EUROPEAN ORGANISATION
FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

Air-ground Communication Safety Study

An analysis of pilot-controller occurrences

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EUROPEAN AIR TRAFFIC MANAGEMENT PROGRAMME

CONTENTS

Executive Summary

Communications between controllers and pilots remain a vital part of air traffic control operations. Problems with it can result in hazardous situations. A first step in reducing the incidence of communication problems is to understand why and how they happen. In the past a number of studies have been conducted on the subject of pilot-controller communication errors. The majority of these studies were based on data obtained from incident reporting systems in the United States. The results of these studies could therefore not reflect the situation in Europe.

Within the EUROCONTROL Safety Improvement Sub-Group (SISG) the Air-Ground Communication Safety has been proposed as a potential subject for a Safety Improvement Initiative. The objective of the present study is to give a synthesis of the issues related to the aviation air-ground communication safety in support of the SISG activities. For this purpose a total of 444 incidents related to air-ground communication between controllers and pilots are analysed in this report. The identified incidents occurred during the years 2002-2003 (August). The analysed incidents are representative for the situation in Europe. The study is limited to commercially operated aircraft with a takeoff mass of 5,700 kg or higher.

This report provides an analysis of the 444 incidents related to air-ground communication between controllers and pilots. Significant safety issues, hazardous scenarios, causal factors, and potential prevention strategies concerning air-ground communication safety are provided in this report. As a result of this study, a number of recommendations are made.

Chapter 1 Introduction

1.1 Background

Voice communications between controllers and pilots remain a vital part of air traffic control operations despite the introduction of data link systems such as ACARS. Voice communication problems can result in hazardous situations. For instance miscommunication has been identified as a primary factor causing runway incursions (EUROCONTROL, 2003). It is therefore important to have an understanding of the problems and factors associated with voice communication problems. The importance of communication in an air traffic system was emphasised by Linter and Buckles (Linter and Buckles, 1993), who stated that "*Regardless of the level of sophistication that the air traffic system achieves by the turn of the century, the effectiveness of our system will always come down to how successfully we communicate*".

A first step in reducing the incidence of communication problems is to understand why and how they happen. In the past a number of studies have been conducted on the subject of pilot-controller communication errors. The vast majority of these studies were conducted in the United States (e.g., Grayson and Billings, 1981; Monan, 1983; Monan, 1986; Morrison and Wright,1989; Morrow, Lee, and Rodvold, 1993; Cardosi, Falzarano, and Han, 1999; Cardosi, and Yost, 2001). It is possible that some of the older studies do not reflect the current situation in air transport regarding air-ground communication. Furthermore the analyses of incidents were mainly limited to those reported to the Air Safety Reporting System (ASRS) in the United States. ASRS reports are submitted voluntarily by pilots and controllers from the United States. The accuracy of the ASRS data is subject to the accuracy of the reporters' perceptions and memory for the occurrences. The ASRS reporting process can have the tendency toward producing a reporting bias because possibly only those incidents are reported in order to take advantage of the limited immunity from regulatory enforcement action provided through the use of the ASRS system. These facts about the ASRS system could limit the applicability of the results of studies using ASRS data to the situation in Europe. For instance, in Europe there is larger portion of pilots flying which are non-native English speaking; in Europe the VHF band is managed differently (8.33 kHz above FL 245); in Europe the sectors are smaller; and Europe has a RVSM airspace (between FL 290 and FL 410). Furthermore, occurrences which involved communication equipment could be underreported in ASRS as these a normally reported to other reporting systems (such as an airline internal safety reporting system).

The EUROCONTROL Safety Enhancement Business Division is supporting the enhancement of Air Traffic Management Safety in a Single Pan-European Sky. As part of its mission, this unit is initiating European-wide safety improvement initiatives based on the risk-derived priorities involving the whole aviation community. The main working and consultation body managing the initiatives is the EUROCONTROL Safety Improvement Sub-Group (SISG). Within the SISG the Air-Ground Communication Safety has been proposed as a potential subject for a Safety Improvement Initiative. The National Aerospace Laboratory NLR was contracted by EUROCONTROL to conduct a synthesis of the issues related to the aviation air-ground communication safety in support of the SISG activities.

1.2 Project objectives and scope

The objective of the present study is to give a synthesis of the issues related to the aviation air-ground communication safety in support of the SISG activities. The study aims to identify significant safety issues, hazardous scenarios, causal factors, and potential prevention strategies concerning air-ground communication safety. Air-ground communication is defined by ICAO as a two-way communication between aircraft and stations or locations on the surface of the earth (ICAO, 2001). Communication can be defined as a process by which information is exchanged between individuals through a common system of symbols, signs, or behaviour in order to affect change. The present study is limited to the communication between pilots of commercially operated aircraft and air traffic controllers.

1.3 Organisation of the report

This report is organised as follows. In section 2 the approach of the study is presented. The result of the data analysis is given in section 3. Section 4 presents the results in a generic model. In section 5 the prevention strategies are discussed and presented. In section 6 and 7 conclusions and recommendations are given respectively. Finally the quoted references are listed in section 8.

Two B737s were operating on reciprocal routes between Brisbane and Darwin. A pilot requested a clearance to a non-standard level of FL 350, which was confirmed by the Darwin Sector 1 controller. The controller advised Brisbane Sector 5 of the change in level, both the trainee and the rated controller believed that the level had been given as 390 and this was read back as “three niner zero”. When the word “niner” was received by Darwin, a temporary loss of signal clarity occurred, and the Darwin controller interpreted the sound as a “five”. While the Brisbane based controllers thought the B737 was cruising higher than usual, absence of any knowledge to the contrary led them to believe that the aircraft could operate at FL390. The other B737 operating from Brisbane and Darwin was also cruising at FL350. In the vicinity of Mount Isa the crew of one aircraft became aware of the other and initiated avoidance action and clearance for operation at a lower level was given.

Source: ATSB

Chapter 2 Analysis method

2.1 Approach

Queries were conducted in the NLR Air Safety Database for occurrences involving problems related to air-ground communication between pilots of commercially operated aircraft and air traffic controllers. Emphasis was placed on occurrences of less serious incidents as obtained from airline reporting systems and confidential reporting systems as accidents and serious incidents only would give a too small a data sample to draw (statistically) meaningful conclusions. Since there could be a bias towards pilot reported occurrences in these data sources, additional data were obtained from mandatory occurrence systems. These reporting systems provided additional data of occurrences reported by Air Navigation Service Providers and airlines to regulators. Additional incident data collected by European Air Navigation Service Providers could also be of interest to the study. However, only a limited number of occurrences were available during the course of the study. Overall, care was taken that duplications were removed from the final data sample. The data covers a period from January 2002 until August 2003. There is no restriction to where the occurrence took place. However, only those occurrences were selected that were considered to be relevant to the situation in Europe. The analysis is limited to occurrences with commercially operated aircraft with a takeoff mass of 5,700 kg or higher.

2.2 Taxonomy

The taxonomy used in the present study to code the air-ground communications occurrences between controller and pilots, adopted several elements and definitions from previous studies (e.g., Cardosi, 1998).

The taxonomy used to classify Pilot-Controller Voice Communication safety occurrences is listed in Table 1.

Consequence

The following consequences are defined in the taxonomy:

- Altitude deviation - *A departure from, or failure to attain, an altitude assigned by ATC.*
- Runway transgression - *the erroneous or improper occupation of a runway or its immediate vicinity by an aircraft that poses a potential collision hazard to other aircraft using the runway, even if no other aircraft were actually present (definition taken from ASRS).*
- Wrong aircraft accepted clearance - *Self explanatory*
- Prolonged loss of communication - *No response from subject aircraft when called by ATC or other aircraft. Typical duration of communication loss in terms of minutes or more.*
- Loss of separation - *Less than the prescribed separation between aircraft.*
- Heading or track deviation - *Failure to fly assigned heading/track*.
- Instruction issued to wrong aircraft - *Self explanatory*
- Unknown - *Self explanatory*
- None - *Self explanatory*

Generic Communication Problem

The following generic communication problems are used in the taxonomy:

- Readback/Hearback errors - *the pilot reads back the clearance incorrectly and the controller fails to correct the error. Also used when a pilot of the wrong aircraft reads back the instruction.*
- No pilot readback - *A lack of a pilot readback*. *The pilot does not indicate to the controller that he/she understands the clearance by repeating (reading back) the message.*
- Hearback Errors - *The controller fails to notice his or her own error in the pilot's correct readback or fails to correct critical erroneous information in a pilot’s statement of intent.*
- Communication Equipment problem - *Problems caused by the improper functioning of communication equipment in the aircraft or on the ground.*

- Loss of communication - *Self explanatory*
- Other - *Self explanatory*

Communication factors

A factor is defined here as an item, which was judged to be instrumental in the causal chain of events leading to the occurrence. Table 2 lists the factors used in the present taxonomy.

Table 1: Data Taxonomy.

DATA FIELD	***REMARKS***
Date	-
A/c type	-
Location	-
Flight Phase	-
Emergency situation?	Did the occurrence took place during normal routine operations or during an emergency (e.g. PAN PAN or Mayday)
Consequence	Describes the outcome of the occurrence. Note that more than one consequence can be assigned to one occurrence.
Generic Communication Problem	General classification of the occurrence.
Communication factors	Specific (causal) factors related to communication, which were applicable to the occurrence. Note that more than one factor can be assigned to one occurrence.

Table 2: Overview factors.

FACTORS	
Ambiguous phraseology	Sleeping VHF receivers*
Blocked transmission	Partial readback
Content of message inaccurate/incomplete	Pilot accent/non-native
Controller accent/non-native	Pilot distraction
Controller distraction	Pilot expectation
Controller fatigue	Pilot fatigue
Controller high speech rate	Pilot high speech rate
Controller non-standard phraseology	Pilot non-standard phraseology
Controller workload	Pilot workload
Frequency change	Radio equipment malfunction - air
Frequency congestion	Radio equipment malfunction - ground
Garbled message	Radio interference
Issue of a string of instructions to different aircraft	Similar call sign
Language problems	Stuck microphone
Long message	Untimely transmission

**Sleeping VHF receivers* - loss of communication type in which the VHF frequency becomes silent for a period of time.

Chapter 3 Results

3.1 General

3.1.1 Overall data sample

The queries in the different databases resulted in a total number of 444 occurrences in which there were problems with air-ground communication between the controller and the pilot. All these occurrences were classified as 'incidents'[1]. All 444 occurrences were coded according to the taxonomy described in section 2.

These 444 occurrences encompass 1% of all reported occurrences and 23% of all ATC related occurrences. The air-ground communication problem occurrence rate is low at an estimated rate of 1.4 per 10,000 flights. This does not mean that air-ground communication problems between a controller and a pilot are low risk events due to their apparent low frequency of occurrence. The consequences of communication problems can be such that associated risks are potentially high.

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[1] *Defined by ICAO as an occurrence, other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operation.*

3.1.2 Generic communication problems

Figure 1 shows that readback/hearback errors were the most common type of generic communication problems found in the data sample. Similar results were reported in previous studies using ASRS data (e.g. Cardosi, Falzarano, and Han, 1999).

3.1.3 Consequences of communication problems

Figure 2 shows the frequency distribution of the consequences of air-ground communication problems for the complete data sample. 'Prolonged loss of communication is cited the most frequent consequence accounting for 28% of consequences assigned. Note that a single occurrence can have more than one consequence associated with it. For 55 occurrences two or more consequences were identified. A combination of consequences that was frequently found with this subset of the sample, was 'Wrong aircraft accepted clearance' followed by an 'Altitude deviation' accounting for 35% of the 55 occurrences.

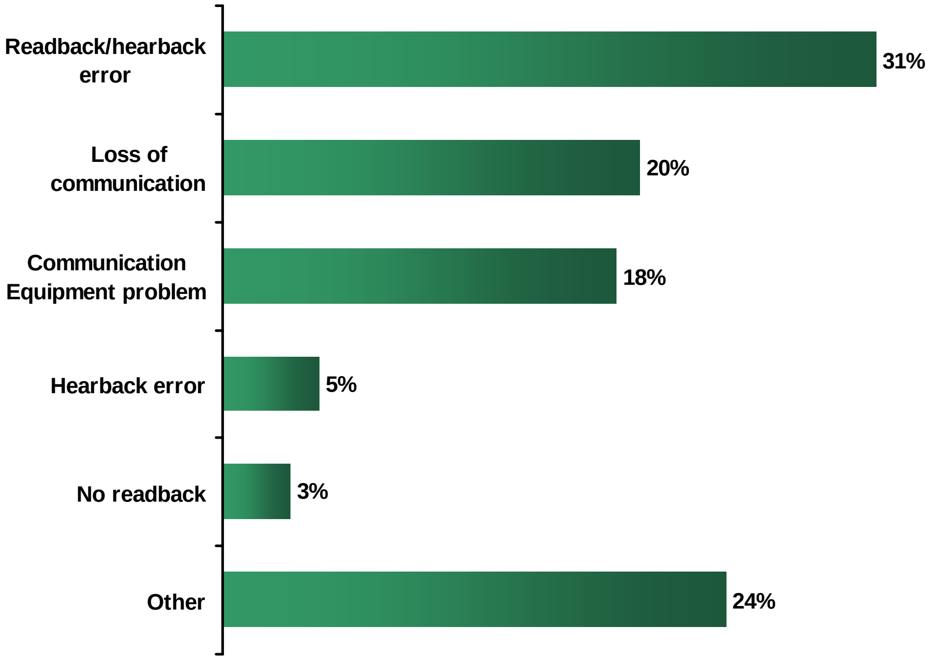

Figure 1: Distribution of generic communication problems.

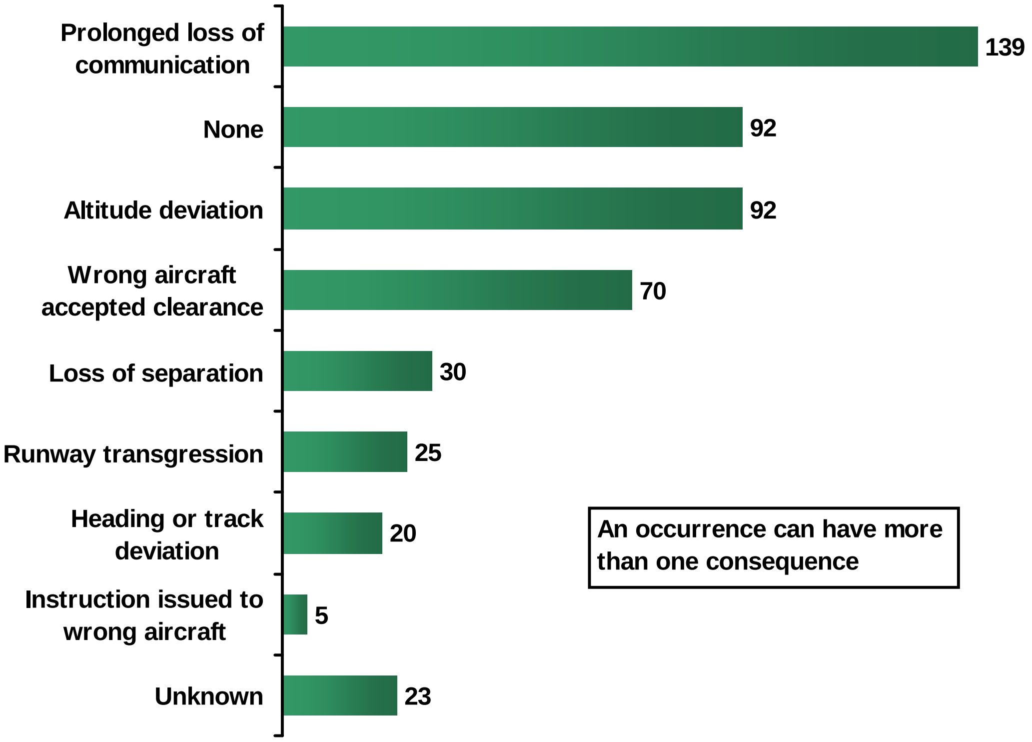

Figure 2: Consequences of air-ground communication problems.

3.1.4 Flight phase distribution

In Figure 3 the distribution of air-ground communication occurrences by flight phase is shown. The data suggest a positive relationship between the rate of communication-related occurrences and the distance between the aircraft and the destination/departure airport. This is inline with the findings of a study conducted by the University of Utah (Linter and Buckles, 1993). The reduction in pilot alertness to RTF instructions when flying further away from the destination/departure airport could be a factor in this relation.

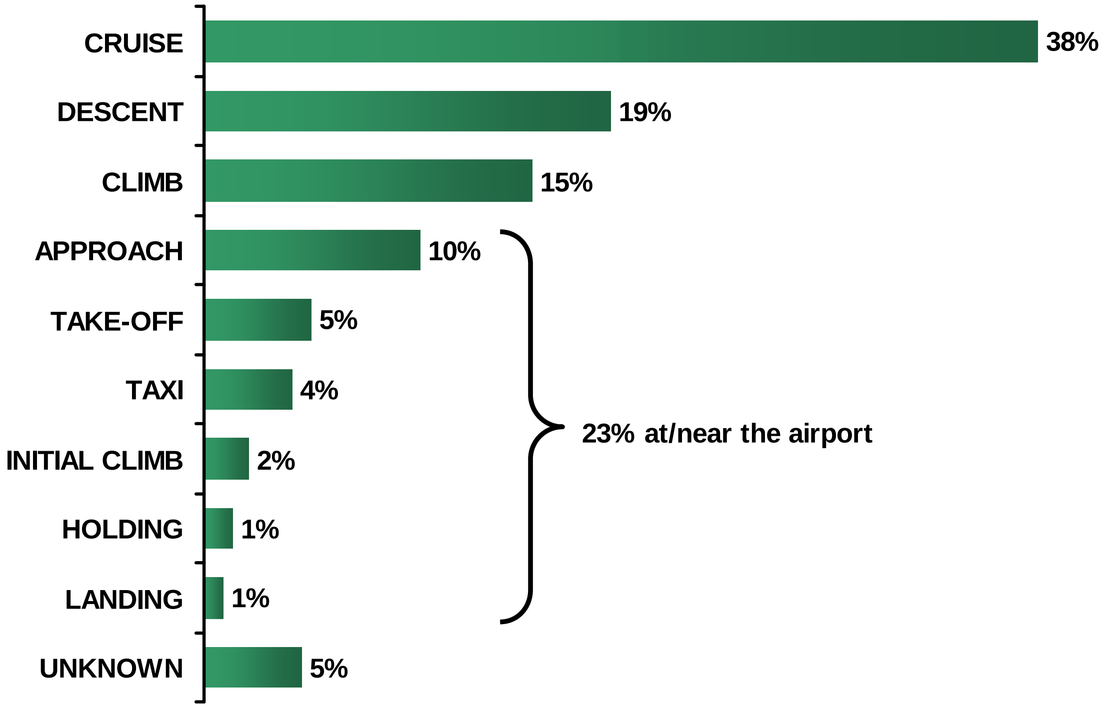

Figure 3: Distribution of air-ground communication occurrences by flight phase.

Studies conducted in the early 90s of day to day pilot-controller communications using voice tapes showed an extremely low error rate (Cardosi, 1994). It was shown that less than one percent of all voice communications examined resulted in a communication error. The controller or pilot corrected the majority (60-80%) of these errors. It was estimated that for the analysed period and fleet of operational aircraft, a total of 183 million instructions/clearances were given to the pilots[2]. With the total number occurrences of 444 this results in a rate of 2.4 communication related occurrences per million instructions/clearances given. It becomes clear from these numbers that only a very small fraction of all communications errors actually result into reportable occurrences. In Figure 4 the communication occurrence rate by operational phase is presented. The number of reported occurrences per flight phase are divided by the estimated number of instructions/clearances given in each of these phases. During the climb and descent phase more communication occurrences have occurred than during the cruise phase and the operations in the TMA and on the ground. This is somewhat surprising as it is often assumed that due to the larger number of instructions given to the pilots and the higher workload during the operations in the TMA or on the ground more occurrences would occur.

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[2] *Based on estimations made by line pilots for each flight segment and/or per flight hour for the cruise phase, combined with the aircraft utilisation data.*

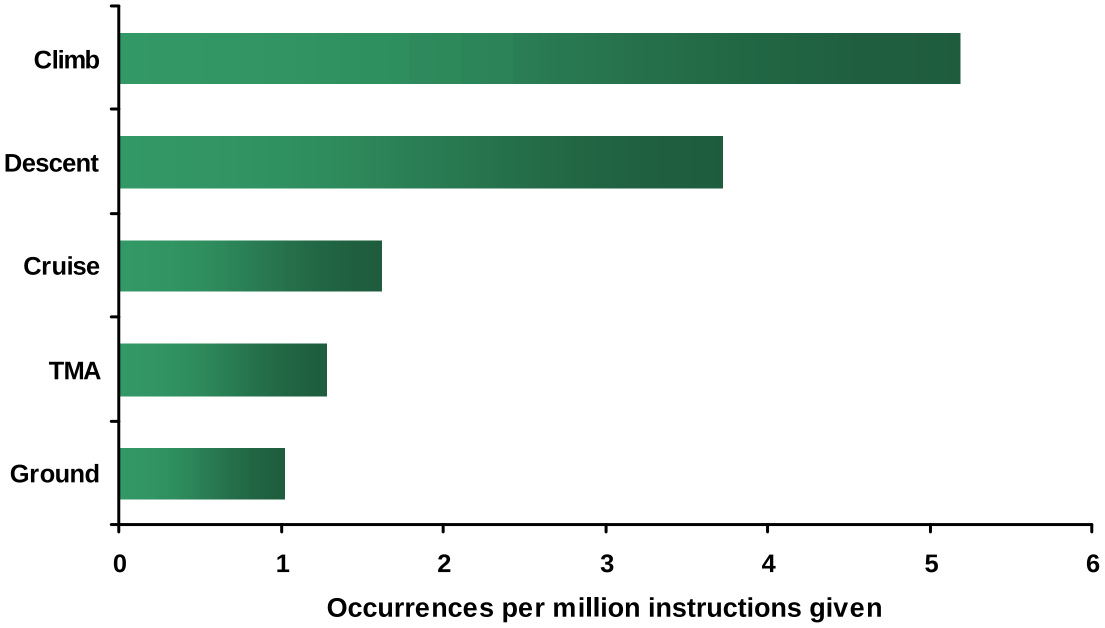

Figure 4: Frequency of communication occurrences by instructions given per flight phase.

3.1.5 Factors contributing to communication problems

In Figure 5 the frequency distribution of the factors contributing to air-ground communication problems is shown for the complete data sample. More than one factor could be assigned to a single occurrence. 'Similar call sign' and 'Sleeping VHF receivers' are the two most commonly cited factors in the complete set of analysed data. The factor 'Similar call sign' was cited in 20% and 'Sleeping VHF receivers' factor in 12% of the analysed air-ground communication occurrences. The number of occurrences in which a 'Sleeping VHF receivers' factor could be actually higher that noted here. Some of the occurrences in which a 'Radio equipment malfunction - air' was cited as factor could be caused by 'Sleeping VHF receivers'.

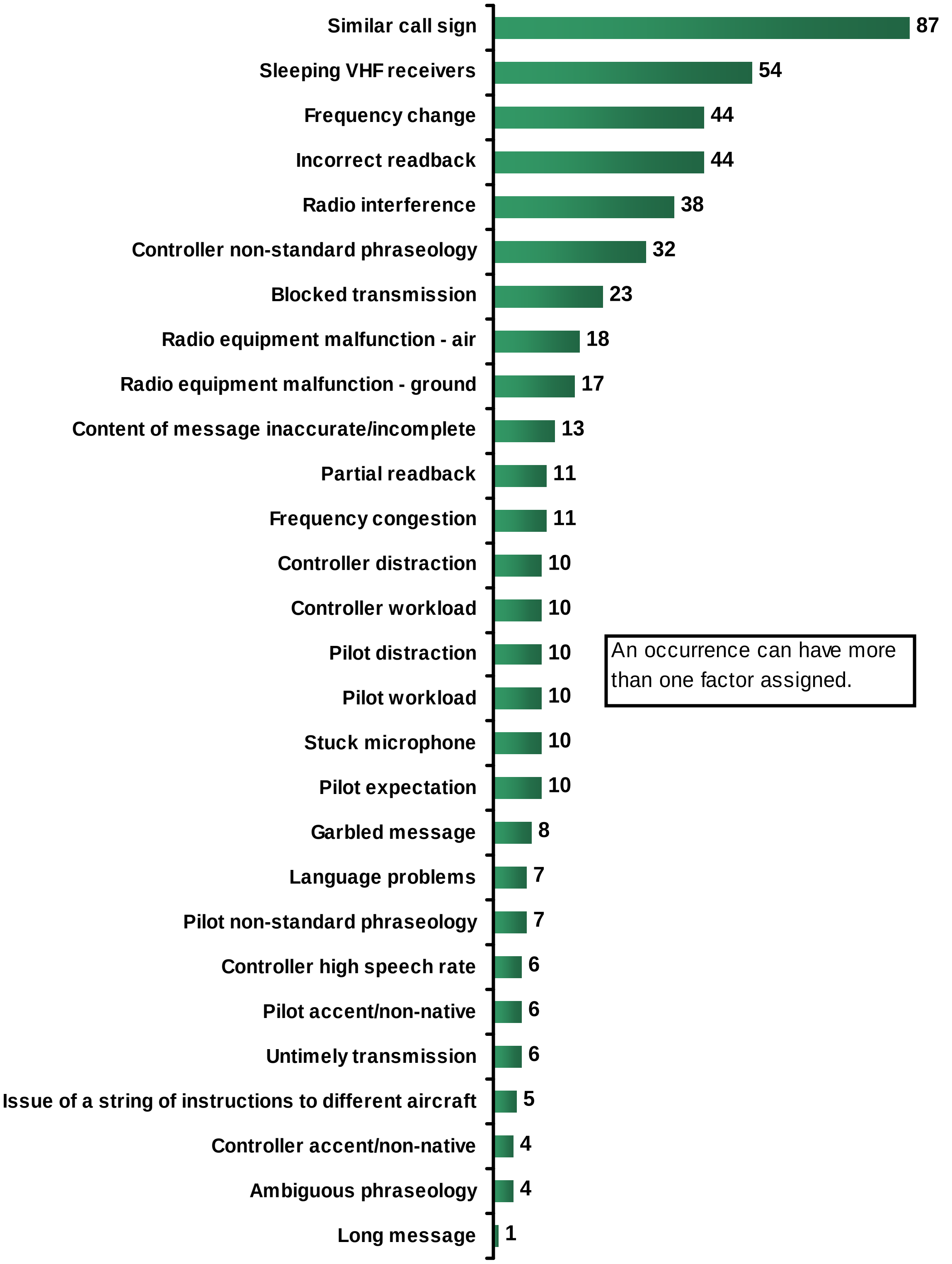

Figure 5: Factors contributing to air-ground communication problems.

3.2 Results by generic communication problem

In the next sub-sections each of the generic communication problems are analysed more in-depth.

3.2.1 Readback/hearback errors

The B737 was outbound from XX maintaining 6000ft. The Tu154 was outbound from YY and on initial call to the KK Sector was cleared to 5000ft. However, the pilot read back clearance as 6000ft, unnoticed by the controller. STCA alerted the controller to the situation and avoiding action was issued to both aircraft.

Readback/hearback errors were the most common generic communication problem found in this study. Figure 6 shows the distribution of readback/hearback errors by flight phase. The vast majority (65%) of all readback/hearback errors occurred during the climb and descent phase. Another large part (18%) took place during the cruise phase.

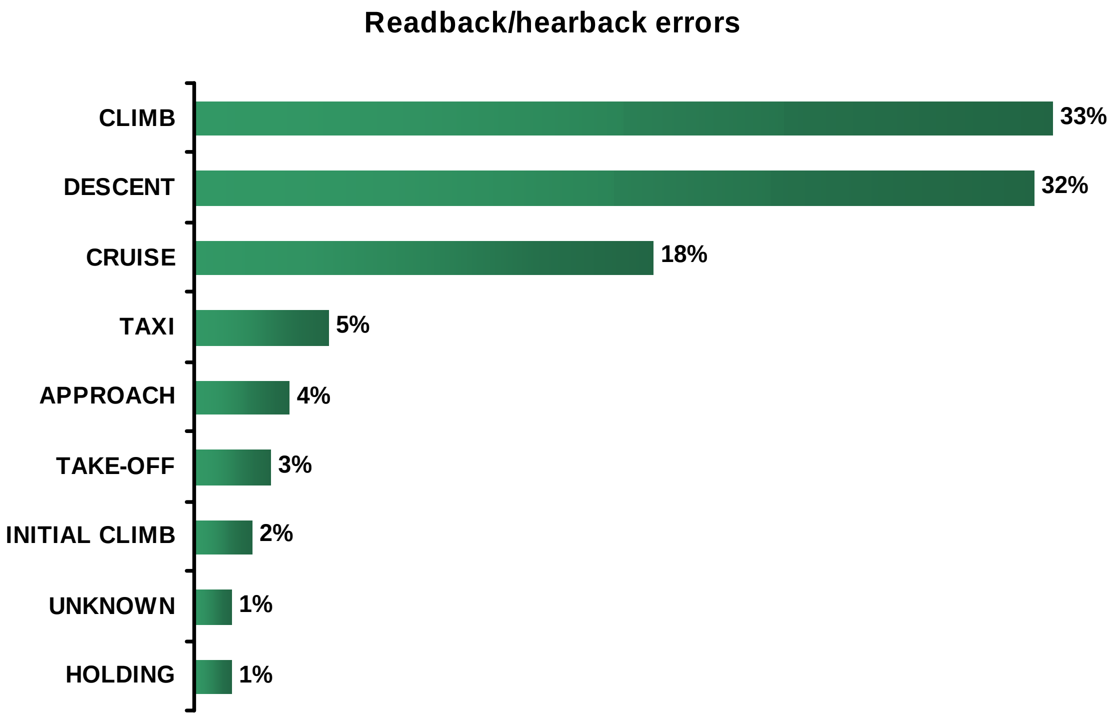

Figure 6: Distribution of readback/hearback errors by flight phase.

The factors that contributed to readback/hearback errors are shown in Figure 7. By far the most common cited factor was the 'similar call sign' and 'incorrect readback'. This last factor is of course somewhat trivial in the category of readback/hearback errors Also interesting are the use of non-standard phraseology by both the controllers and the pilots.

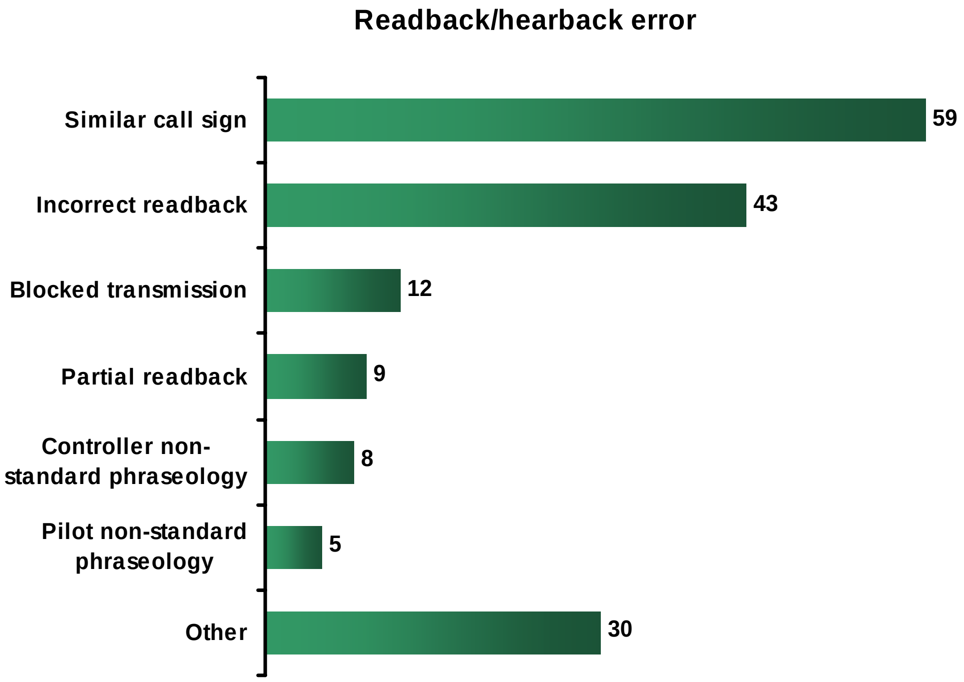

Figure 7: Factors in readback/hearback errors.

Figure 8 shows the consequences of readback/hearback errors. 'Altitude deviation' and 'Wrong aircraft accepted clearance' are the most common consequences of readback/hearback errors. In many cases the 'Wrong aircraft accepted clearance' consequence was followed by an 'Altitude deviation' (an occurrence can have more than one consequence assigned). In a typical case the controller issues a clearance to an aircraft which is then accepted by another aircraft with a similar call sign. Subsequently the controller fails to hear that the wrong aircraft accepted the clearance. In some cases the transmission was blocked or the pilot did not mention his call sign so that the controller could not determine that the wrong aircraft accepted his/her clearance.

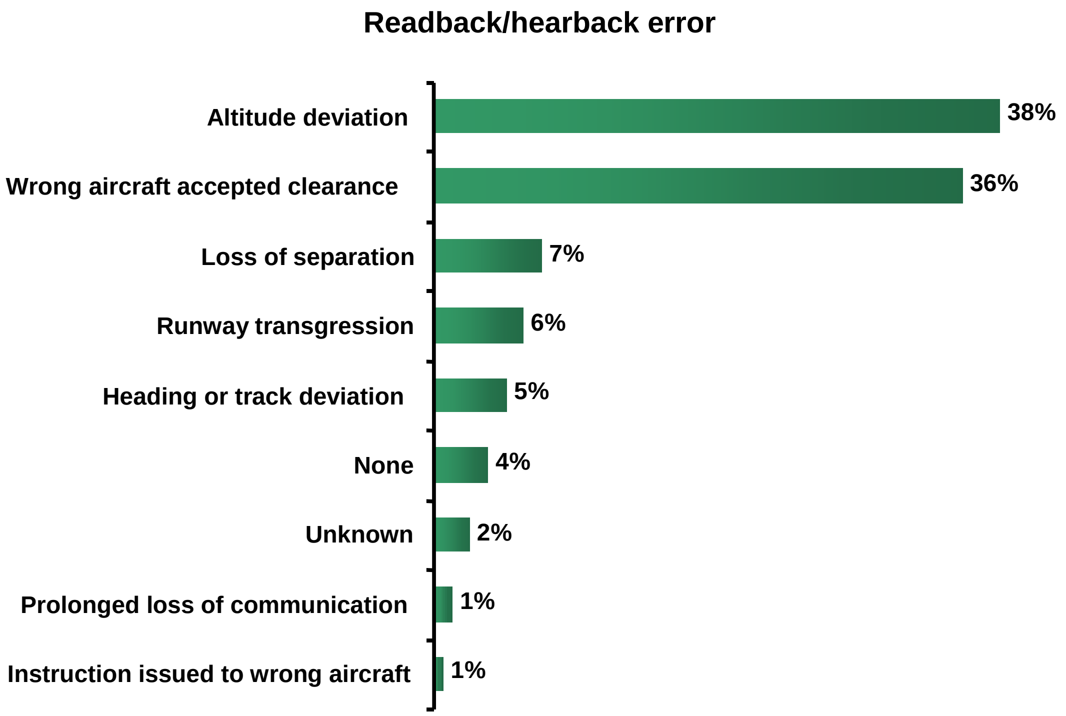

Figure 8: Consequence of a readback/hearback error.

While the aircraft is slowing down after landing in low visibility on runway 16R, the F/O reads back the *usual (!!)* clearance: "Cleared to cross 16L". Though the captain had missed the original call from the tower (because it interfered with the autopilot disconnect aural warning), he is satisfied with the situation as the readback is correct and ATC does not respond. However the original clearance had been: "Hold short of 16L." The F/O auto-responded, "cleared to cross". On the control tower this incorrect readback is drowned out by a simultaneous call on the loudspeaker from a towing operation. Both the tower controller and the supervisor miss it. The pilots of the aircraft that is rolling for takeoff on 16L missed the incorrect readback as well, because they are busy setting take-off thrust. The aircraft on 16L gets airborne and manages to climb over the tail of the intruder, missing it by less than 100 ft.

3.2.2 Loss of communication

ATC called MD11 to change from frequency 133.67 to 134.77, but there was no reply. Relays were tried on frequency 133.67 and 121.5, company telex and Shanwick were also asked to Selcal, but still there was no reply. MD11 eventually raised by another airliner on frequency 133.67 and transferred to frequency 134.77.

The 'Loss of communication' category is a rather general one. For instance, it covers those occurrences in which there was a clear loss of communication, which could not be assigned to any failure of communication equipment.

Figure 9 shows the distribution of 'Loss of communication' occurrences by flight phase. The vast majority (53%) of all 'Loss of communication' occurrences occurred during cruise phase.

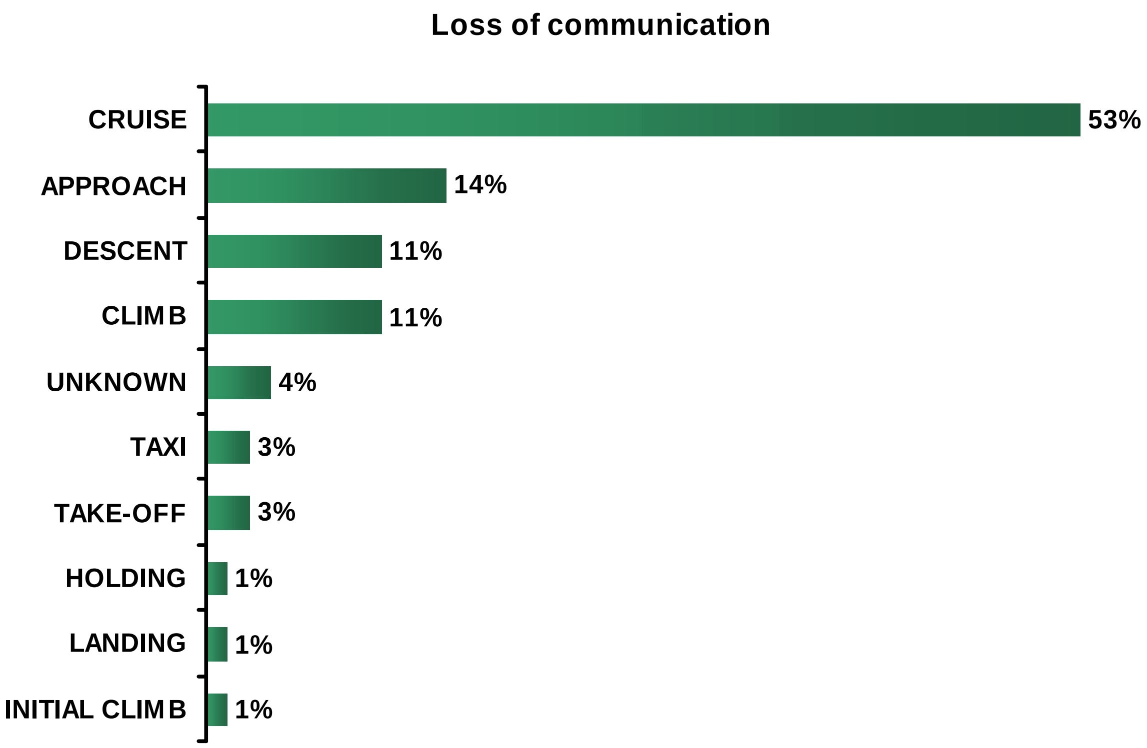

Figure 9: distribution of 'Loss of communication' occurrences by flight phase.

Figure 10 shows the factors that contributed to 'Loss of communication' occurrences. 'Radio interference' and 'Frequency change' are the most common factors found. Radio interference often comes from music stations on the ground. These occurrences are very annoying to pilots, which can make communication with controllers difficult or even impossible. ATC receivers are usually not affected by this kind of interference, since their antennae are close to the ground. The 'Frequency change' factor occurs when the pilot forgets to change the frequency or uses a wrong frequency. Normally this would not necessarily result into a problem unless the old frequency (unchanged) gets out of range.

A B777 was transferred from frequency 129.22 to XX Sector frequency 134.77 and readback appeared to be correct. Approximately 5mins later XX controller telephoned to ask for the B777 to be transferred and informed it had been. Subsequently the B777 called frequency 129.22 to advise of having gone to the wrong frequency. Total absence from frequency 10-15mins.

The consequences of 'Loss of communication' occurrences are shown in Figure 11. In many cases (43%) there were no serious consequences. However in 40% of the cases there was a prolonged loss of communication. Prolonged loss of communication can be particular hazardous when the aircraft is flying in a busy airspace, into another sector or into a restricted airspace.

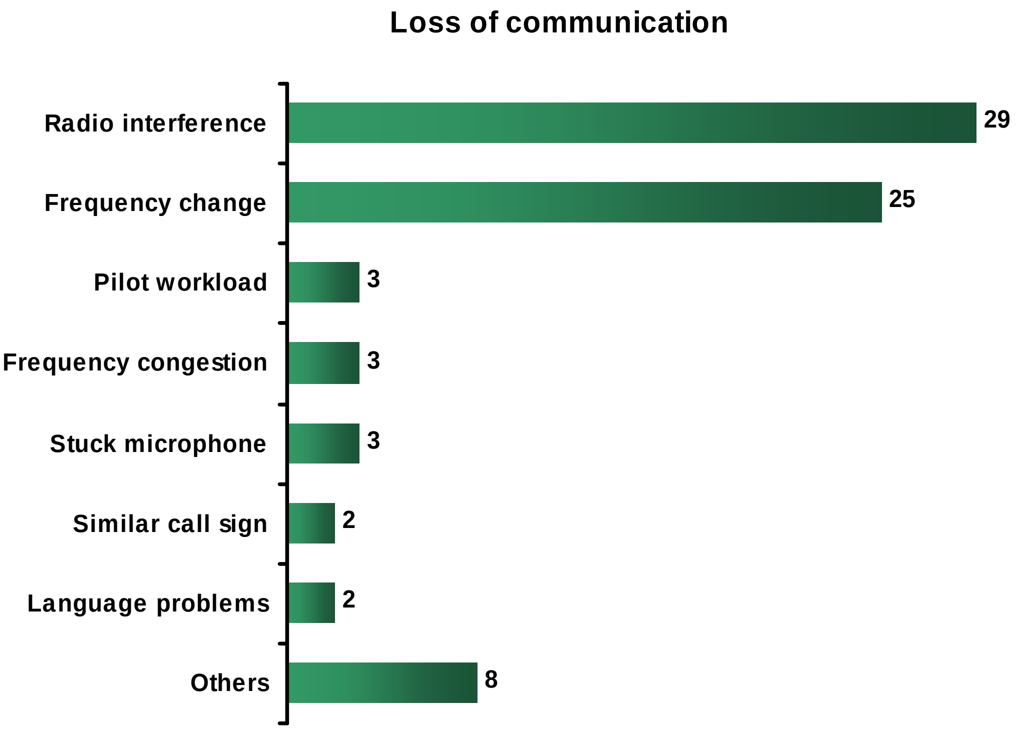

Figure 10: Factors in 'Loss of communication' occurrences.

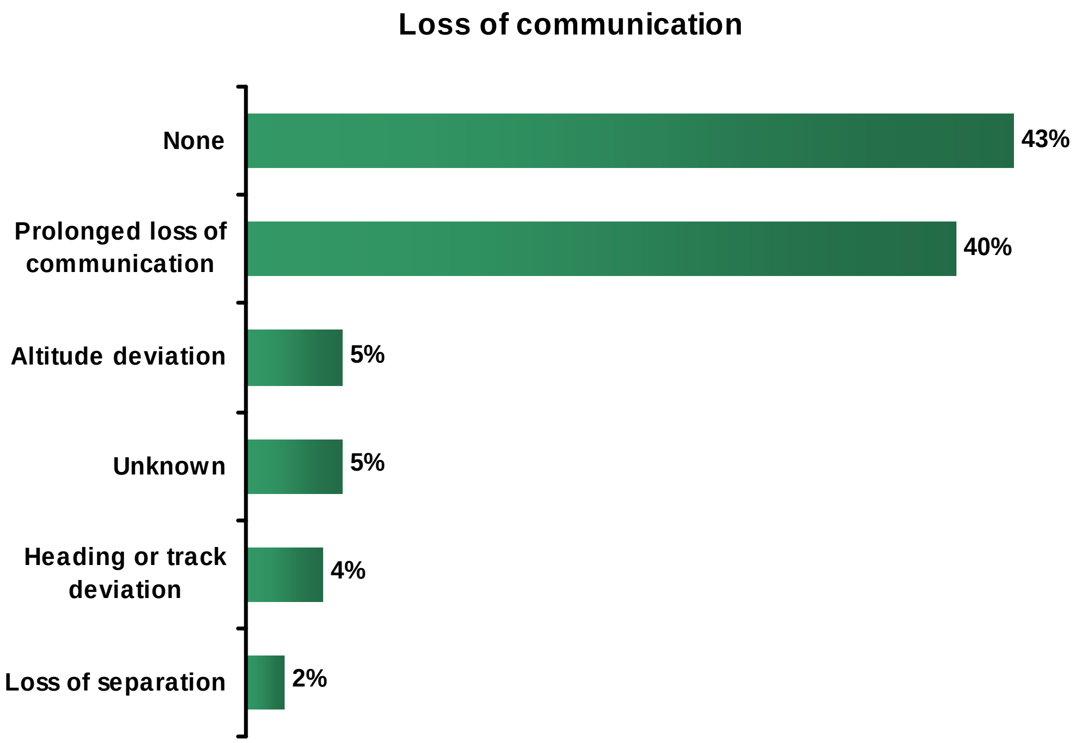

Figure 11: Consequences of 'Loss of communication' occurrences.

3.2.3 Communication Equipment problem

ATC attempted to call the aircraft a number of times, but received no reply. Eventually, the crew responded and two way communication was re-established. The crew reported they noted the RT was quiet, consequently they momentarily pressed the TX switch. The crew believed the fault to be a 'sleeping VHF receiver'.

'Communication Equipment problem' occurrences cover those in which it is clear that a problem (e.g. failure) with some kind of communication equipment in the aircraft or on the ground has occurred. In many cases the actual reasons for the problems with the equipment were not known or reported.

In Figure 12 the distribution of 'Communication Equipment problem' occurrences by flight phase is shown. Clearly shown is that most of the 'Communication Equipment problem' occurrences took place during the cruise phase.

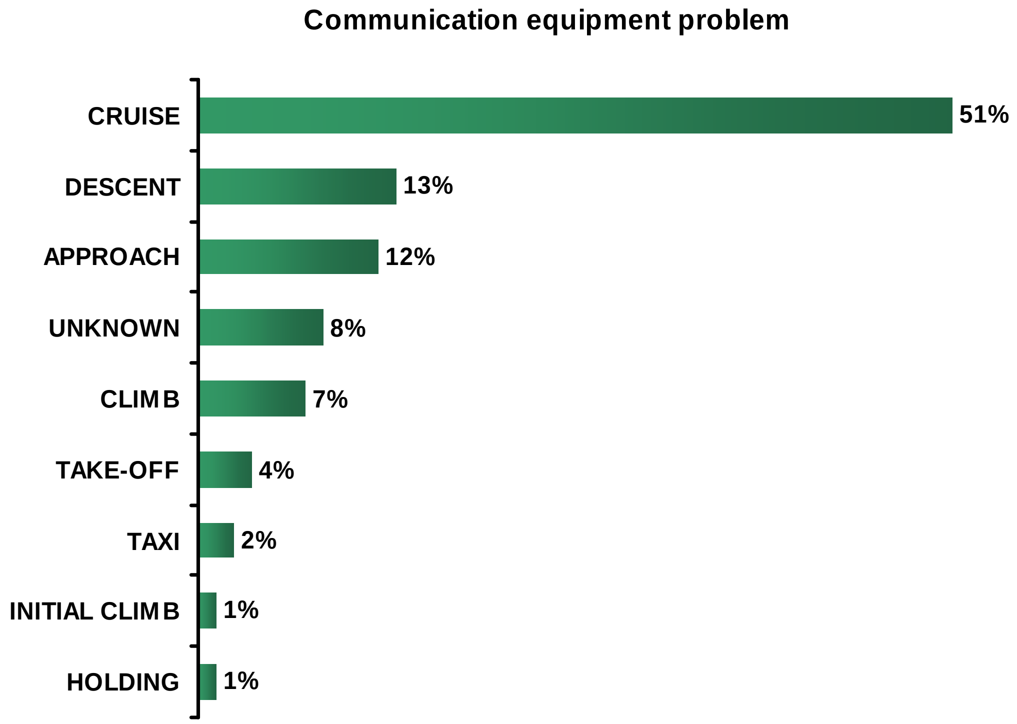

Figure 12: Distribution of 'Communication Equipment problem' occurrences by flight phase.

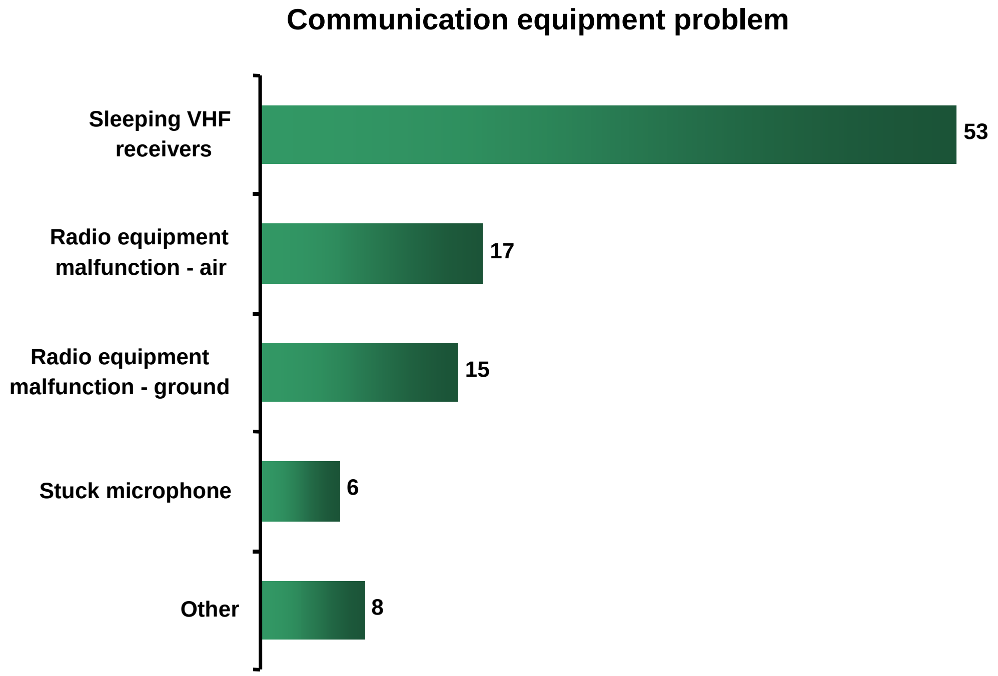

Figure 13: Factors contributing to 'Communication Equipment problem' occurrences.

Figure 13 shows the distribution of factors that contributed to 'Communication Equipment problem' occurrences. 'Sleeping VHF receiver' is the most common factor cited. It is possible that some of the 'Radio equipment malfunction - air' could actually be a 'Sleeping VHF receiver'. Airlines, radio & aircraft manufacturers, air traffic service providers, and regulators are studying the problem of sleeping VHF receivers. So far these studies have found no correlations between the problem of sleeping VHF receivers and for instance aircraft type, radio type, use of headsets, airline, and sectors. Also the data sample examined during the present study does not show any correlations or trends. For instance Figure 14 shows the distribution sleeping VHF receivers occurrences by flight phase including the exposure as percentage of flight time for each phase. The distribution of sleeping VHF receiver occurrences is inline with the time spent in each phase. Therefore there are no flight phases in which there are relatively more 'Sleeping VHF receiver' occurrences.

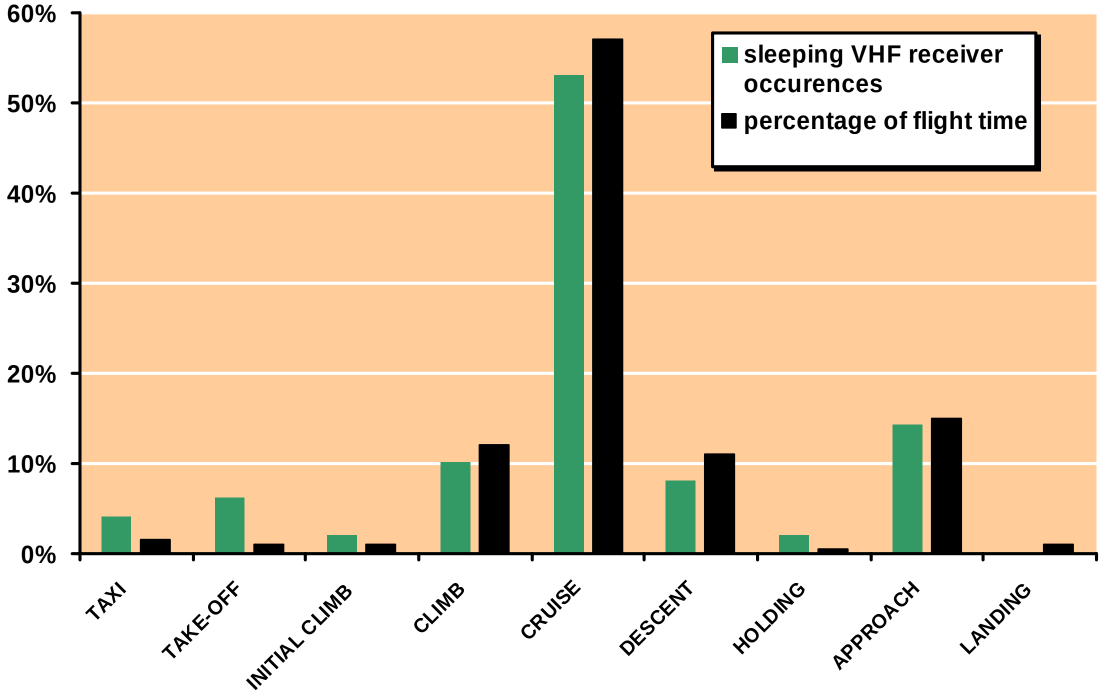

Figure 14: Distribution of occurrences with 'sleeping VHF receivers' cited by flight phase.

The distribution of the consequence of 'Communication Equipment problem' occurrences is shown in Figure 15. Prolonged loss off communication is by far the most common consequence.

After the '9/11' events[3], a 'silent' aircraft has become an unacceptable security risk. Indeed in some of the analysed occurrences, fighters were sent out to intercept the 'silent' aircraft.

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[3] *Refers to the acts of terrorism with four passenger aircraft in the United States dated 11 September 2001.*

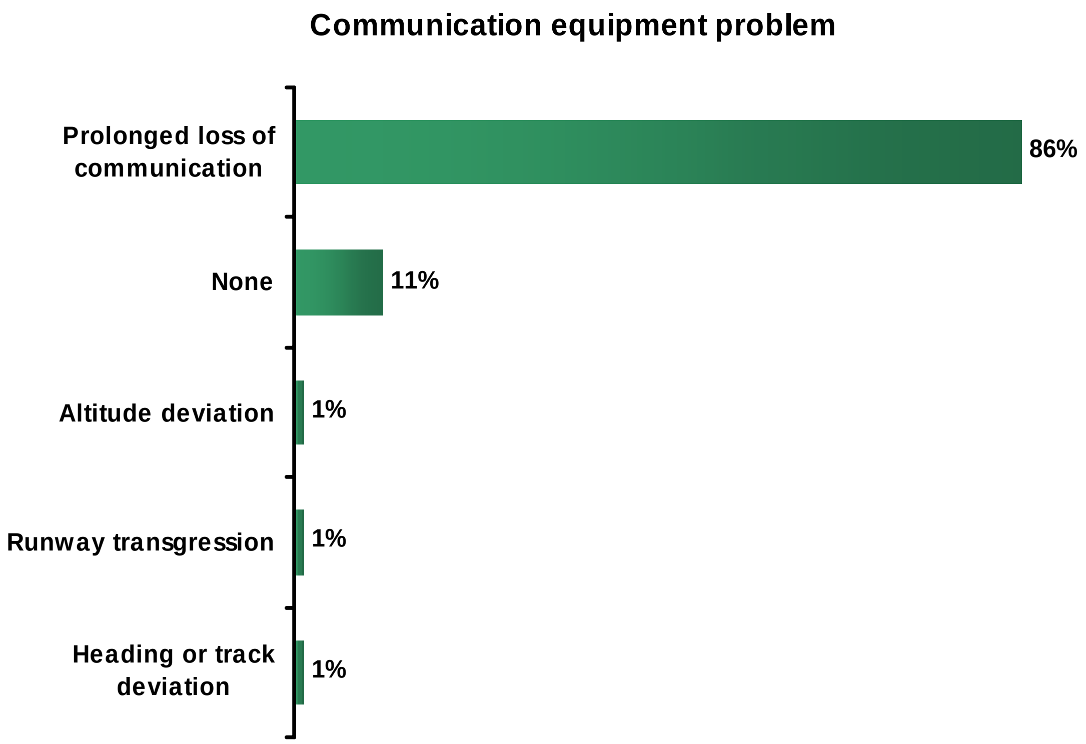

Figure 15: Consequences of 'Communication Equipment problem' occurrences.

3.2.4 Hearback error

> **The aircraft was cleared to descend to FL150, but acknowledged descent to FL180. This was challenged by the controller who then inadvertently cleared aircraft to FL130. This incorrect flight level was read back by the pilot and was not corrected by the controller.**

In a hearback error the controller fails to notice his or her own error in the pilot's correct readback or fails to correct critical erroneous information in a pilot's statement of intent. Only 20 occurrences (5% of total) were coded as hearback errors. Care must be taken to draw any conclusions from such a small sample. Distributions of flight phase, factors and consequences have therefore only limited value. The factors that were cited the most in the 20 occurrences were controller distraction and controller workload. These factors are not surprising as they can increase the probability of incorrect instructions made by the controller and of a reduction in the perceptiveness of the controller of his or her own errors.

3.2.5 No readback

In some cases a 'ROGER' or 'WILCO' is given by the pilot whereas a full readback would be required. Such cases would also be considered as 'No readback' occurrences. Only 14 occurrences (3% of total) were code as 'No readback'. Any conclusions from such a small sample should be interpreted with great care. Distributions of flight phase, factors and consequences have only limited value. The factors that were cited the most in the 14 occurrences were pilot distraction and pilot expectation. The pilot distraction factor can easily be linked to giving no readback. However, the pilot expectation factor cannot be easily linked to 'no readbacks' occurrences.

3.2.6 Other

The generic category 'other' contains those occurrences, which did not fit into one of the 5 other categories. In some cases there was insufficient information to make a fair judgement about which generic communication problem would apply to the occurrence.

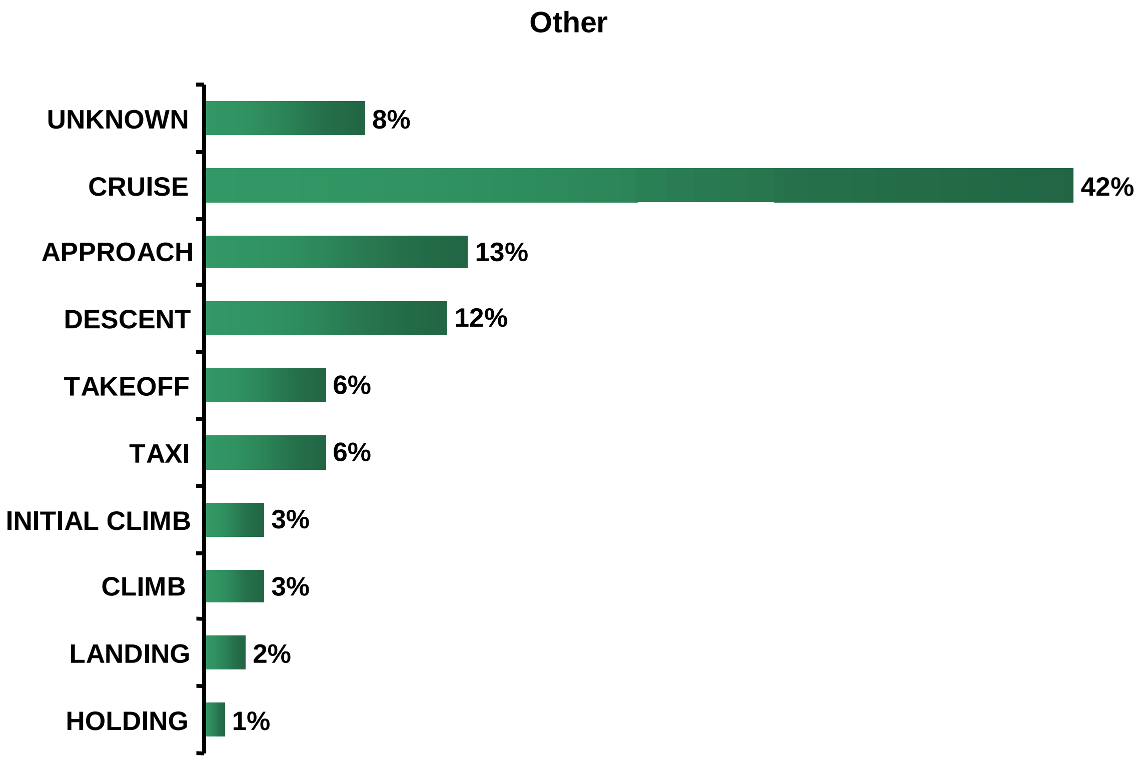

Figure 16: Distribution of 'other' occurrences by flight phase.

In Figure 16 the distribution by flight phase is shown. The vast majority of the 'other' occurrences took place during the cruise phase of flight. A wide variety of factors contributed to the category 'other' occurrences, which is not a surprise considering the category 'other' (see Figure 17). 'Similar call sign', 'Controller non-standard phraseology', and 'Frequency change' were amongst the most common cited factors. An overview of the consequences is shown in Figure 18.

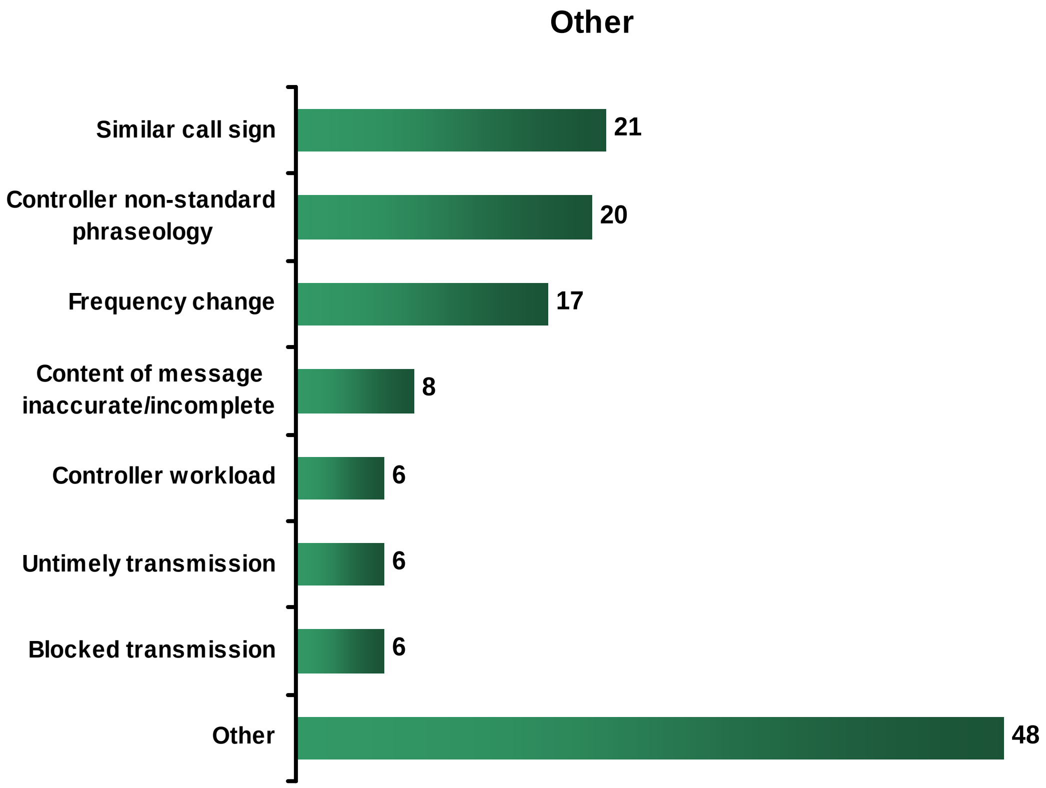

Figure 17: Factors contributing to 'other' occurrences.

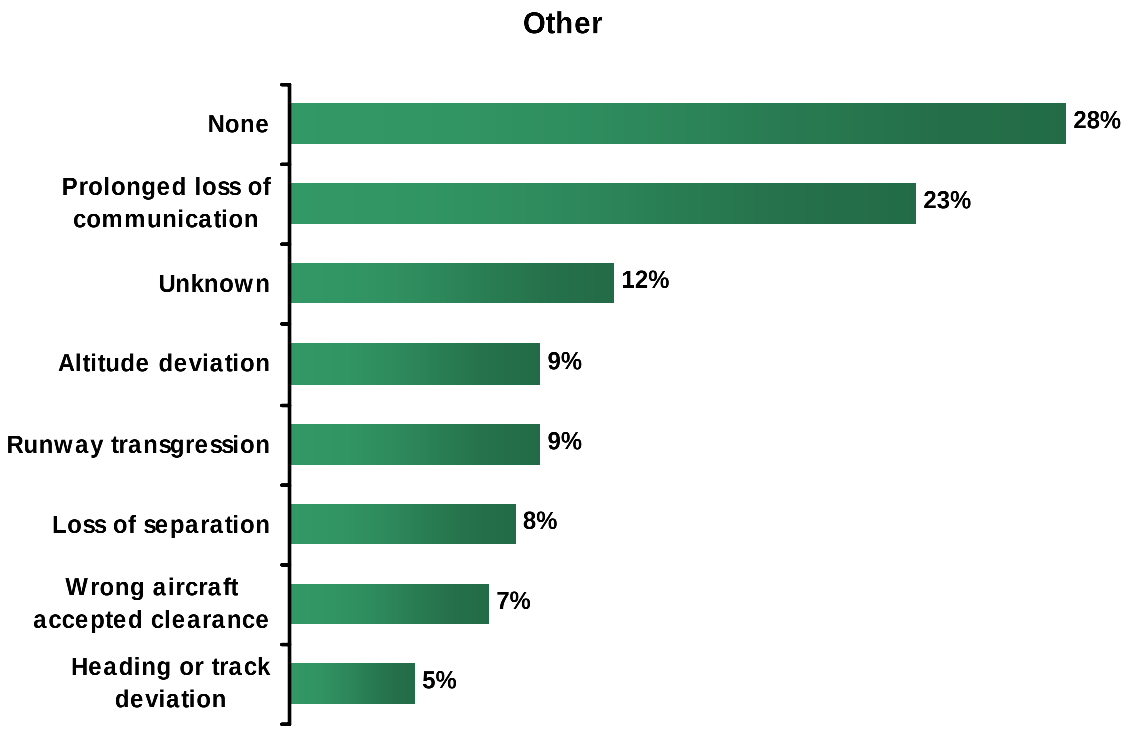

Figure 18: Consequences of 'other' occurrences.

3.3 Discussion of the results

Table 3 lists the consequences of communication errors by the most important factors that were identified as contributing to them.

Table 3: Overview of consequences by the most important factors.

Consequence	*Most important contributing factor(s)*
Prolonged loss of communication	'Sleeping VHF receivers'; 'Frequency change'
Altitude deviation	'Incorrect readback' ; 'similar call sign'; 'Controller non-standard phraseology'
Wrong aircraft accepted clearance	'Similar call sign'; 'Blocked transmission'
Loss of separation	'Similar call sign'
Runway transgression	'Controller non-standard phraseology'
Heading or track deviation	Not enough data to make a rating
Instruction issued to wrong aircraft	Not enough data to make a rating

Prolonged loss of communication

'Prolonged loss of communication' is always a hazardous situation and even more after the '9/11' events. 'Sleeping VHF receivers' and 'Frequency change' are the most important factors which contributed to 'Prolonged loss of communication'. 'Sleeping VHF receivers' has become a serious problem in which the VHF transceiver appears to go to 'sleep'. The frequency becomes silent until the microphone is keyed and a transmission is made. Normal reception is usually restored after this action. The problem of 'Sleeping VHF receivers' is being studied by several aviation organisations such as airlines, air traffic control organisations, and radio manufacturers etc. (Delhaise and Perry 2003). When a pilot notices that the radio has gone unnaturally quiet in a busy sector, a receiver might have gone to 'sleep'. The pilot should then recycle the Push-To-Talk Switch or conduct a radio check. Another important cause of 'Prolonged loss of communication' might be that the pilot has used or received the wrong frequency. Again the pilot should also check this when the pilot notices that the radio has gone unnaturally quiet in a busy sector. During the cruise phase however this might not be practical, as it is not unlikely to have longer periods of no radio traffic during this phase.

Altitude deviation

'Altitude deviation' is a hazardous consequence in busy sectors. Three important contributing factors have been identified in this study; 'Incorrect readback', 'similar call sign' and 'Controller non-standard phraseology'. The 'Incorrect readback' factor is directly linked with the readback/hearback errors. Observational studies conducted in the US have shown that readback errors are very rare (less than one percent of all readbacks made contains an error) and that most of these errors (60-80%) are corrected by the controller (Cardosi, Brett and Han 1996). Controllers should always actively listen to the readback and pilots should be aware of any expectation that they might have regarding a clearance/instruction. The 'similar call sign' problem is well known and has been studied for many years now (e.g. Monan 1983; Cardosi, Falzarano and Han 1999; CAA UK 2000). Whenever there are similar call signs on the frequency the controllers should inform the pilots about this. The pilots should always use their full call signs in their readbacks. The controller should be aware that a transmission could be blocked when two or more aircraft are responding to the same clearance. Typically the controller would hear a partial or garbled readback. The use of non-standard phraseology by a controller can result in confusion with the pilots. Non-standard phraseology is typically used when the workload is high and the frequency congested. The controllers then tend to condense the message to reduce the time that they are transmitting. Controllers (and also pilots) should always use standard phraseology when communicating to pilots. Pilots should not accept instructions, which are not clear due to the use of non-standard phraseology. Frequency congestion often leads to controllers issuing message – BREAK – message to other aircraft, i.e. readback is not allowed. Also, controllers tend to pack more instructions into one message (more than two instructions in one message can really be too much for pilots to store in their short-term memory). Pilots should read back instructions in the same order as the controller issued them. This improves the recognition of incorrect readbacks by the controller.

Wrong aircraft accepted clearance

'Wrong aircraft accepted clearance' is a consequence which is clearly associated with 'Similar call sign' and 'Blocked transmission' factors. The background of the similar call sign problem is already discussed in the previous paragraph. The 'Blocked transmission' factor is closely connected to the 'Similar call sign' factor. A pilot who acknowledges an instruction intended for another aircraft might very well block the readback by the aircraft for which the instruction was originally intended. These multiple simultaneous transmissions are not always detected by the controller or the pilots involved. Although not an official rule, any pilot hearing that two transmissions block each other calls out “Blocked”, after which all transmitting parties try once more to pass their message. A busy frequency can also lead to blocked transmissions. A 'stuck mike' can also lead to blocking a transmission. The fitting of so-called anti-blocking devices has been recommended by several agencies responsible for accident & incident investigations (O'Neil 1999). For instance Britannia Airways has such a system installed on their aircraft.

Loss of separation

Again the "similar call sign' factor is the most important one in 'loss of separation' outcomes. This factor is discussed under 'Altitude deviation'.

Runway transgression

The consequence 'Runway transgression' can lead to runway incursions. The use of non-standard phraseology by controllers was found to be the most important factor regarding 'Runway transgression'. This factor is discussed under 'Altitude deviation'.

3.4 Correlation of present study results with accidents

The present study was limited to the analysis of occurrences of less serious incidents as discussed in section 2.1. To have some feeling how the results of the present study correlates to accidents a 'quick and dirty' analysis was made of air-ground communication related accidents. For this purposes the NLR Air Safety Database was queried for accidents in which air-ground communication problems were a factor in the period 1980-2002. Some caution must be taken regarding the outcome of such a query as the timeframe differs significantly from the period covered by the data sample analysed in the present study. The number of air-ground communication related accidents encompass a similar low share in the total number of accidents as found in the present study for less serious incidents. The accident sample showed similar problems as identify in the present study. Amongst the important factors identified in the accident data sample are the use of non-standard phraseology by controllers and pilots, incorrect readbacks, hearback errors, call sign confusion, malfunctioning of radio communication equipment, and language problems. Examples of the fairly new problem of sleeping VHF receivers were not identified in the accident sample.

Chapter 4 Generic causal model

4.1 SHELL model

In Figure 19 a model representation of a flawless communication between a controller and pilot is shown. The controller issues an unambiguous instruction the pilot (step 1), the pilot reads back this instruction correctly (step 2), and finally the pilot executes the instructions as intended by the controller (step 3). The focus of the present study is on the first two steps of the communication process outlined in Figure 19. The third step is the result of the communication. Adequate communication requires that the recipient receives, understands and can act on the information gained. Complete redundancy is not incorporated into radio communication. Therefore particular care is required to ensure that the recipient receives and fully understands a radio communication. There are numerous factors that will influence the communication process between a controller and a pilot. These factors can be analysed using the well-known SHELL model (ICAO, 1998). This model provides a conceptual framework to help to understand human factors. As controller-pilot communication is dominated by human factor elements, the SHELL is a useful tool to understand how and why communication errors take place. The SHELL model describes the interaction between human beings and the other elements.

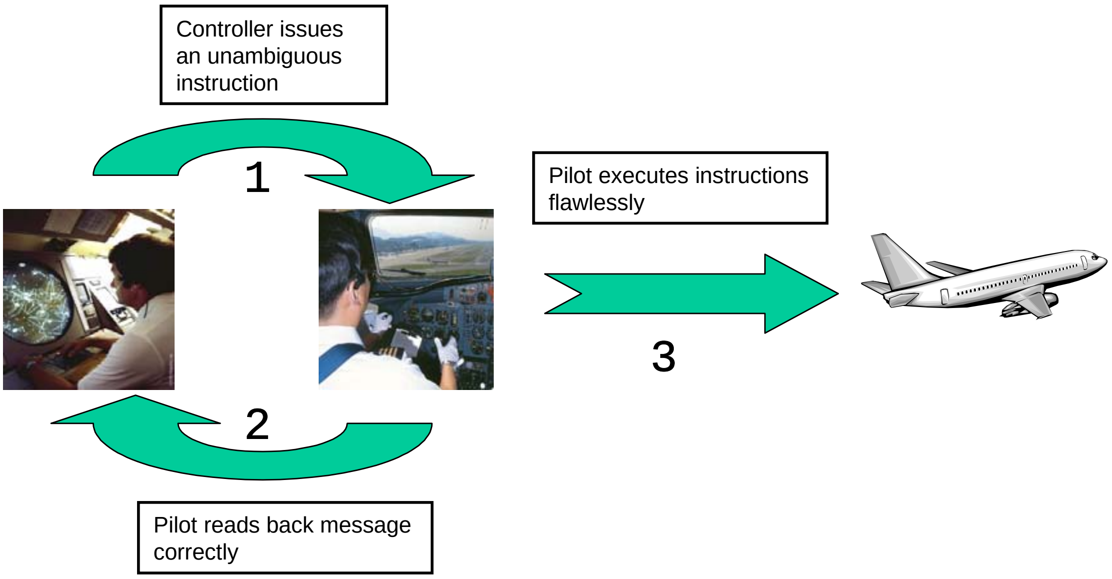

Figure 19: Model of controller-pilot communication.

In the SHELL model the human factor elements are broken down into four conceptual categories:

- **S**oftware
- **H**ardware
- **E**nvironment
- **L**iveware

The SHELL ‘building block’ model is shown in Figure 20, in which the letters in the acronym SHELL represent Software, Hardware, Environment and Liveware (twice). In the centre of the model is the human element, called Liveware (L). The human factor elements under the Liveware category include those relating to the psychological state and the physical well being of for instance the pilot or controller. The remaining components in the SHELL model must be matched to this central component. There are four interfaces in the SHELL model:

- Liveware-Hardware L-H (*Human-Machine*)
- Liveware-Software L-S (*Human-System*)
- Liveware-Environment L-E (*Human-Environment*)
- Liveware-Liveware L-L (*Human-Human*)

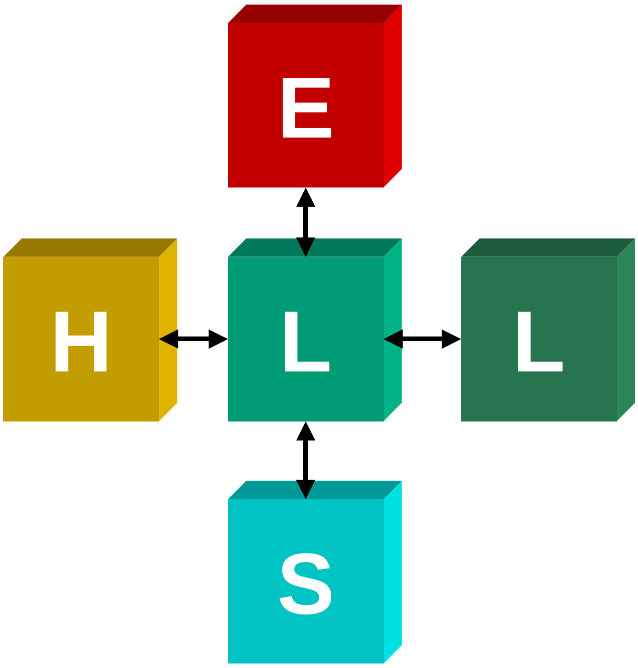

Figure 20: SHELL model.

The **Liveware-Hardware** interface is concerned with ergonomics, such as displays switches and controls. The L-H interface addresses the mismatch in the human-machine design relationship and the source of confusion and error caused by poorly designed equipment. The **Liveware-Software** interface encompasses the non-physical aspects of the system, such as procedures, operating manuals, and checklists. The **Liveware-Environment** interface is associated with environment factors (such as noise, heat, lighting and vibration). In addition, the L-E interface also can encompass the effects of the political, social and economic environments and their impact on the operation. The **Liveware-Liveware** interface is between people. Shortcomings at this interface reduce operational efficiency and cause misunderstandings and errors. It can concern the interface between people within a single crew (e.g. interface between captain and first officer) but also between different crews (e.g. between flight crew and controller). In the SHELL model the match or mismatch of an interface is just as important as the characteristics of the blocks themselves. A mismatch of an interface can be a source of human 'error'.

4.2 Results in terms of the SHELL model

In the following section, the occurrences are analysed according to the SHELL model. In contrast to section 3 of this report, this does not involve an analysis of the frequency of various factors. The SHELL model provides a simple framework within which to review and discuss some of the common features of the air-ground communication problems between controller and pilots.

For the problem of controller-pilot communication the SHELL model is extended as shown in Figure 21. The interface L-L is between the controller and the pilot responsible for radio communication in an aircraft. The controller and the pilot have interfaces with their own environment, hardware, and software blocks. For instance, a pilot cannot have an interface with the controller's hardware.

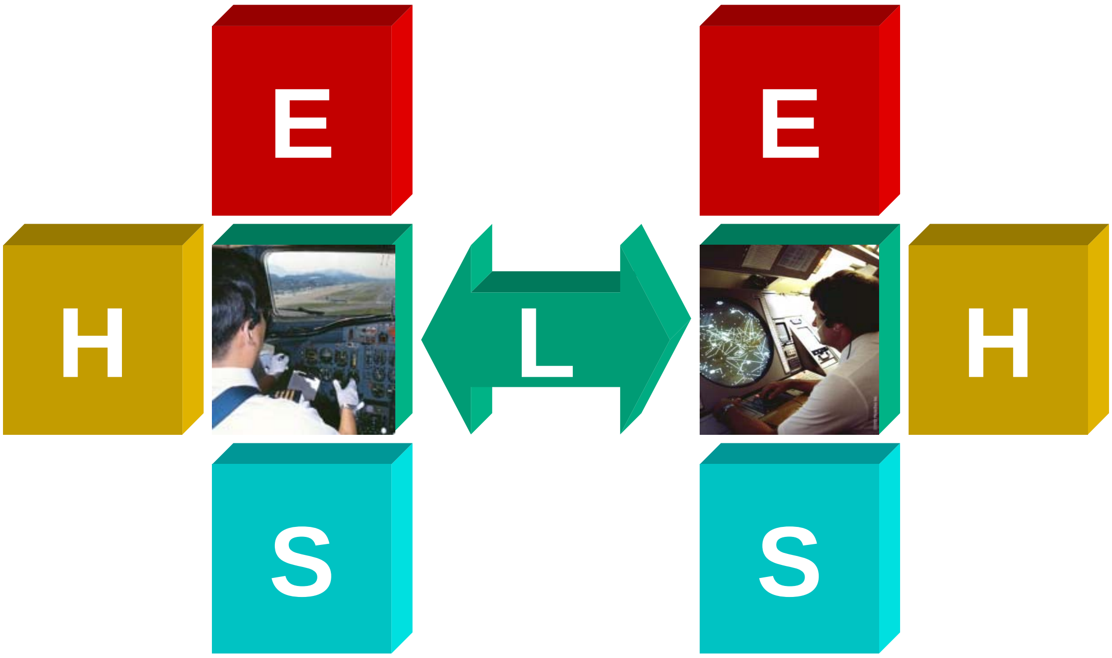

Figure 21: SHELL model of controller-pilot communication.

For the present analysis use was made of the SHELL checklist given by ICAO (ICAO, 1993) to identify the sources for a mismatch in an interface. Besides the interfaces, the psychological state and the physical well being of the liveware component (the individual) is also importent.

Liveware (the individual)[4]

Controller

High workload was identified as a factor relating to a number of occurrences. The controller's workload typically goes up when handling a lot of aircraft in a short period of time. Also frequency congestion can increase the workload.

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[4] *The italic printed words refer to factors commonly used in the SHELL taxonomy.*

Pilot

Also for the pilot *high workload* was identified as a factor relating to a number of occurrences. The pilot's workload is high during particularly phases of the flight (e.g. preparation for landing). Pilot's *lack of knowledge* of the 'sleeping VHF receiver' problem seems to have a contributed to a number of occurrences. Pilots should have been more *conscious* of the fact that a silent radio could be caused by a sleeping VHF receiver. A spot check under a number of airline pilots indicated that not every pilot is aware of the sleeping VHF problem. In some occurrences pilot *expectation* was cited. In such cases the pilot perceives that he/she heard what he/she expected to hear.

Liveware-Liveware interface

Controller & Pilot

This interface is probably the most important one in air-ground communication as it concerns the interface between the controller and the pilot. Numerous interface problems were identified between controllers and pilots that were, not surprisingly, all related to oral communication issues. Important factors are *misinterpretation* (call sign confusion by a pilot, wrong frequency selected), *radio* (noise) *interference*, use of *non-standard phraseology* (mainly by controllers), *incorrect readback*, and *inaccurate/incomplete message content*. Less frequent reported, but still cited in a number of occurrences, are *language barriers problems*, controller/pilot *accent* and controller *high speech rate*.

Liveware-software interface

Interface problems between controllers or pilots and the supporting systems (such as manuals, checklist, and standard operating procedures) could not be identified in the analysed data.

Liveware-hardware interface

Interface problems (e.g. problems with switches, controls, displays and workspace) between a pilot or a controller and their communication equipment (hardware) could not be identified in the analysed occurrences. There are no indications yet available that the cases in which the VHF transceiver appeared to go to 'sleep' are related to a poor hardware interface.

Liveware-Environment interface

Controller

Noise interference (e.g. due phones ringing) has distracted the controller in a number of occurrences.

Pilot

Assignment of flight numbers is typically a function of an airline's marketing department. The use of similar call signs within a single operator is (partly) driven by reasons of efficiency and economics. This can be considered as a mismatch between the individual (pilot) and external environment (in this *case economic constraints*). For instance an operator can use a call sign with four digits with the first two digits indicating to which region or country a flight goes. This is easier for the planning department of an airline and also for frequent travellers.

Chapter 5 Potential prevention strategies

Prevention strategies should be focused on solving the mismatches in the interfaces of the SHELL model as identified in the previous section and on factors relating to the individuals (controllers and pilots). Table 4 gives an overview of problems related to air-ground communication between controllers and pilots as identified in the present study and the potential prevention strategies. Prevention strategies could not be provided for all problems identified in this study.

The overview of communication problems given in Table 4 is arranged alphabetically and does not suggest any prioritisation of particular problems. A prioritisation should be based on the associated risk (combination of frequency and consequence). This approach would put the problems of similar call sign and sleeping VHF receivers on top of the list of important problems to be solved in air-ground communication.

> **Communication is not a one sided process and it is essential that pilots and controllers understand the need for clear and unambiguous communication so that normal situations are not turned into incidents and incidents do not become something far more worse.**
>
> ***Source: Dr. Sue Baker in***
> ***Focus on Commercial Aviation Safety, summer 1996***

Table 4: List of problems and prevention strategies.

Problem	***Prevention strategy (potential mitigating factor(s) / action(s) required / recommendations)***
Blocked transmission	Whenever there is a busy frequency or there are aircraft with similar call sign on the same frequency both pilots and controllers should be aware of blocked transmissions. Stuck microphone can lead to blocked transmission and can be prevented by the use of anti-blocking devices.
Expectation	Pilots should be aware of any expectation that they might have regarding a clearance/instruction.
Frequency change	Pilots should check the selected frequency whenever the radio has gone unnaturally quiet in a busy sector.
High speech rate (controller)	Controllers should be urged always to speak slowly when communicating with pilots.
High workload	During situations of high workload both the controllers and pilots should be urged continue to use standard phraseology and should not clip any message to save time at any time.
Inaccurate/incomplete message content	Pilots should never readback an ATC instruction if in doubt about the accuracy or completeness.
Incorrect readback	Controller should be urged not to use readback time to execute other tasks. This will help in detecting readback errors.
Language barriers	Particular caution should be exercised when language difficulties exist between the controller and the pilot. Communications between controllers and pilots should always be conducted in a mutually agreed language.
Non-standard phraseology	Controllers and pilots should be urged always to use standard RTF phraseology.
Similar Call sign	Airline operators should following the recommendations given in ICAO ANNEX 10 and ICAO Doc 8585 for allocating call signs as much as practically is possible. When the use of similar call signs is inevitable the following should be considered in mitigating problems with similar call signs: Pilots should use full calls signs (no clipping) in their readbacks; When there are similar call signs on the frequency, controllers should inform the pilots about it; Pilots should actively monitor at critical flight stages using their headsets (instead of flight deck speakers).
Sleeping VHF receiver	The initiative taken by a sector working group, comprising airlines, manufacturers, regulators and air traffic service providers, should continue their task in investigating the problem of sleeping VHF receivers. In the meantime pilots and controllers should be made aware of the problem of sleeping VHF receivers by means of a brochure, through pilot and controller unions and other communication means (airline safety magazines).

Chapter 6 Conclusions

Based on the results of this study the following conclusions are made:

- Incidents involving air-ground communication problems between controllers and pilots are rare and encompass about 1% of all reported incidents and 23% of ATC related incidents.
- The majority of the analysed incidents took place during the cruise flight phase (38%), followed by the descent (19%) and climb phase (15%).
- Despite the low frequency of occurrence, air-ground communication problems can still be high-risk events due to the seriousness of the associated consequences.
- The top-six of most frequently cited factors in the analysed incidents involving air-ground communication problems are: similar call signs, sleeping VHF receivers, frequency change, incorrect readback, radio interference and use of non-standard phraseology by controllers.
- Many of the air-ground communication problems identified are not new and have been reported in older studies. However due to the present scale of aircraft operations these old problems (such as similar call signs) have become more evident than 20 years ago.
- Potential prevention strategies for a number of air-ground communication problems have been identified.

Chapter 7 Recommendations

It is recommended to:

- Disseminate the findings of the present study to airlines, air service providers, regulators, pilot and controller organisations (unions).
- Conduct a comprehensive literature study on air-ground communication errors[5].
- Study communications occurrences related to data link problems.
- Analyse the use of similar call signs based e.g. timetable data, in order to identify those specific call signs used by airlines that cause confusion.
- Prepare information packages on risks and (new) mitigating measures for pilots and controllers regarding air-ground communication.
- Relate ICAO DOC 4444 r/t SARPS to occurrences, to check whether the currently prescribed mitigating measures in the r/t system are still adequately covering all hazards.
- Investigate radio communication between ground controllers and taxiing aircraft in greater detail (e.g. use of non-standard r/t because controller often has to explain in plain language what a/c should do, aircraft not all painted in company colours anymore, new means of pointing out a/c to other pilots necessary, tower designators are sometimes difficult to follow, many conditional instructions, etc.).

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[5] *A literature study was not requested by EUROCONTROL to be part of the present study.*

Chapter 8 References

CAA UK (2000). *ACCESS: Aircraft, Call sign, Confusion, Evaluation, Safety, Study*. Civil Aviation Authority. CAA UK CAP 704.

Cardosi, K. and Yost, A.. (2001). *Controller and Pilot Error in Airport Operations: A Review of Previous Research and Analysis of Safety Data*. Federal Aviation Administration Report DOT/FAA/AR-00-51.

Cardosi, K., (1994) *Analysis of Tower (Local) Controller-Pilot Voice Communications.* Federal Aviation Administration Report DOT-VNTSC-FAA-94-11.

Cardosi, K., Falzarano, P., and Han, S., (1999). *Pilot-Controller Communication Errors: An Analysis of Aviation Safety Reporting System (ASRS) Reports*. Federal Aviation Administration
report DOT/FAA/AR-98/17.

Cardosi, K., Brett, B., and Han, S. (1996). *An analysis of TRACON (Terminal Radar Approach Control) controller-pilot voice communications*. Federal Aviation Administration
report DOT/FAA/AR-96/66.

Delhaise, P. and Perry T.J. (2003). *PLOC incidents investigation Progress Report*. Presentation made to the EUROCONTROL COM Team.

EUROCONTROL, (2003). *The European Action Plan for the Prevention of Runway Incursions.* published by EUROCONTROL.

Linter, T and Buckles, J. (1993). *Why Can't We Talk to Each Other?* Journal of Air Traffic Control, January-March.

Grayson, R.L. and Billings, C. E., (1981). *Information transfer between air traffic control and aircraft: Communication problems in flight operations.* In Billings and Cheaney (Eds.) Information Transfer Problems in the Aviation System. NASA Technical Paper 1875, National Aeronautics and Space Administration.

ICAO, (1993). *Investigation of Human Factors in Accidents and Incidents.* International Civil Aviation Organization, ICAO Circular 240-AN/144 Human Factors Digest No.7.

ICAO, (1998). *HUMAN FACTORS TRAINING MANUAL*. International Civil Aviation Organization, ICAO Doc 9683-AN/950.

ICAO, (2001). *Rules of the air and air traffic services: procedures for air navigation services.* International Civil Aviation Organization, ICAO Doc 4444.

Monan, W.P., (1986). *Human factors in aviation operations: The hearback problem.* NASA Contractor Report 177298, National Aeronautics and Space Administration.

Monan, W.P., (1983). *Addressee errors in ATC communications: The call sign problem.* NASA Contractor Report 166462, National Aeronautics and Space Administration.

Morrison, R., and Wright, R.H. (1989). *ATC controls and communications problems: An overview of recent ASRS data*. In R.S. Jensen (ed.,) Proceedings of the Fifth International Symposium of Aviation Psychology, Columbus, OH: The Ohio State University, pp. 902-07.

Morrow, D., Lee, A., and Rodvold, M. (1993). *Analysis of problems in routine controller-pilot communication*. International Journal of Aviation Psychology, 3(4), pages 285-302.

Morrow, D. and Rodvold, M. (1993). *The influence of ATC message length and timing on pilot communication*. NASA Contract Report 177621, National Aeronautics and Space Administration.

O'Neil, K. (1999). *Improving the Safety of Communications.* Advanced Aviation Technology Ltd. CNS/ATM Seminar, Taipei.