p. 6).
- ³ The HFACS model is used in Figures 2 and 3 to depict the causes and contributory factors, but this model was not used in the original accident investigations. Consequently the investigators did not necessarily consider organizational factors. Some commentators have, however, suggested that organizational problems within the Zagreb Area Control Centre resulted in unsafe supervision of the flights, and also led to the upper sector controller being overloaded (Weston and Hurst, 1982).
- ⁴ After noting that ‘there is no such language as Serbo Croat or... Serbo-Croatian’, Weston and Hurst (1982, p. ix) go on to use these terms because they occur widely in source documents. This paper follows the usage in the two accident reports, and uses the term ‘Serbocroatian’.

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