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Language Error Analysis

Report on Literature of Aviation Language Errors

And Analysis of Error Databases

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Note: An annotated list of the documents used in compiling this report is given in Appendix 1.

1. Communication in Aviation Safety

Communication is defined as a dynamic and irreversible process by which we engage and interpret messages within a given situation or context, and it reveals the dynamic nature of relationships and organizations (Rifkind, 1996). In the context of aviation maintenance and inspection, communication has been the most frequent aspect studied since the human factors movement began in the early 1990's. Taylor and Patankar (2001) provide a historical perspective of the time since early human factors programs, showing that interpersonal communication was a major emphasis, and that training in improving communications skills was seen as the essence of applying Human Factors to aviation maintenance. In this report, we will review the literature on communications, and in particular on communications in an aviation context, to show that it is indeed an important aspect of ensuring flight safely. We will look at more general communications models as a background for an analysis of communications errors from a number of existing databases.

Communication can be formal, i.e. written documents, or informal. Most on-the-job communication is informal, unwritten, and sometimes even unspoken. Davidmann (1998) made a distinction between formal and informal communication, where formal communication implies that a record is kept of what has been said or written, so that it can be attributed to its originator. On the whole, written communications are formal. Oral (spoken) communication consists of direct or transmitted speech between two or more people. Oral communications are more likely to be misinterpreted than written ones, a nd were originally regarded as informal, but are now often recorded and treated as formal. The defining characteristic of many formal oral communications, such as selection, grievance or appraisal interviews, or negotiation, is that those participants keep a record, and hence provide an audit trail.

Formal communication within the aviation maintenance domain is defined and regulated. A hierarchy of written correspondence is defined in the Federal Aviation Regulations (FARs), which includes airworthiness directives (ADs), notices to airmen (NOTAMs), maintenance manuals, work cards, and other types of information that are routinely passed among manufacturers, regulators, and maintenance organizations. The international aviation maintenance community adopted a restricted and highly structured subset of the English language to improve written communication, such as ATA-100 and AECMA Simplified English. However, verbal communication among aircrews and air and ground controllers has significant safety implications. Communication is based on the use of language. In order to eliminate or at least minimize potential ambiguities and other variances, people establish rules regarding which words, phrases, or other elements will be used for communication, their meaning, and the way they will be connected with one another. The aggregation of these rules is known as a “protocol”. There are four types of protocol related to flight and aircraft safety (Rifkind, 1996): verbal protocols, written protocols, graphical protocols, and gestural protocols. Verbal protocols have been used for many years, primarily in two-way radio communication. A number of aviation accidents have been caused by the failure to use established verbal protocols. Verbal protocols are not generally seen as applicable to aviation maintenance, although establishing verbal protocols can reduce ambiguity and uncertainty in critical maintenance tasks such as ground movement and shift turnover. According to Rifkind (1996), the only verbal protocol that has been established throughout aviation, including maintenance, is the use of English as the standard language. This was done when the International Civil Aviation Organization (ICAO) was established in 1944.

About 70% of the first 28,000 reports made to NASA's ASRS were found to be related to communication problems (Sexton and Helmreich, 1999; Connell, 1995). The importance of communication in aviation cannot be overemphasized. A full-mission simulation study conducted on pilots discovered that crew performance was more closely associated with the quality of crew communication than with the technical proficiency of individual pilots or increased physiological arousal as a result of higher environmental workload (Smith, 1979; quoted in Sexton and Helmreich, 1999). Based on examination of accident investigations and incident reports, Orasanu, Davision and Fischer (1997) summarized how ineffective communication can compromise aviation safety in three basic ways:

1) Wrong information may be used.
2) Situation awareness may be lost.

3) Participants may fail to build a shared model of the present situation at a team level.

Along with the increasing volume of international traffic, the risk of communication errors escalates even further because of participants' culture and native language difference (Orasanu, Davision and Fischer, 1997).

Although aviation communication is extremely important to air safety, Kanki and Smith (2001) pointed out that "besides some acronyms and jargon, the essence of aviation communication is not exceedingly unique; it encompasses all of the nuances, subtleties, and complexities of human interaction."

After analyzing a set of reports submitted to the Aviation Safety Reporting System (ASRS) and to the International Air Transport Association (IATA) on communication problems encountered by pilots flying in foreign airspace, previous studies (Orasanu, Davision and Fischer, 1997; Cushing, 1994) categorized communication failures as shown in Table 1.

Besides types of communication failures, Orasanu, Davision and Fischer (1997) also proposed levels of miscommunication:

1) A message may not get through due to transmission problems.
2) When transmission is adequate but the message is misunderstood.

The message may be accurately transmitted and understood, but may not adequate to convey the speaker's intent.

Language Category	ASRS	IATA
Language/Accent	47	5
Partial or Improper Readback	24	8
Dual Language Switching	23	2
Unfamiliar Terminology	17	4
Speech Acts	9	0
False Assumptions or Inference	7	23
Homophony	5	1
Unclear Hand-off	4	3
Repetition across Languages	3	2
Uncertain Addressee	1	13
Lexical Inference		0
Lexical Confusion (speed/heading/runway/altitude)		4
Mistakes (unexplained)		3
Total	152	68

Table 1. Categorization of communications errors (Orasanu, Davision and Fischer, 1997)

Several different approaches may be applied to reduce these three types of failure. Transmission problems are most amenable to prevention through use of technology, such as data link or electronic transmission of text message. For reducing comprehension errors, standardized vocabulary and phraseology have been designed to eliminate problems associated with unfamiliar terms, local jargon, or ambiguous phrases. Communication failures are more likely to occur in non-routine circumstances, when non-standard language is being used. Everyday speech patterns, which may differ enormously across cultures and be exacerbated by language barriers, open the door to misunderstanding. Speakers are recommend to use their knowledge of the addressee, the situation, and social norms to formulate what they believe will be an effective message that elicits the desired response from the addressee rather than rely on assumption.

The communication concept is two-fold: communication as a tool, and communication as a skill (Kanki and Smith, 2001). The fundamental function of communication as the skill is to deliver a message from one human being to another. In almost every aspect of aviation work, communication also fulfills a secondary role as an enabler (or tool) that makes it possible to accomplish a piece of work.

Fegyveresi (1997) summarized many variables that influence communication, such as workload, fatigue, personality traits, gender bias, standard phraseology, experience level, and vocal cues, etc. An important part of aviation communication uses the radio, which eliminates some visual components (e.g., body language, lip reading) that people rely on in day-to-day communication.

Saffley (1984) stated that all poor communication involves human factors of one kind or another, and can be divided into two categories “stemming from people misusing language” and “stemming from people interacting”. Several things can go wrong when people use language:

1) The words and sentences we use are too difficult.
2) The words are so general and abstract that they mean one thing to us but something entirely different to someone else.
3) The language sometimes has such an abrasive tone that audience reaction is negative.
4) Some other contributing reasons, such as long-windedness, ambiguity, poor grammar, incoherent expression and improper logic, etc.

Analysis of business and technical communication shows that the first three are the most frequently cited weakness (Saffley, 1984).

In previous research, the role of language use in communication processes has been relatively neglected; a deeper understanding of language, its basic characteristics, and how it works should be beneficial as we move towards an era of globalization of all aspects of aviation.

Language and cultural diversity can intensify differences and confusions in communication, but a language barrier does not necessarily result in unsafe operations. Merritt and Ratwatte (1997) conducted a study to compare safety performance between mono- versus multi-cultural cockpits. They found that although language barriers and cultural differences are inhibiting the open communication and team fellowship, multi cultural crews, especially crewmembers with English as a second language had to concisely verbalize their intent and requirements and perform “by the book”. This led to rule-based behavior, with a high degree of Standard Operation Procedures (SOPs) being used. In addition, greater reliance on crew resource management principles, such as more precise communication and more crosschecking, also support the assertion that mix-cultural cockpits may actually be safer. Although English is the official language of aviation and its practice should be mandated, language training should be intensified and standardized for the non-native speakers of English. Instead of being arbitrarily granted the linguistic advantage, native English speakers should be taught how to communicate simply, slowly and precisely with their non-native English speaking colleagues.

In the ASRS database, verbal information transfer problems account for roughly 85% of reported information transfer incidents (Nagel, 1988). Matthews and Hahn (1987) identified four major contributing factors to voice communication errors in the ATC environment:

1) Quality of the Very High Frequency (VHF) radios
2) Phraseology
3) Fatigue
4) Workload

Solutions to verbal communication errors generally fall into one to two categories: those that transfer some or all of the voice communication to another communication medium (e.g., Datalink), and those that attempt to eliminate some of the current volume of voice communication (e.g., Mode S transponder, TCAS).

2. Communication Principles and Models

Many models have been proposed by psychologist, linguists, and engineers to study communication in the 20^{th} century. Generally, they fall into three categories:

1) Mechanical models
2) Psychological models
3) Integrationist models of communication

Based on basic communication theories, a communication process is composed of the sender/receiver (e.g., people, manuals, procedures, instruments, computers, etc.), the message (e.g., information, facts, emotions, feelings, questions, etc.), the medium (e.g., speech, text, video, audio, sensory, etc.), filters and barriers, feedback, and so on (Kanki and Smith, 2001; Griffith, 1999).

Kanki and Smith (2001) state that human communication always takes place with a set of contexts, such as a social context, a physical context and an operational context. The social context refers whether the receiver appropriately understands the message intended by the speaker, beyond merely using the correct words and grammar. The physical context for communication refers to aspects of the location of the communication event: co-located and speaking face-to-face, or remotely located and speaking via interphone or radio. Compared to some other working settings, the aviation operational context is relatively structured by flight phase and standard operating procedures that organize task performance.

Operational aviation communications are unique in several ways as summarized by Kanki and Smith (2001):

1) Most aviation communication is confined to small audience.
2) It is usually time-sensitive and expeditious.
3) It is constrained or limited in some way by the physical environment.

4) Circumstantial factors (noise, static, vibration, weather, etc.) are combined with barriers (cockpit doors, workstations, distances, etc.) to limit, restrict, and confound the channels used in everyday communication.

In studying communication, we are naturally interested in communication errors. Nagel (1988) categorized methods of studying errors into four categories:

1) Direct observation (which can yield a wealth of information concerning the type, frequency, and causes of errors in airline operations in a natural setting)
2) Accident data and post accident analysis, such as NTSB data base
3) Self report
4) Error studies conducted in laboratory and in simulators

3. Use of Languages other than English in Aviation

Language is an important element in effective and competent communication. Language usage is known to be a problem in cross-cultural communication (Rifkind, 1996). As the whole of aviation, including maintenance, takes on an increasingly global dimension, we need to understand the issues involved in cross-language communication. First, we must understand the demographics of globalization in maintenance. One driver in the move towards offshore outsourcing of aviation maintenance and inspection has been the relative wage rates in various countries. The US Bureau of Labor Statistics (BLS) has relevant data in the index of hourly compensation costs. They publish overall country data on 29 countries in North America, Asia/Oceania and Europe (e.g. 2000 data) and less comprehensive data for SIC codes 372 and 376: aircraft, space vehicles and parts manufacturing (e.g. 1994 data), see Table 2.

Country	Year 2000 Overall Index	Year 1994 Aircraft, etc. Index
USA	100	100
Canada	73	81
Taiwan	49	30
France	90	83
Germany	119	121
Italy	58	74
UK	63	80

Table 2. Relative wage indices for selected countries, overall and for aviation

Many other countries have no aviation data (e.g. Mexico) but do have low compensation indexes (e.g. 12). The conclusion from these statistics is that most countries of the world have lower compensation cost. In Europe the costs are comparable to the USA or even higher, but in Asia and Latin America labor costs are considerably less.

A second useful demographic comes from the US Census data of 2000, which counts the language abilities of non-native English (NNESs) speakers who are residents of the USA. Of all US households, 13.8% speak a language other than English at home. Of these 51.6% speak Spanish with the next most common language being Chinese. There is also data on the individuals' facility with English, and the number of households where there are no English speakers. This data will be used in our prkject as a basis for estimating NNESs in US employment, particularly to compare with NNESs in Part 145 operators. Although international agreements have designated a particular form of English as the standard for written communication in the aviation maintenance workplace (Rifkind, 1996), the fraction of the available labor force, inside and outside the USA, who speak English as their primary language will decrease slowly.

To speak and to understand a language it is not sufficient to know the words and the grammar. Bilingualism consists in the capacity of an individual to express himself in another language and to adhere faithfully to the concepts and structures of that language rather than paraphrasing his native language (Connolly, 2002).

In addition to language difference there are also variation of accent and dialect within a language. The core difference between accents and dialects is that accents indicate characteristics of speech variations in pronunciation, whereas dialects indicate language differences as well as speech differences. Accent and dialects need not be international to be considered foreign (Fallon, 1997; Hulit and Howard, 1993).

Willingness to communicate (WTC) is an emerging concept to account for individuals' first language and second language communication. Yashima (2002) studied English usage as a second language in a Japanese population and found that several factors affect WTC using English, such as general attitudes toward English, motivation, and language anxiety concerning achievement/proficiency. The model proposed in the study fits the data well, which indicates the potential for using the WTC and other constructs to account for second language communication.

Previous research has revealed that gender differences influence language behavior in vocabulary, intonation and sentence structure. Turney (1997) recognized gender bias (i.e. pitch differences, volume, and or social expectations) as a factor in controller/pilot communication in a survey study.

4. Analysis of Existing Error Data Bases

Before field data is collected on language-related maintenance and inspection errors, existing databases need to be searched for relevant reports of such errors. There are three sources of potential data available.

1. Aviation Safety Report System (ASRS)

Besides the United States, some other countries such as the United Kingdom and Australia operate aviation incident reporting systems too. In the United States, the primary reporting system is the Aviation Safety Reporting System (ASRS), which was developed and operated by NASA for the Federal Aviation Administration. The ASRS has more than 60,000 reports contributed by pilots, controllers, flight attendants, ground crews and others.

According to Nagel (1988), the ASRS is an excellent resource to study errors in aviation operation. First of all, data from the ASRS have proven to be a practical and indispensable source of information for the operational community and the scientist alike. For example, in some cases, modifications to the Federal Aviation Regulations (FARs) have resulted from ASRS data and analyses. Secondly, incidents of the kind and type that are reported to the ASRS are representative of those circumstances that underlie accidents. Thirdly, as an incident reporting system, the ASRS was designed to have one major advantage relative to accident analysis database, because it is possible to query the incident reporter prior to report de-identification and it is possible to learn more about why errors are made as well as something of the circumstances in which they are made. Finally, the voluntary reporting feature of the ASRS is a drawback as well as strength. The reports are not contributed on a purely random basis, for example safety conscious people may report more often than others. In practice, ASRS reports are mainly from flight crew, although maintenance is included.

2. National Transportation Safety Board (NTSB)

The National Transportation Safety Board (NTSB) has the overall responsibility to review the facts that surround major civil aviation (and other transportation system) accidents and to issue a format finding of causality. The electronic database provides complete reports and findings on all recent NTSB investigations. A search revealed no relevant reports when searched for “language” “English” or “communications”.

3. Accident/Incident Data System (AIDS)

The Accident/Incident Data System (AIDS) database contains data records for general aviation and commercial air carrier incidents since 1978. The NASDAC database for AIDS contains incidents only because NASDAC uses the National Transportation Safety Board (NTSB) accident database as the primary source for accident information. The information contained in AIDS is gathered from several sources including incident reports on FAA Form 8020-5.

The Aviation Systems Data Branch, AFS620 is the custodian of record for the FAA Accident/Incident Data System (AIDS), which contains records of aircraft accidents and incidents occurring in the United States, and those involving U.S. registered aircraft if out of the United States. The definition of an aircraft accident is an occurrence associated with the operation of an aircraft that takes place between the times any person boards an aircraft with the intention of flight until all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage. The definition of an incident is an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations.

4.1 Analysis Methods

Our main interest was in maintenance and inspection errors, but few were reported in the databases studied. Hence, the objective changed to include all language-related errors, whether by flight crew, ATC, cabin crew or ground crew. This decision was in line with our literature search, which we broadened to include all communication errors. With a large enough set of aviation-related language errors, we can form more general models, of which maintenance and inspection errors will be a specific instance.

Based on a preliminary reading of about 60 incident reports, a taxonomy was developed of error manifestations, causal factors and recovery mechanisms. Some entries in this taxonomy reflect the earlier analysis by Orasanu, Davision and Fischer (1997), although we have tried to separate contributing factors from recovery mechanisms. This preliminary reading also found likely key words. Two keyword searches were made of the ASRS and AIDS databases. The first was on "English" and the second on "Language". Some uses of these words were colloquial and specific, for example, passengers using abusive "language" to cabin crew. These usages have been removed from our analysis. There remained 684 incidents that were classified as shown in Tables 1, 2 and 3. Note that outcomes were not analyzed, although we did classify them, as our interest was in the causation of errors rather than the full error propagation.

The main division of error types was between synchronous communication (real time, person to person) and asynchronous (person to document). This is a standard classification of communication systems. Within these, a relatively fine classification was made by the roles of the two communicators, e.g. flight crew with ground crew. As will be seen later, this classification was eventually collapsed into four categories. Contributing factors are those noted in the reports. They do not represent the results of detailed fault tree analysis on human factors investigation, and so are biased towards factors seen as contributing by participants reporting the incidents. Note that "language" was used to refer to both of the first two items. Language could mean the actual language used (e.g. French, Spanish, Chinese, English) on the choice of words/phrases (e.g. expected one term but communicator used what was thought to be a synonym). Some of the communication channels themselves were poor, classified here as low signal/noise ratio. In many cases, the report mentioned that at least one of the communicators was inexperienced, for example a crew's first flight for some years into a Mexican airport.

Synchrony	Error Type	# of Reports out of 684
1. Synchronous (person to person in real time)	1.1 Flight crew/ATC miscommunication	465
	1.2 Wrong/miscommunicated action by other traffic	41
	1.3 Unable to communicate	22
	1.4 Miscommunication on flight deck	61
	1.5 Miscommunication with audio FMS (?)	12
	1.6 Miscommunication between flight deck/cabin crew	4
	1.7 Miscommunication between ground crew and operations	5
	1.8 Miscommunication between flight deck and ground crew	41
	1.9 Miscommunication with passengers	7
2.Asynchronous (person to document	2.1 Wording unclear in documentation	25
	2.2 Incorrect wording on placards	1

Table 1. Initial Classification of Error Types

Contributing Factor	# of Reports out of 684
1. Communicators not using native language (includes use of foreign language, difficulty understanding accent, unclear pronunciation)	105
2. Unclear terminology/wording	169
3. Low Signal/noise ratio on communications channel	130
4. Experience/inexperience of communicators	121

Table 2. Contributing Factors

Recovery Mechanism	# of Reports out of 684
1. No recovery attempted	340
2. Readback to other communicator	175
3. Repeated message	193
4. Ask for clarification	133

Table 3. Recovery Attempts

There are specific flight crew/ATC measures to assist in maintaining error-free communications. For example, the flight crew is expected to read the information back to the controller to confirm its accuracy. Other recovery mechanisms include repeating the message verbatim, and asking for clarification in different words. In many cases no recovery mechanism was reported.

Finally, it was found that a number of reports contained more than one error. For example, the flight crew communicated with ATC about another aircraft but this aircraft did not behave as expected. When the database was expanded to include these multiple errors, the total number of errors rose to 725 from the 684 original reports.

4.2 Results

The analysis of the database used a cross-tabulation technique developed by Drury and Wenner (2000) for drawing conclusions from an aviation accident database. The aim was to relate the contributing factors to the incident types to reach one of two conclusions:

1. No significant differences in frequency of each contributing factor across incident types using Chi-square test. The conclusion is that the factor is equally important across all types.

2. A significant difference (Chi-square, $P < 0.05$) showing that some combinations of error types and contributing factors are over-represented or under-represented. The actual factors over or under-represented are determined from the standardized

residuals in each cell of the contingency table. Any standardized residual greater than 1.96 is significant at p = 0.05. These significant cells lead to a focusing of countermeasures by error type.

The first analysis cross tabulated the 11 error types with the contributing factors and the four recovery mechanisms using the classification of error types in Table 1. Because of small cell frequencies for some errors (e.g. error type 1.6 had 4 cases, error type 2.2 had 1), the Chi-square tests were unreliable. Hence, a decision was made to combine logical categories by the locus of the communication error. This produced four error locus categories as shown in Table 4. Examples of the raw ASRS narratives typical of each are reproduced in Appendix 2. These give an indication of both the detail and the contractions typical of ASRS reports. They also help illustrate the multi-causal nature of most incidents.

Synchrony	**Error Locus**	**Error Types from Table 1**	**# of Reports out of 684**
1. Synchronous	Traffic-related	1.1, 1.2, 1.3	528
2. Synchronous	Intra-cockpit related	1.4, 1.5	73
3. Synchronous	Other Groups (ground crew, cabin crew, operations)	1.6, 1.7, 1.8, 1.9	57
4. Asynchronous	Written Communications	2.1, 2.2	26

Table 4. Final Error Classifications

The second analysis was performed to determine whether the separation of multiple errors in reports produced different patterns of analysis when moving from N = 684 to N = 725. Tables 5 and 6 show these analyses for contributing factors and recovery mechanisms, respectively. As can be seen, there were no difference in pattern and only minor differences in significance level between the two databases. Hence, all further work used the expended database of N = 725 where multiple errors per report were permitted. The overall pattern of percentages of contributing factors by error locus is shown in Figure 1. Similarly, Figure 2 shows the overall patterns by recovery attempts.

	N = 684			N = 725		
	Signif	**Over**	**Under**	**Signif**	**Over**	**Under**
Native language	P=0.061		(Asynch)	P=0.076		(Asynch)
Language/ terminology	P<0.001	Asynch		P<0.001	Asynch	
Low S/N Ratio	P<0.001		Asynch Other Gps	P<0.001		Asynch Other Gps
Inexperience	P<0.001	Cockpit		P<0.001	Cockpit	Traffic

Table 5. Pattern of Significance from Chi-Square Tests of Contributing Factors

	N = 684			N = 725		
	Signif	**Over**	**Under**	**Signif**	**Over**	**Under**
No Recovery	P<0.001	Asynch Other Gps		P<0.001	Asynch Other Gps	
Readback	P<0.001	Traffic	Cockpit Other Gps	P<0.001	Traffic	Cockpit Other Gps
Repeat	P<0.001		Asynch Other Gps	P=0.002		Asynch Other Gps
Ask Clarification	P=0.491			P=0.514		

Table 6. Pattern of Significance from Chi-Square tests of Recovery Attempts

The first finding was that communication using native language was not significantly different by error locus ($\chi^2(3) = 6.87$, $p = 0.076$), although the standardized residual for asynchronous errors (-1.98) showed that this was significantly under-represented. In fact, for written communications, much less language difficulty would be expected, as the communication does not take place in real time. When the Asynchronous data was removed from the analysis, there was a much reduced Chi-square (χ^2 (2) = 2.09, p = 0.361) and none of the standardized residuals reached significance. The conclusion is that, apart from Asynchronous communication, difficulties with native languages are equally common for all error locii. This appears to be a general factor.

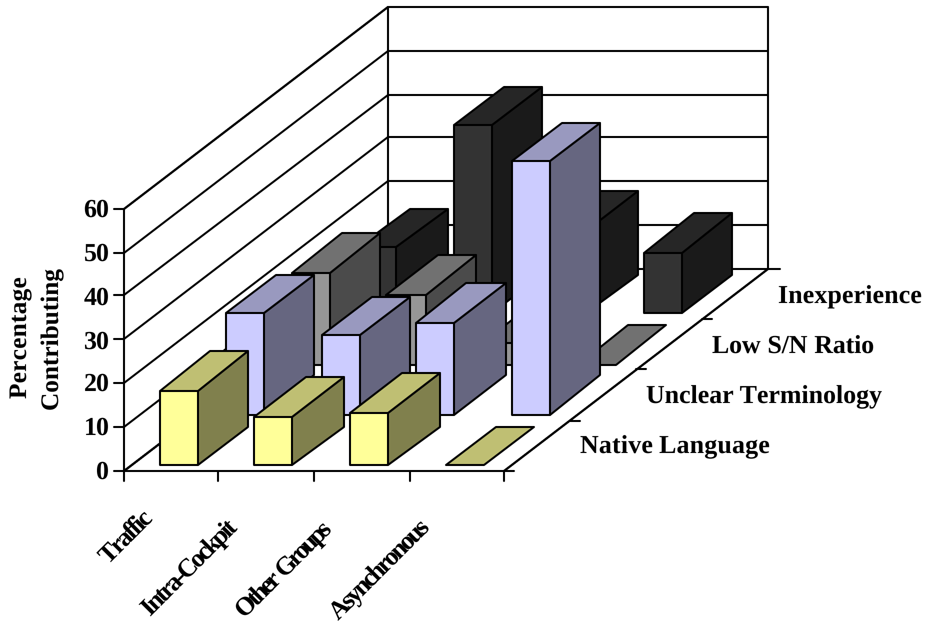

Figure 1. Pattern of Contributing Factors across Error Locii

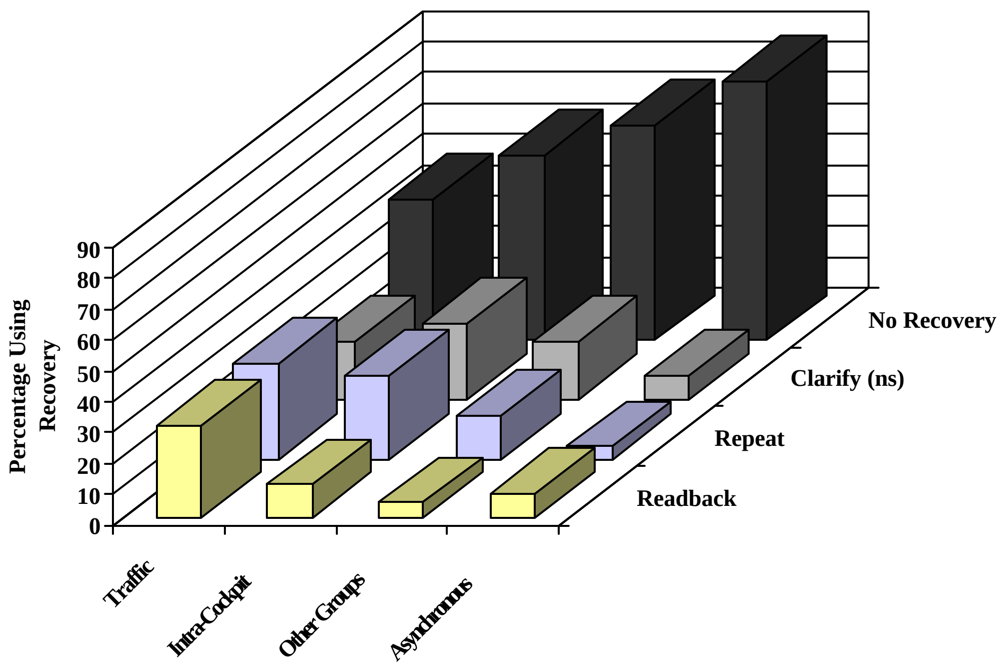

Figure 2. Pattern of Recovery Attempts across Error Locii

Unclear terminology showed significant effect of error locus (χ^2 (3) = 18.2, $p < 0.001$) with the asynchronous error type being significantly over-represented. For Asynchronous errors, 58% had unclear terminology as a contributing factor, compared with 23% for all other error locii. Thus, while unclear terminology was a relatively large contributor to all communications errors (23%), over twice that rate was found for communications with documents. As many have noted in aviation (Kanki and Walters, 1997; Drury, 1998) written communications need to be better designed for human use, particularly in terms of layout, wording and standardization. These ASRS findings re-emphasize the same point.

Low signal/noise ratio would logically not be expected to be an issue in Asynchronous communications, and indeed the significant Chi-square (χ^2 (3) = 15.7, $p < 0.001$) showed Asynchronous significantly under-represented with zero errors. However, Other Groups were also under-represented compared with the remaining error categories when the analysis was repeated without Asynchronous communications. This result still held (χ^2 (2) = 9.1, $p = 0.010$), with the standardized residual for Other Groups was –2.44. As with terminology errors, low signal/noise ratio had a relatively high incidence (21%), but for Other Groups this was only 5%. Re-reading the relevant reports showed that communications with Other Groups are often face-to-face, so this low error incidence is expected.

The contributing factor of inexperience was significantly different for the error locii (χ^2 (3) = 38.7 $p < 0.001$), with intra-cockpit errors over-represented (43%) and traffic errors under-represented (14%), compared to an overall rate of 17%. The major contribution to inexperience in the cockpit was trainee pilots. As ASRS includes general aviation and training flights, this is to be expected.

Recovery from the initial error was not attempted on 50% of occasions. Multiple recovery strategies were used at times, with rates of:

Readback	25%
Repeat Message	28%
Ask for clarification	19%

Note: For all four analyses (no recovery plus three recovery records) analyses were also undertaken with Asynchronous communications removed, and all showed the same pattern.

Where there was no recovery recorded, the over-represented error locii were Asynchronous and Other Groups, with rates of 84% and 70%, respectively. Asynchronous communication was expected to have a relatively high non-recovery rate as there are few strategies available except re-reading. Similarly, for Other Groups, less recovery strategies were available than for flight crew/ATC communications.

Readback to the other communicator was largely confined to traffic communications, where 93% of all instances were found. Thus, the other categories are relatively under-represented, averaging only 8% use of this strategy compared to 30% for traffic related communications. These differences show the power of a standard and well-practiced strategy: those trained often use it for error recovery while those who have had different training do not.

The recovery strategy of repeating a communication message verbatim was commonly used, particularly for traffic communications where 86% of all usage occurred (χ^2 (3) = 15.2, $p < 0.002$). Results were very similar to the readback strategy. For traffic, 31% used the repeat strategy, but it was only used on 14% of reports by Other Groups and only 4% for Asynchronous. Again, the results reflect the database itself, which is mainly reported by flight crew and mainly traffic-related.

Asking for clarification was statistically evenly distributed across error types (χ^2 (3) = 2.3, $p = 0.514$). This recovery strategy, like the causal factor of different languages, appears to apply to all communications errors represented in the database, with no differentiation between different types of communication.

5. Conclusions

From the literature on communications, particularly in aviation, we have been able to classify the communications process in context. This has led to listings of error types, difficulties and contextual factors potentially affecting communication performance. First, communications was shown to be an important aspect of human and system performance in all aspects of aviation, from maintenance to flight operations. It has been emphasized in training programs for cockpit crews via CRM training programs, and for maintenance via MRM programs. These began as close relatives of each other, but have gradually diverged, without losing their communications emphasis.

More general communications models list the tasks to be performed, attributes of the personnel communicating, and possible error pathways. For our purposes, we have been most concerned with the causation of error and potential recovery actions, rahter than with relating error antecedents to outcome severity.

Analysis of the ARSR, NTSB and AIMS databases showed significant and often interesting conclusions. When the error locus was classified by the roles of the communicators, differences in contributing factors and recovery mechanisms were seen. Our four categories of causal factors gave roughly equal counts in the databases, showing that the use of other than a native language was an important causal factor in these errors. This contributing factor appeared to be distributed across error loci, except for asynchronous (largely written) communication, where it was under represented. In fact, for asynchronous communication as a whole, native language and low signal/noise ration were under represented factors while unclear terminology was over represented. For recovery, asynchronous had the least opportunity for recovery mechanisms, in particular the repetition so useful in synchronous communications was not usually fruitful.

Inexperience was cited as a contributing factor for many of the incidents, but primarily for traffic-related errors. Readback of the message was used mainly by flight crew for traffic-related errors. Communications with other groups, such as ground crew, had few instances of recovery.

From such patterns, the potential errors in maintenance environments can be seen more clearly. Although ASRS has few reports from this field. The characteristics of maintenance communications errors found here (asynchronous, terminology-related, few recovery mechanisms) helps set the stage for our direct measurement of these errors from maintenance participant interviews and questionnaires.

The analysis of the databases available was useful in putting language errors into context, but necessarily contains the known limitations of the databases themselves. The raw data consisted of self-reports, largely by flight crew, with some facility for further questioning (ASRS) but largely reflecting the thought and feelings of those on the flight deck. Thus their relevance to maintenance and inspection was indirect, although they did afford the opportunity to access a wide range of language related incidents.

A final quote on language is worth repeating here (Turney, 1997 quoting Brightman, 1988:

> *In order to transmit proper meaning, the encoder and decoder must be on the same wavelength. They must speak the same language. We do not hear with our ears, we hear with our minds. And we are different from one another. All of us*

suffer from selective perception. What we hear depends on who we are. (Turney, 1997; Brightman, 1988).

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Appendix 1.

Aviation Communication Research

What	Whom/Where	Authors and Year
Voice Communication	Air Traffic Control Environment	Mattews and Hahn (1987)
Culture and Language Barriers	Communication in Global Aviation	Orasanu and Davison (1997)
Vocal Cues	Pilot/ATC Communications	Fegyveresi (1997)
Links between Language, Performance, Error, and Workload	Cockpit Communication	Sexton and Helmreich (1999)
Gender Bias	Controller-Pilot Communication	Turney (1997)
Safety	Mono vs. Multi-cultural Cockpits	Merritt and Ratwatte (1997)
Readbacks, Volume of Information, Experience Level, Personal Problems, Standard Phraseology, and the Relationship to Safety	Controller/Pilot Communication	Wulle and Zerr (1997)
Accents, Dialects	Pilot/Controller ATC Communication	Fallon (1997)
Cockpit Data Link Technology	Flew Crew Communication	Logsdon and et al (1995)
Communication Strategies	Pilot	Fischer and Orasanu (1999)
Communication Discrepancies	Pilots and Maintenance Technicians	Mattson, Crider, and Whittington (1999)
The Impact of Automation	Flight Crew	Bowers (1993)
Collaboration	Pilot/Controller	Morrow, Lee, and Rodvold (1991)
Message Length, Training	ATC	Morrow and Rodvold (1993)
Routine Operation Problems	Controller-Pilot	Morrow, Lee, and Rodvold (1993)
Culture Difference	Cockpit-Cabin	Chute and Wiener (1995)
Modes of Communication	Pilot-Pilot	Zimmer and Scheuchenpflug (1995)
Aircraft Radio Communication	Radio	Weller and Wickens (1991)
Communication Strategies, Personalities, and Crew Performance	Airline Captains	Orasanu (1991)
Crewmember Communication	Astronauts and Cosmonauts	Kelly and Kanas (1992)
Bilingual ATC	ATC	Stager and et al (1980)
Data-Link Communication	Controllers and Pilots	Kerns (1991)
Mixed-media Communication (Voice, Data Link, Mixed ATC)	Flight Deck	McGann and Morrow (1998)
Satisfaction, Information Exchange	Cockpit-Cabin Crew Interaction	Skogstad and et al. (1995)

English in Aviation

In 1995, then-Department of Transportation secretary Pena recommended requiring all commercial pilots to pass a test for proficiency in speaking English.

Famous quote about communication/ language

#1 Even in face-to-face interaction, speech is a complicated process. Language not only conveys information but also express a worldview… there is room for distortion, uncertainty and ultimate conflict.

#2 In order to transmit proper meaning, the encoder and decoder must be on the same wavelength. They must speak the same language. We do not hear with our ears, we hear with our minds. And we are different from one another. All of us suffer from selective perception. What we hear depends on who we are. (Turney, 1997; Brightman, 1988).

Appendix 2.

Typical ASRS examples of the four Error Locii

1. Synchronous Traffic-related

172961 SYNOPSIS

ACR LGT at hold line for RWY sees SMA pass in close PROX LNDG on RWY, TWR not speaking in English.

NARRATIVE

Waiting short of hold line 05r for DEP, 05l closed, TWR is talking to numerous ACFT in Spanish. In my limited Spanish can tell TWR is CLRING numerous ACFT to land. Looking across cockpit talking to f/o when outside his window appears an early 1960's SMA y, faded red in color with Mexican registration, approx 100' to the r of our airplane parallel to us less then one wing span (30') off the GND in a 30-40 deg bank HDG around our nose for the RWY (05r) to land. ACFT passed BTWN us and RWY, approx 60' off our nose! Shocked, we contacted the TWR who said they had CLRED the ACFT to land but would not answer any other attempts by us to acquire info by radio! Why can't they speak English like most of the worlds ATC sys?

2. Synchronous Intra-cockpit related

138028 SYNOPSIS

NMAC at night. ACFT x on VFR on top descent and ACFT y opposite direction IFR.

NARRATIVE

We were descending on VFR on top from 12500 MSL. Center had advised us of IFR TFC at 9000 MSL, 1 o'clock, SBND. The TFC was an SMT jet with APCH lights on. I spotted the ACFT and advised ATC as such. My F/O was of south American background having trouble understanding English. The F/O was constantly missing radio calls and having difficulty in understanding the instrument APCH we were about to do. We were to the point the FO was a DISR rather than help. I was keeping an eye on the SMT and estimated it would pass off well to our rear. The f/o failed to call the BC loc alive and was calling out wrong MDA numbers. While shepherding the f/o along and glancing at his HSI for course interception, I had lost sight of the SMT y FLT path. Looking up I realized the SMT was closing much too close. I leveled off at about 9200' AGL and started a slight left turn. The SMT spotted us and started a left turn. The f/o looked up and gave a cry. The SMT asked about the TFC passing overhead. I apologized to the SMT. This incident was my error because I allowed cockpit DISTRS to let us get too close to the TFC. In the future I will start a new f/o earlier in the DSCNT checklist and APCH review, stay on a hard IFR CLRNC (no on top) and try to maintain continuous outside contact.

3. Synchronous Other Groups (ground crew, cabin crew, operations)

430515 SYNOPSIS

An MD super 80 was unable to taxi out after pushback from the gate due to failure of the pushback crew to remove the nose gear steering pin. FLC was unable to communicate with the GND crew due to a severe language prob.

NARRATIVE

I would like to relate to you the following story that not only happened to me this morning in ZZZ but in a couple of other cities as well. During pushback, it was just about impossible to communicate with the GNG man due to his very, very poor English. I was able to once again get around this by me asking all the questions back to him and asking for an affirmative or negative. At the completion of the push, when it was time to be shown the pin, blink the taxi light the GND man holds up his gloved r hand, and crossed wands in his l. After I blink the light I get the salute and with CLRNC from GND I try to taxi but can go nowhere. It seems that once again I am shown a bypass pin that does not have a red flag on it -- or came from his pocket. Ops was called and someone else came to remove the real pin. I am not sure what the solution is here but I believe that all pins should have long streamers attached to them and the GND personnel should not be allowed to have their own pins.

4. Asynchronous Written Communications

502081 SYNOPSIS

AN air carrier after TKOF at 1400 ft declared an EMER and diverted due to #2 eng thrust REVERSER deployed.

NARRATIVE

I was called over to ACR to placard a r eng REVERSER unlock warning LITE. Never having deactivated a 717's REVERSER I called their MAINT coordinator and asked to have the PROCS faxed. Received a fax cover sheet and 3 pages from ACR MEL manual for the 717. When finished with the deactivation called back ACR MAINT to make sure I was completing the proper signoff in the logbook and get a MAINT CTL number for the placard. The coordinator never mentioned anything about pinning the deflector doors. They were mentioned in the MEL, but the verbal language in the manual threw me off. After lift off the 717's r eng REVERSER deployed at 1400 AGL. The PLT shut down the RT eng while keeping a airspeed of 200 KTS. The ACFT returned safely. While going over the PROCS again with MAINT coordinator, found that the 4th page of the deactivation was not faxed. Without this page, missed the crucial step of pinning the deflector doors closed. This would not have happen if the MEL would state in the beginning paragraphs of the steps what had to be deactivated along with graphics and explanation. ACR XXX keeps these books on the ACFT at all times. Some of the airlines don't, you have to depend on getting info over the fax. I work at ACR XXX airlines and many times we are contracted out to work on other carriers. At ZZZ, I work on 6 carriers besides ACR XXX which has us working on 3 different kind of ACFT that we don't work on a daily basis. More in depth training would help. Callback conversation with RPTR revealed the following info: the RPTR stated the crew discovered #2 eng thrust REVERSER unlock light on during a PRE FLT CHK. The RPTR said he was contacted by the ACR to call the MAINT CTLR to get PROCS for deferring the #2 eng thrust REVERSER. The RPTR stated upon contacting the ACR MAINT CTLR was advised to follow the MEL special PROCS and render the thrust REVERSER inoperative. The RPTR said a request was made to the MAINT CTRL to fax the PROCS as the RTPRS experience was limited to a few hrs of logbook and serving training on this new airplane. The RPTR said the ACR MAINT CTLR faxed three sheets of PROCS with no page identification as 1 of 3, 2 of 3 and 3 of 3. The RPTR said the three page document was accomplished and assumed that the deflector doors were stowed meant they were in the lock pos. The RPTR said the airplane was dispatched and at 1400 ft the REVERSER deployed incurring damage to the deflector doors linkage. The RPTR stated it was then discovered a 4th page with the proc for installing lock pins locking the deflector doors in the forward thrust was never sent by the ACR MAINT CTRL. The RPTR said that, Boeing revised the proc adding pictures of the lock pins location. The RPTR stated the only work experience gained on the 717 was serving oil, hydraulics and tires. The RPTR said more training on the contract ACFT we are assigned to work would help but none of the carriers do it.