Communication Barriers in Aviation:
Terminology Science as a Means of Improving Specialist Communication in the Domain of Aircraft Accidents

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Abstract

In aviation, specialist communication can play a safety-critical role. However, owing to the exponential growth of specialist knowledge efficient communication is often impeded. This paper describes some communication barriers that can occur in aviation. In this connection, the inconsistent and ambiguous use of specialist terms in aircraft accident reports will be commented on. As a possible solution for reducing communication obstacles a proposal is made to apply the principles and methods of terminology science - the field of knowledge which deals, among other things, with harmonizing and standardizing concepts and terms of special subject fields. Finally, an ongoing research project will be briefly outlined in which British and German aircraft accident reports are analysed conceptually as well as linguistically with a view to improving not only the use of terms in accident reports but also the representation of specialist knowledge in this area.

1. Introduction

The 21st century is often referred to as the era of the 'Information Society'. Information can therefore be regarded as the 'currency' of the future where the exchange of information and knowledge will play a key role with many countries moving closer together through the liberalization of borders and barriers (e.g. the Member States of the European Union). With respect to aviation, for example, the implementation of the Single European Market has resulted in significant new 'freedoms' for airlines, such as 'freedom of access', 'consecutive cabotage', and eventually 'full cabotage rights' that became effective from 1st April 1997. This means that from now on any airline will have the right to fly anywhere in this community, and in order to deal with such a big 'aviation community', the increased need for information and knowledge exchange should become a prime concern for the countries involved.

In aviation, new technologies have emerged quite rapidly during the past few decades. This has resulted in an exponential growth of specialist knowledge which is usually concomitant with a large increase in specialist terminology. For instance, one of the most notable technical developments in aviation in the recent past was the advent of computer-controlled fly-by-wire systems which are intended to replace the non-computerized systems where the pilot's commands are transmitted to the control surfaces via mechanical cables and hydraulic actuators. It is clear that with the introduction of these computerized flight-control systems, for example, pilots had to deal with a whole range of new specialist knowledge which entailed a large number of new specialist concepts and terms. Many of the terms used to describe this fly-by-wire technology were borrowed from computing science, e.g. *category prompt, free text address field, uplinked information message, Bite Interface Unit (BIU), Dedicated Serial Data Link* (British Airways A320 Technical Manual 1991; British Airways A320 Flying Manual 1996). Referring to the Airbus A320, the comment that "in effect it's an aeroplane wrapped around a computer network" (Mellor as cited in Faith 1996: 81) describes this technological development quite appropriately. Further sources of new terms in aviation include 'cabin water spray systems' to fight fires in the fuselage and 'thermal neutron analysis equipment' to find explosive materials (cf. Hall & Campbell 1991). Moreover, Airbus is currently examining a 'combined operation of aircraft systems' using touch screens as well as 'voice input' and 'voice output' in future cockpits. Through this new touch screen technology, pilots will again be confronted with new specialist terms, such as *operator* *pyramid, dialog sequence, information output unit, top level menu*, and so on (cf. Liebig 1992).

The process of communicating ideas plays a considerable and crucial role in aviation. This is particularly important in some subdomains of aviation where communication, i.e. the transfer of information, is considered to be safety-critical. For instance, if pilots and air traffic controllers do not strictly adhere to the standard terminology and phraseology which is prescribed, aircraft incidents and accidents may be the result, as has been described exhaustively by Cushing (1994), who lists a wide range of pilot-Air Traffic Control (ATC) communications during which non-standard phraseology was used (1994: 29-34). It is interesting to note that despite the fact that pilot-ATC communications have the sole and all-important purpose of transmitting vital information and instructions in order to ensure secure and prompt aircraft operations, non-standard phrases are frequently used (cf. Cushing 1994). The question of why standard phrases and terms are not always adhered to remains an open one. Such misuse has reportedly already led to a number of incidents and accidents although the need to use correct and precise standard phraseology has been stressed repeatedly (e.g. CAA 1992: 9).

Efficient and effective communication, i.e. transfer of knowledge, depends to a large extent on the use of correct and unambiguous specialist terminologies. The fact that communication obstacles can arise easily has already been recognized by UNESCO who acknowledge

> “the exponential increase of the terminologies emerging in the course of scientific-technical and economic-industrial development which creates communication barriers.” (UNESCO 1992: 96)

Professional communication can be obstructed at a number of different levels. Below, the most salient types of communication barrier will be outlined and exemplified.

2. Major Communication Barriers

There are several layers at which communication problems can occur. In studies dealing with Languages for Special Purposes (LSP), a distinction is usually made between ‘vertical’ and ‘horizontal’ layers of communication (Hoffmann 1985: 58-70). The vertical structuring of specialist communication refers to information being exchanged between participants with different levels of expertise. Communication at a horizontal level is usually described as occurring across different domains. Situations where specialist communication takes place between experts at the same level of knowledge within the same domain/subdomain will also be dealt with. The systematization of communication levels described here is not intended to be a rigid one. The borders of this division are deliberately kept fuzzy and flexible in order to account for the many degrees and facets of specialist knowledge as well as for the multitude of specialist communication situations.

Communication Barriers at a ‘Vertical Level’

- Between experts and laypersons, e.g. between pilots and visitors on the flight deck. A communication situation between such an aviation expert and a layperson may be impeded because of the different levels of expertise. It is, for example, often difficult for pilots to explain aircraft-specific concepts to passengers owing to the use of specialized terms. More general expressions would facilitate this type of communication, e.g. instead of the specialist term *engine r.p.m. indicator* (cf. Thom 1991: 3) laypersons may understand the less specialized expression *tachometer* more readily.

Communication Barriers at a 'Horizontal Level'

- Between experts from different subdomains within aviation, e.g. pilots and aircraft engineers. A certain amount of knowledge may be shared by both types of experts but there is also a large amount of knowledge which is not shared, i.e. that which is specific to each subdomain. A good example for a potential communication problem is, for instance, the term *dump valve*. Pilots tend to understand this term to mean "a high capacity valve sometimes installed on aircraft fuel tanks to permit quick emptying of the fuel tanks during an emergency" (Transportation Safety Institute 1975: 27) whereas aircraft engineers generally understand by it "an automatic valve which rapidly drains the fuel manifold when the fuel pressure falls below a predetermined value. It usually operates when the engine is stopped" (Cescotti 1993: 92). These different understandings might lead to a breakdown in communication if both sides are not aware of the possible interpretations of *dump valve*.

Communication Barriers between 'Interlocutors at the same Level of Knowledge and within the same Domain/Subdomain'

- A breakdown in communication would be least expected to occur at this level but it may happen. Communication problems might, for instance, arise in the case of an exchange of specialist knowledge between Boeing and Airbus pilots (e.g. during type conversion training, or during a joint project). Both types of expert can be described as aviation experts in the same field; however, their use of terminology may differ since Airbus Industries and Boeing are well known for using different terminology for exactly the same purpose. For example, the terms *fuel control switch* (British Airways B747-400 Technical Manual 1997) and *engine master switch* (British Airways A320 Technical Manual 1991) demonstrate this. Both terms indicate a device which has the function of letting fuel into the engine. Hence, both pilots may actually be talking about one and the same thing without being aware of it, or they may think that two different purposes are fulfilled by the two switches.

- Between experts from the same subdomain but with different languages of habitual use, e.g. German and British aircraft engineers. These experts may have more or less similar knowledge about their particular field. Their communication, may, however, not only be impeded by their different languages but also by their culture. What ought to be borne in mind on this level of information exchange is that communication problems are magnified as soon as the communication setting involves more than one language.

- As a further example of a communication situation within a domain/subdomain where communication barriers are likely to exist, one could name company mergers, e.g. between individual airlines. Different companies often use terms in different ways, and in order to ensure efficient communication their use of terminology has to be harmonized and systematized.

The above sketch of communication barriers highlights the fact that it is crucial to increase awareness with respect to the fact that communication difficulties can and do arise. Depending on the situation, experts have to adapt their modes of communication, and most importantly have to be clear - if necessary reach a consensus - about the meanings of the terms they are using.

So far, I have outlined a framework which is well-known within LSP studies in order to describe certain problems in aviation communication. Let us now go on to some specific communication problems resulting from the misuse of terminology in aircraft accident reports.

3. Terminology Problems in Aircraft Accident Reports

Many different subject fields are involved in aircraft accident investigations including engineering, material science, medicine, psychology, meteorology, and so on. It should be noted that the number of such subject fields is virtually open-ended since every air crash is unique. The interdisciplinary nature of aircraft accident investigations means that particular attention has to be paid to the terms used in this field. As long ago as 1975 a statement by the Transportation Safety Institute pointed out that

> "a review of aircraft accident reports reveals inconsistencies in technical terminology. Investigators use words such as *shear*, *stress*, *camber*, *stability*, etc., without fully understanding their meaning. Readers are misled by incorrect terminology, and the accident investigation and resultant report are discredited." (Transportation Safety Institute 1975: i)

Not much has changed since then. What follows are some examples of inconsistent and ambiguous terms identified during an analysis of official British aircraft accident reports (AARs). The data presented stem from a preliminary analysis undertaken as part of an ongoing doctoral research project[1] and therefore no statistical information is yet available. The data has, however, been validated by several real-world experts including an aircraft accident investigator from the British Air Accidents Investigation Branch (AAIB), two British Airways pilots and one Royal Air Force pilot.

Altitude versus *Height*

The apparently straightforward terms *altitude* and *height* are prime examples of inconsistent usage of terminology. *Height* is generally defined as "the vertical distance of a level, a point or an object considered as a point, measured from a specified datum" (Hall & Campbell 1991: 140). This specified datum is normally understood to be ground level, and one therefore speaks of the *height above ground level* which is often abbreviated as *height agl*. In comparison to this, *altitude* refers to "the vertical distance of a level, a point or an object considered as a point, measured from mean sea level (amsl)" (Hall & Campbell 1991: 31). According to the experts consulted, *altitude* is always referenced to *amsl* whether the abbreviation is added or not. This is also true for *height; height* refers to ground level even if the abbreviation *agl* is not given. Yet, during the analysis of various accident reports the following usages were encountered. By looking at the list in Table 1 below several usages of the terms *height* and *altitude* can be observed. In this list, the author first uses the term *altitude* within the expression *altitude 150 feet agl*. Bearing in mind that *altitude* is measured *above mean sea level (amsl)*, this expression is clearly wrong. It should therefore state either *altitude 150 feet amsl* or *height 150 feet agl* depending on the point of reference. Further on in the list, the author uses the term *height* in connection with *agl* on two occasions, before changing back to the term *altitude* again, only this time without any explicit reference which, as has been mentioned before, is not necessarily required.

"Time	Elapsed	Event
1056:13	0:00	N605PE lined up for take-off runway 26L
1057:10	+0:57	Take-off roll began
1057:58	+1:45	7º nose up elevator applied
1058:03	+1:50	Main landing gear left the ground
1058:06	+1:53	Significant decrease in longitudinal acceleration
		No 4 engine indicated abnormal performance
		Stick shaker activated
1058:12	+1:59	Aircraft at pitch attitude of 22º
		Airspeed 147 kt, ***altitude 150 feet agl***
		No 4 engine thrust lever retarded by 12%

[1] This PhD research will be described in more detail in section 6 of this paper.

1058:15	+2:02	No 4 engine EGT 1000º C Thrust levers of remaining engines fully advanced
1058:36	+2:23	IAS 161 kt
1058:39	+2:25	Minimum ***height of 105 feet agl***
1059:01	+2:47	V_2 was achieved for the first time.
1059:32	+3:18	Flap retraction began, aircraft pitch was reduced to 10 nose up, ***height was 600 feet agl*** and airspeed was 168 kt IAS.
1101:02	+3:48	Flaps were fully retracted. ***Altitude was 2100 feet*** and airspeed 250 kt IAS."

Table 1: Extract from British AAR 4/89 (AAIB 1989: 16; emphasis in bold and italics added)

To deliver unambiguous specialist communication in the above context the author should have avoided the synonymous use of *altitude* and *height*. While the mix-up of the terms *height* and *altitude* had nothing to do with the aircraft incident described in the above-mentioned AAR, the experts consulted confirmed that the terms *altitude* and *height* are often confused in aviation circles. According to them, this mix-up might have potentially disastrous consequences, e.g. at high-elevation airports.

Standard Altitude: Is there such a Term?

An example of an expression in an aircraft accident report which is not readily understandable is the compound noun *standard altitude* which was encountered in the context below.

> "The DFDR recording also showed that, whilst the aircraft was in level cruise at a pressure altitude of 37,000 feet, the cabin pressure was equivalent to a ***standard altitude*** of 7,030 feet, with a cabin pressure differential of 8.19 psi." (AAIB 1991: 11; emphasis in bold and italics added)

The expert consultants commented unanimously that *standard altitude* was a non-existent term. Various interpretations were given however, including *pressure altitude* and *cabin altitude*. One interpretation was that the term *pressure altitude* would be correct in this context because it refers to "an atmospheric pressure expressed in terms of altitude which corresponds to that pressure in the Standard Atmosphere" (Cescotti 1993: 190). The other interpretation was that the term *cabin altitude* should be used as it denotes "the simulated altitude condition in a pressurized aircraft cabin" (Cescotti 1993: 60). Although it is clear that the suggested terms are not synonymous with each other they both could be used in the above example sentence. The reason for this is - according to the experts - that both terms express *altitude* but just from different frames of reference. Hence, both terms would make sense in this particular context but not the original 'pseudo-term' *standard altitude* which clearly obstructs the transfer of knowledge. It needs to be pointed out, however, that in specialist documents of this kind the meaning of terms should not be dependent on context because this may lead to different reader interpretations resulting in communication problems.

Small Aircraft: Same Meaning in US and UK?

The English language has undoubtedly become the 'lingua franca' of aviation. However, in spite of the fact that 'Aviation English', which has a wide range of technical terms, is used in many countries throughout the world, some of these terms display striking differences in meaning from country to country. One only needs to think about the terminological discrepancies between British and American Aviation English. For instance, the term *light* *airplane*[2] which was encountered in an American aircraft accident report (NTSB 1987: 6). In American aviation terminology a *small aircraft* is defined as an "aircraft of 12,500 pounds or less maximum certificated takeoff weight" (Transportation Safety Institute 1975: 69) whereas in British aviation terminology the definition encountered for *small aircraft* reads "for the purposes of wake turbulence categorisation, aircraft between 17 000 kg and 40 000 kg are categorised by the United Kingdom as 'small' " (Hall & Campbell 1991: 246). Surprisingly, none of the experts consulted had been aware of a difference in weight categorization between the United States and the UK. One of the experts suggested yet another definition for *small aircraft*, namely an aircraft with a maximum authorized take-off weight of less than 2250 kg, e.g. Cessnas, Pipers, and so on. According to this expert, this last definition is the one that generally tends to be accepted in aviation circles. He conceded, however, that the ones mentioned above are the official definitions although their application appears to be limited. At the point of writing this paper it could not be determined which one of these definitions is correct, or whether the term *small aircraft* does have several meanings, i.e. is polysemous.

4. Terminology Science as a Possible Remedy

It is reasonable to assume that the various examples discussed so far can impede specialist communication. But how might such problems be overcome? One possibility is to look to terminology science, a discipline which has since the 1930s been concerned with improving the efficiency of professional communication through the standardization and harmonization of concepts and terms in special subject fields.
Generally, one distinguishes between 'descriptive' and 'prescriptive' terminology work.[3] Descriptive terminology work deals with the recording of terminological data of concepts on a monolingual or multilingual basis, and prescriptive terminology work has a normative function. This normative approach has the aim to eliminate, or at least reduce to a minimum, 'synonymy' (several terms denote the same concept), 'polysemy' (one term designates two or more concepts which are related to each other in some respect) or 'homonymy' (one term denotes two or more concepts between which no semantic relationship exists). These linguistic phenomena are all unwanted in terminology science because they interfere with communication.

> "Synonyms cause confusion and give rise to the false impression that more than one concept exists. For this reason they should be avoided in special languages. Technical communication is a matter of clarity rather than of variety." (Felber 1984: 180)

Measures of a regulatory nature with respect to the development of specialist terms have become necessary since it has been argued that any unregulated development of terms eventually creates "intolerable confusion" (Felber 1984: 15) and a chaotic specialist communication environment. The problems of synonymy and polysemy that have been encountered in the respective aircraft accident reports may under some circumstances even have safety-critical consequences, e.g. if certain terms are used synonymously (cf. *altitude*, *height*), or if a term has several meanings (cf. *small aircraft*). In their research on the 'language of safety', Ahmad & Salway criticize the "typical *laissez-faire* attitude to systematic and quality-assured terminology" and stress that "safety may be compromised by the inconsistent and polysemous use of terms" (1996: 296). Hence, in terminology science the optimal case is considered to be that one concept is denoted by one term and vice versa (mononymy/monosemy) although this situation is difficult to achieve. The speed with which

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2 With respect to the use of the terms *light airplane* and *small aircraft* the following ought to be noted. The experts commented that the adjectives *small* and *light* tended to be used randomly and they did not think that there was a regional preference. According to them the main difference between American and British usage is that the former prefer *airplane* whereas the latter use *aircraft.*

3 Descriptive terminology work necessarily precedes any prescriptive work.

new technical and scientific developments happen means that 'concept meanings' can undergo shifts whereas the terms denoting them remain the same. However, specialist communication would definitely be facilitated if terms were assigned to concepts in a permanent and unambiguous way (cf. Felber 1984: 179).

In order to avoid uncontrolled terminological developments it is necessary to carry out appropriate terminological work, including the standardization and harmonization of concepts and terms. Specialist terms as well as LSP phrases[4] and their underlying conceptual structures are at the centre of terminology science which forms the scientific basis of practical terminology work. The nature of terminology science is that of a transdisciplinary and interdisciplinary field of study since it draws on disciplines such as linguistics, philosophy, information science and special subject fields. What these disciplines have in common is that they each deal, in some way or other, with formally organizing the complex relationships between concepts and the terms denoting them.

Terminology science may be defined as the field of knowledge which is concerned with concepts[5] and their linguistic (e.g. terms) and extra-linguistic (e.g. symbols) representation (cf. Felber 1984; 1987). This science encompasses the practices and procedures used for collecting, describing and presenting terms, and it has been argued that it is vital for ordering, organizing and systematizing human knowledge (cf. Budin *et al.* 1993: 480).
The results of terminology work are usually publications in which the terms representing the concepts of a particular subject area are codified, e.g. special-subject dictionaries, glossaries, printouts from term banks, and so on. These specialist vocabularies are important tools for efficient expert communication and knowledge transfer.

In the following section a brief introduction will be given to the most important principles and methods of terminology science. The main emphasis will be on how terminology work can assist in overcoming difficulties on the linguistic level, i.e. the focus will be on the identification of synonymy and polysemy/homonymy in order to standardize the use of terminology in expert communication. To begin with, we will briefly deal with the concept of LSP as any terminological work is carried out within this framework. The reason why concepts have a key position in terminology science will also be commented on.

5. Terminological Principles and Methods

The knowledge we possess as human beings is in the form of ideas, concepts, and so on, but in order to be able to communicate these ideas we need to make use of natural language and symbols. In this context, we therefore have to deal with two sides of communication, namely the content side (concept/meaning) and the form side (linguistic symbols) (cf. Felber 1982: 14).

The language we use in everyday life - usually referred to as Language for General Purposes (LGP) - can be understood as the totality of all linguistic means which is common to all members of a linguistic community and therefore allows linguistic communication between them (cf. Hoffmann 1985: 48). In order to communicate specialist knowledge in any given subject field we make use of a specific kind of language which is generally called Language for Special Purposes (LSP). Languages which are used for specific purposes receive material for their concrete 'communication acts' from LGP, and in this context LSP

[4] The study of LSP phrases within terminology science is a recent development, and researchers still differ considerably in their definitions of LSP phraseology. Confusion also exists with respect to what exactly a LSP phrase is. For further reading on this topic, the reader is referred to the journal *Terminology Science & Research*, Vol. 1 (1990), no. 1-2.

[5] In terminology science, concepts are generally defined as mental representations of individual objects. Such objects (material or immaterial) may be described as any section of the perceivable or conceivable world.

may be said to overlap with LGP to a certain extent. Words are considered to be the lexical elements of general language whereas in the context of special languages we speak of terms. LSP, however, does not share the specialist terms with LGP. There is also a difference between LSP and LGP with respect to the method of how they are analysed. For example, one of the most important terminological principles is the fact that concepts and not terms are the starting point of all terminological work. In lexicological investigations, which usually deal with LGP, words are normally the starting point. Below, some of the reasons for assigning concepts a key position in terminology will be described.

Concepts: The Cornerstone of Terminology Science

One of the reasons for assigning concepts a central position in terminology work can be traced back to the fact that terminology science was founded by the Austrian engineer Eugen Wüster (1898-1977) who was, among other things, concerned with standardizing and harmonizing the concepts in his field which only subsequently resulted in the standardization and harmonization of the corresponding terms. Wüster also founded the Vienna School of Terminology. According to Laurén & Picht (1993: 513), a second reason for concepts being the natural point of commencement may be seen in the Vienna school's traditional orientation towards German philosophy of language, where the commonly held view[6], albeit unusual, is that concepts and not words constitute the 'definiendum'.

Starting from concepts, terminological work consists of several activities whose individual steps or phases may vary, overlap, be shortened, or even omitted depending on the specific terminological task (cf. Cole 1987). Since the main concern in this paper is to present a method that allows synonymy and polysemy/homonymy to be avoided, we will only deal with the major phases relevant to this task which may be described as having a kind of normative function.

Identification and Delimitation of Individual Concepts

The first step of any terminology work is that the individual concepts belonging to a particular subject field or subdomain have to be identified and delimited from each other.[7] The reason for doing so is that it is only possible to determine precisely which terms denote which concept (in order to establish whether synonymy or polysemy/homonymy exists) once the individual concepts have been differentiated (cf. Felber 1984: 165). This is usually done by comparing the characteristics of individual concepts by means of a conceptual analysis (cf. Arntz & Picht 1995: 53). Characteristics may be defined as component parts of a concept which are used to characterize particular properties of the object represented by that concept. Characteristics may be established by consultation with subject-field experts.

For example, the concept *CLEAR AIR TURBULENCE* can be described as having the following characteristics which were extracted from the respective definition found in Cescotti (1993: 66):

1. *atmospheric turbulence*
2. *encountered in clear air*
3. *at great heights above the Earth's surface*
4. *near a jet stream*

[6] For example by Immanuel Kant.

[7] Before concepts can be analysed, first the subject field under investigation needs to be delimited which often has to be done on a pragmatic basis. Such a pragmatic approach stems from the fact that is difficult to clearly define what constitutes a 'subject field', 'domain', 'area', and so on, since many disciplines are intertwined with each other (cf. Rey 1995: 138-140).

Hence, using the above characteristics, the concept *CLEAR AIR TURBULENCE* can be delimited clearly from the related concept *CONVECTIONAL TURBULENCE* which shares the first characteristic but also has distinguishing characteristics (cf. Cescotti 1993: 76).

1. *atmospheric turbulence*
2. *associated with varying vertical air currents*
3. *caused by heating of the atmosphere adjacent to the Earth's surface*

Establishment of Definitions for Concepts

Having identified the individual concept characteristics it is now possible to formulate the definitions for the respective concepts. In terminology science definitions play an important role because they are the link between a concept and its term. Because of this mediating function, definitions are a valuable means of identifying and avoiding synonymy and polysemy/homonymy on the linguistic level. Hence, clear definitions are crucial to effective specialist communication since, as has been said before, terms can only be assigned to concepts once individual concepts have been delimited from each other and defined. Ideally, the formulation of definitions[8] should take place through a combined effort from subject-field experts, who need to agree on a consensual definition, as well as terminologists, who are trained in writing efficient, adequate and appropriate definitions. The various types of definition that are important for terminological purposes are listed below.

(1) Intensional Definitions
They typically list the individual characteristics of the concept to be defined (ISO 704 1987: 5), e.g. *ornithopter:* "A heavier-than-air aircraft supported in flight chiefly by the reaction of the air on wings to which a flapping motion is imparted" (Cescotti 1993: 176).

(2) Extensional Definitions
This type of definition is "based on the exhaustive enumeration of the objects [...] referred to by the concept [...], or of the specific concepts [...] at the next level of abstraction" (ISO 1087 1990: 4), e.g. *aircraft:* "aeroplanes, gliders, kites, airships, balloons, rotorcraft, ornithopters" (cf. Felber 1984: 163).

(3) Contextual Definitions
This kind of definition shows the actual usage of a term and its underlying concept, e.g. *gyroscope rotor:* "The gyroscope rotor in these instruments is an AC synchronous motor, operating from a 115V AC 400H three-phase supply" (AAIB 1996: 13).

Investigation and Determination of Relations between Concepts

It is important to know how individual concepts are related to each other because this will also allow the identification of synonyms and polysemes/homonyms on the linguistic level. In terminology science concepts cannot occur on their own but are always linked to other concepts (Nedobity 1983: 2). Therefore, one of the aims with respect to the identification of individual concepts of a particular domain or subdomain is to eventually build up a systematic picture of a subject area or of part of it because a classification of concepts, i.e. system of concepts is a very "powerful key to knowledge" (Nedobity 1983: 4). However, a system of concepts can only be built after an investigation of the relations existing between the individual concepts. Conceptual relations become recognizable by delimiting individual concepts from one another. Such relations may be best described as some kind of mental

8 Various guidelines have been established in order to assist terminologists and subject-field experts in writing definitions, cf. Felber 1984, Picht & Draskau 1985 and Wüster 1991.

unit which forms some sort of bond between individual concepts (Nuopponen 1994: 238). These mental bonds may be characterized by a similarity of the concepts involved, or because they are of a temporal, spatial or cause-effect nature.

Below (see Figure 1), we will give an example of a small classification using relations that are based on the similarity of the concepts *ATMOSPHERIC TURBULENCE, CLEAR AIR TURBULENCE, CUMULONIMBUS TURBULENCE* and *CONVECTIONAL TURBULENCE*. By just looking at the respective terms denoting these concepts the only thing that can be seen is that they all seem to be types of turbulence. It is not possible, however, to see straight away how these concepts can be classified, i.e. which one is the most generic concept, and so on. This is only possible after having established the corresponding definitions which contain the concepts' characteristics. Using these definitions, a kind of hierarchy for these concepts can be worked out which also displays the individual relations linking these concepts.

It can be seen in this figure that the concept *ATMOSPHERIC TURBULENCE* is the most generic (abstract) concept; the remaining ones become more specific the lower one moves down in the hierarchy. Therefore 'superordinate' relations via two levels can be identified, existing between, for instance, the concepts *ATMOSPHERIC, CONVECTIONAL* and *CUMULONIMBUS TURBULENCE*. It is also possible to identify 'subordinate' relations. For example, the concept *CUMULONIMBUS TURBULENCE* is subordinate to the concept *CONVECTIONAL TURBULENCE*. Furthermore, there are 'co-ordinate' relations between the concepts *CLEAR AIR*, *CONVECTIONAL* and *FRICTIONAL TURBULENCE* which can all be described as being on the same level of abstraction.

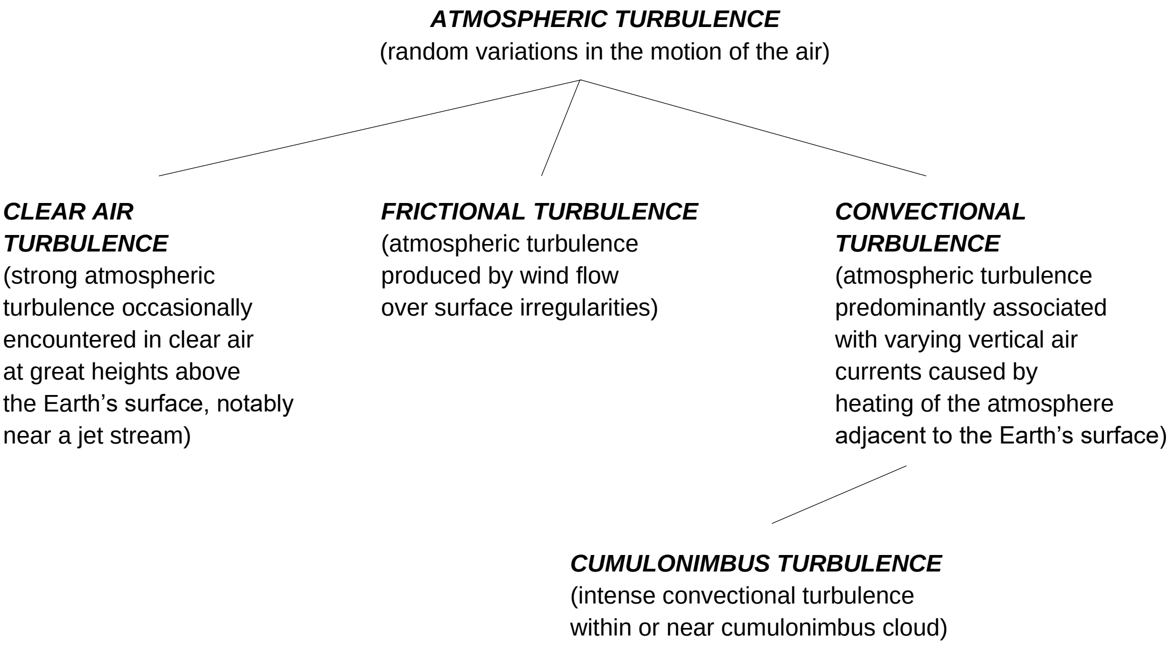

Figure 1: Concept system based on the similarity of concepts ('genus-species' relations)
(Definitions taken from Cescotti 1993)

The above classification has been established by comparing the characteristics of the individual concepts with each other but this cannot be done for 'spatial', 'temporal' and 'cause-effect' relations. These relations do not link similar concepts with each other but concepts which represent objects of the real world that are in a spatial or temporal contact, or are characterized by a cause-effect connection. ‘Part-whole’ relations can be named as the most important and well-known types of spatial relation, e.g. *FUSELAGE* is part of an *AIRCRAFT*. Concepts connected to each other by a temporal relation are, for example, *TAKE OFF* and *GEAR RETRACTION*. The former concept precedes the latter in time. Temporal relations are predominantly found underlying the terms used in processes, procedures, activities, events, and so on. An example for concepts related to each other by a cause-effect relation would be, for instance, *ENGINE FAILURE* and *AIR CRASH* since one can say that *ENGINE FAILURE* is the cause concept and *AIR CRASH* the effect concept.

As has been shown, conceptual relations are vital for terminology work as the ordering and presenting of specialist knowledge is usually carried out in the form of concept systems. Furthermore, concept systems also aid the comparison of concepts viewed from the perspective of different languages, hence facilitating cross-linguistic expert communication.

Assignment of Terms to Concepts (Concept-Term Relations)

Concept systems also present an invaluable tool for standardizing and unifying terminologies because individual concepts assume particular positions in such a system, thus allowing the identification of synonyms and polysemes/homonyms.

Once the concept definitions and concept relations have been determined and the individual concepts have been placed into a concept system, it is possible to make decisions on the terms which denote these concepts. The fact that the starting point is concepts allows the identification of the relations between concepts and terms in a relatively straightforward manner. As indicated earlier, this means it is possible to identify clearly whether two or more terms represent exactly the same concept in which case we may speak of true synonymy. Or, we can identify whether terms are wrongly used as synonyms, e.g. as in the case of *altitude* and *height* because in this case each term designates a different concept. In addition, it is possible to see whether one term denotes two or more concepts, i.e. polysemy/homonymy. The example of *small aircraft* that was discussed earlier may perhaps be such a polysemous term as it may designate two different concepts.

In general, it can be said that the terminological method of starting from concepts may allow difficulties on the linguistic level to be overcome. Hence, using this method it is possible to disambiguate and improve specialist communication.

In the last section, the most important principles and methods of terminology science have been introduced. It should be noted that these methods and principles also encompass rules and criteria for the formation and creation of new terms on a national as well as international basis. As a thorough treatment of this particular topic would have gone beyond the scope of this paper the reader is referred to Sager (1990: 55-98) in particular. In the next section, an ongoing doctoral research project in terminology science will be discussed. Among other things, this work has the specific aim of revealing temporal relations linking the concepts underlying the terms and phrases used in aircraft accident reports.

6. Temporal Conceptual Relations in Aircraft Accident Reports

We have seen in the last few sections that it is not only important to have clearly defined concepts but it is equally important to know how the individual concepts are interrelated as this knowledge can help in identifying synonyms and polysemes/homonyms on the linguistic level. The research which will be described in this section focuses on temporal conceptual relations. These relations will not only be investigated on the conceptual level but also on the linguistic level, i.e. we will look at concept-term relations with a view to seeing how temporal relations are represented in text.

The Nature of Temporal Conceptual Relations

What exactly constitutes a temporal conceptual relation? The general terminological view is that objects of the real world can not only be arranged alongside each other, i.e. have a spatial contact, they can also follow each other in time, i.e. be in succession to one another (cf. Felber 1995: 20). With regard to the dimension of time three aspects can be distinguished, namely duration, succession and coexistence, as has been argued by the philosopher I. Kant (Kemp Smith 1995: 209, B_{219}). Hence, the contact that objects as well as the concepts that represent them can have in time may express itself either as a successive, continuous or a simultaneous event. In the former case the objects are described as following one another without the first one influencing the second one.

The main reasons for investigating temporal relations in the current research project are listed below.

- Temporal relations have been researched much less from a terminological point of view than, for example, relations based on the similarity of concepts (genus-species relations). There have been few attempts to establish a typology of temporal relations and it has to be noted that, with the exception of a few basic types of temporal relation, the classification of such relations is of a highly subjective and ‘ad-hoc’ nature.
- It is proposed that greater understanding of temporal relations between concepts and a consolidation of certain typological aspects of such relations, the conceptual representation of specialist knowledge in the form of concept systems or fields may be improved.

- With respect to how temporal conceptual relations are realized linguistically, it is hoped that more knowledge about the respective concept-term relations may assist in avoiding problems on the linguistic level, e.g. synonymy and polysemy/homonymy. LSP phraseology will play an important role here. It has been mentioned before that the study of LSP phrases within terminology science is a recent development. Traditionally, terminological research and work has been limited to the study of nominal terms as designations for specialized concepts. Only recently has the scope been extended to the analysis of other linguistic units as well, e.g. verbs. There is a growing tendency to consider verbs to be specialist terms as well (Budin 1990; Picht 1990). It has been argued (e.g. by Felber 1984) that verbs and verb phrases denote dynamic concepts, which, for example, can be said to underlie processes, procedures, and so on. Hence, verbs and verb phrases are one of the points of focus during this doctoral research as it is hypothesized that there are links between certain temporal conceptual relations and particular verb types which may express some of these temporal conceptual relations on the linguistic level. As a starting point therefore for the analysis of the linguistic level verbs will be investigated in their contextual environment, as in *to arrest the high-speed descent*, *to kill the engine*, *to shrink the engine thrust reverser plume,* and so on. However, the research will also include other linguistic units that are found in the texts under scrutiny, i.e. any LSP structures which may express temporal conceptual relations.

The materials and tools that have been chosen to carry out this study consist of a machine-readable untagged corpus[9] of LSP texts and a terminology management software, System

[9] The text corpus consists of official British and German aircraft accident reports (British corpus: 275 000 words; German corpus: 112 000 words).

Quirk[10], that can be used to analyse such a text corpus. This suite of programs enables, for instance, the creation and management of machine-readable corpora and the acquisition and elaboration of potential terms from these texts (Ahmad & Holmes-Higgin 1995: 183). Among other tasks, System Quirk allows concordances, collocations, statistical analyses and term identifications to be carried out. Thus, it can be observed, for instance, what kind of valency patterns verb terms establish. These patterns on the linguistic level may then enable us to determine links to the underlying conceptual structures, in particular to temporal conceptual relations, for which it is also intended to establish patterns.

The fact that I am looking at linguistic as well as conceptual patterns aims not only at solving problems on the linguistic level, i.e. synonymy and polysemy/homonymy, but also at remedying problems experienced during manual as well as computerized concept analysis and identification. It is hoped that some linguistic patterns can be specified enabling a prediction that certain temporal relations are likely to be represented by particular linguistic patterns or units. In related studies a similar approach has been made for relations that are based on similarity (genus-species relations); for example, Ahmad & Fulford (1992) hypothesize that genus-species relations are represented on the text level by expressions, such as X *is a type of* Z or X *is a kind of* Z, and so on.

Below, an actual example from one of the accident reports in the pilot study, which is currently being conducted, is shown. During this initial analysis the verb term[11] *to backtrack* was encountered and analysed in its contextual environment which is as follows.

> "Having backtracked the runway to line up, the aircraft took off from Runway 14 at 1647 hrs [...]." (AAIB 1996: 3)

The syntax in this sentence makes it clear that *aircraft* is the underlying subject of both non-finite and finite verb forms. The sequence of verbs also makes it clear that, first, the *aircraft* needs to *backtrack* before it can *line up* and *take off*. It is therefore possible to say that the underlying concepts *AIRCRAFT*, *TO BACKTRACK*, *TO LINE UP* and *TO TAKE OFF* are linked to each other 'in time'. All these concepts are part of a procedure the aircraft is following, and the individual steps of this procedure have to be carried out one after the other. This relation may therefore be classified as a so-called 'temporal relation of successive events' (see Figure 2 below).

AIRCRAFT
↳ *TO BACKTRACK*
↳ *TO LINE UP*
↳ *TO TAKE OFF*

Figure 2: Temporal succession of concepts

Since the pilot study is still in progress the analysis of linguistic patterns has not taken place yet. What can, however, be established is that so far the verb term *to backtrack* seems to appear only in connection with the nominal term *runway* but not with any other nominal terms. At this stage of analysis, a preliminary observation with respect to the linguistic realization might be that this type of temporal relation may perhaps be indicated on the linguistic level by a certain sequence of verbs.

[10] System Quirk has been developed by the Artificial Intelligence Group of the Department of Mathematical & Computing Sciences in collaboration with the Department of Linguistic & International Studies at the University of Surrey.

[11] Terms as such were identified by applying one of System Quirk's procedures in which the relative frequencies of open-class words that occur in specialist texts are compared with their relative frequencies in general-language corpora (cf. Ahmad *et al.* 1994).

A further aspect of this doctoral study is to compare the results from the English aircraft accident reports with those from German aircraft accident reports. This bilingual approach might provide insights into the linguistic mechanisms for the representation of temporal conceptual relations since it is well-known that the linguistic realization of concepts in different languages exhibits many differences. For example, one language may just employ a verb to designate a concept (EN *to stop*) whereas another language may need longer patterns, e.g. a preposition plus a noun plus a verb (DE *zum Stillstand bringen*). It is assumed that cross-linguistic evidence may provide stronger substantiation of such concept-term relations and their ‘generalizability’ than monolingual evidence. This part of the research will have some implications for matching terms and LSP phrases cross-linguistically. Since this is done by comparing concepts and conceptual structures across various languages it will be possible to establish the various degrees of overlap, i.e. equivalence, between British and German terms. Hence, the bilingual aspect of this research project may facilitate specialist communication across different languages.

7. Conclusion

In conclusion, it can be said that a lack of awareness of terminology can lead to various communication barriers at a number of levels. Without any terminological awareness such barriers could remain unidentified and hence, unresolved. In this paper the most important principles and methods of terminology science have been introduced, including the analysis of concepts, the identification of conceptual characteristics, and the investigation of relations between concepts. It has also been described how concept systems are established, concepts are defined and how concept-term relations are determined. The paper’s intention was to show how appropriate and adequate terminology work can assist in overcoming difficulties on the linguistic level, i.e. on how to identify synonymy and polysemy/homonymy in order to facilitate specialist communication. Finally, it is hoped that the current work may contribute to aircraft accident reports being written with clearer and more consistent terminology. It is also hoped that storing air accident reports in any existing or future databases will be facilitated, i.e. cross-referencing of keywords could be improved not only by using standardized terms but also by indicating conceptual relations or term relations. It seems reasonable to expect that the indication of related concepts or related terms within data records of aircraft accident reports might help in creating links between certain air crashes. For instance, in the case of an accident which may partly be attributed to a failure of a certain aircraft part it would help to know whether similar crashes owing to the same aircraft part have happened. This can only be realized if the terms and concepts used in such databases are standardized, and linguistic problems such as synonymy and polysemy/homonymy have been reduced to a minimum. In particular, the use of different terms for the same concept by various aircraft manufacturers, e.g. Airbus Industries and Boeing, needs to be eliminated.

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