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TECHNICAL ANALYSIS OF ATC CONTROLLER TO PILOT VOICE COMMUNICATION WITH REGARD TO AUTOMATIC SPEECH RECOGNITION SYSTEMS

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TITLE:

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Abstract:
Humans verbal communication is a very complex domain. International air traffic needs a more robust technical oriented language for its communication. State of the art speech recognition techniques should be able to achieve acceptable results with such a restricted language corpus. But how far this default ATC language (ICAO recommended phraseology) is used in the real ATC world? Nearly 10 000 controller utterances from 3 different on-route ATC centres (Karlsruhe, Zürich, Geneva) with 11 controllers have been recorded. These utterances have been transcript, normalised and classified for the analysis. This note try to give some facts for an answer.

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1 Abstract

Humans verbal communication is a very complex domain. It is well known that the language is part of the culture of a people. This mean that the real finesse of a language cannot be used for the ATC (Air Traffic Control) communication between mainly non native English speakers with reduced communication channel quality.
International air traffic needs a more robust technical oriented language for its communication. Therefore simple basic parts of English were selected and published as ICAO (International Civil Aviation Organisation) recommendations for an ATC phraseology.

State of the art speech recognition techniques should be able to achieve acceptable results with such a restricted language corpus. Such a “default ATC language”(recommended ICAO phraseology) should be usable with innovative of the shelf speech techniques.
But how far this default ATC language is used in the real ATC world? This report try to give some facts for an answer.

The aim of this study is not to point out what’s right or wrong with controller’s speech, it is to analyse realistic speech for a potential use with speech recognisers for a real-time ATC simulator environment (i.e. to replace pseudo-pilots by a speech recogniser). Student controllers learn the use of standard ICAO phraseology. By years of experience this trained phraseology may change without be noticed by the controller.

In conclusion of this report may be said that only a small number (less than 30%) of the examined utterances have been in detail fully conform to the ICAO recommended phraseology. In a questionnaire the controllers stated their opinion on their employed phraseology. They estimated about 85% (mean) of the said utterances conform to ICAO recommendations. Recogniser systems for student controllers (initial training) may give acceptable results with today’s technology. The examined recorded spontaneous speech would bring professional speech technology in unacceptable difficulties.

2 Introduction

To celebrate Niels Bohr's birthday the "Journal of Jocular Physics" (7.10.1955) of the 'Institute for Theoretical Physics, Copenhagen' published an article from H.B.G.Casimir with the theme "Broken English" with the following excerpt:

> "There exist today a universal language that is spoken and understood almost everywhere: it is Broken English. I am not referring to Pidgin English, a highly formalised and restricted branch of BE, but to the much more general language that is used by waiters in Hawaii, prostitutes in Paris and ambassadors in Washington, by businessman from Buenos Aires, by scientists at international meetings and by dirty-postcard peddlers in Greece, in short by honourable people like myself all over the world."

The aim of the ATC language is very similar and it could be even said, it should be a subsidiary of it, as an important majority of all ATC communication participants are non-native English speaking. In parts of the world other languages (French, Spain and Russian) are allowed but the ATC controllers have to been able to speak English too. ATC security is depending on verbal communication between pilots and controllers. The ATC language should be a **simple** language of commands, requests and acknowledgements to give no place for misinterpretation of a message. For this reason ICAO (International Civil Aviation Organisation) had published 'International Standards, Recommended Practices and Procedures for the Navigation Services' for the aeronautical telecommunication. These ATC phraseologies were developed by ICAO to eliminate possible ambiguities, established as basic principles by the "Forth COM Division" meeting in April 1951. The same conference gave to ICAO the task to assist in these international English language training. The following interesting paragraph (from the "Forth COM Division" meeting in April 1951) of the ICAO manual "Aeronautical Telecommunications - Annex 10 to the convention on *i*nternational civil Aviation' 'Attachment B to Volume II - Development of Radiotelephony Speech for International Aviation" shows the importance of this training:

> "2.6 The fulfilment of this programme is prerequisite to the efficient universal use of radiotelephony in aviation. In attacking the problem with the sole objective of attaining the highest efficiency in air-ground communication, the co-operation of all States may be expected and the burden now largely carried by non-English-speaking countries will be more equitably shared; for the extent of the new language having to be acquired by non-English-speaking personnel will be reduced, **while the English-speaking States will at the same time accept the obligation of training their personnel to keep within the agreed limits in the use of their own language**."

Up till now and in the near future, human speech is the main mean of communication between pilots and Air Traffic Control (ATC). The technical performance of the communication channels hasn't increased significant during the last forty years. The principle, that all aircraft pilots within a specific airspace and the responsible ATC controller speak on the same frequency is unchanged since the begin of international collaboration in ATC. This requests an extreme discipline by all participants of the

communication. For world-wide ATC communication concept common rules were specified by the International Civil Aviation Organisation (ICAO) as recommendations. The states may specify in their aeronautical information publication (AIP) particular requirements for first contact when entering or leaving national aerospace.

From 20/01/97 until 14/02/97, at the Eurocontrol Experimental Centre (EEC), was the 3rd continental real-time simulation S08ANT-RVSM.This simulation was set-up for the upper parts of the airspace of Switzerland (sectors Zürich and Geneva), east part of France (sectors Reims and French military) and south-west part of Germany (sectors of Rhein Control).
During the this simulation sectors from Zürich (ZU-2), Geneva (GE-4) and Rhein-Control (SOL) were temporarily recorded.
The aim of the voice recordings were to collect 'live' voice samples for comparative testing of different speech recognition systems on their potential use in our real-time ATC simulator environment ('Comparative experiments with speech recognisers for ATC simulations', EEC Note No. 09/98). The work reported here is deviated from this study.

Let me point out the limits of speech recognition systems with the following example. If a human being is learning a strange language and he knows same words now. So if the man hears words in this language he will be able to understand the learned words – for all other words he will say: 'sorry I have not jet learned this one'.
A speech recognition system works very similar. The recogniser compares learned (stored) words with the spoken ones. With learned word this works well, but for a new (not stored) word, the statistical comparing algorithms of the system will give another known word of the stored vocabulary with some similarities as matching result. This means, the result will be rather arbitrary for humans understanding. The success of a speech recognition is based on exact prediction of all ever in an utterance used words. A study of the phraseology employed by the controllers of the target ATC environment became evident.
The known study of Eric Janet, 'Analyse du langage employé dans les communications d'un système de contrôle' (1982) is based on the simultaneous use of French and English in the French airspace. The present study relates on the exclusive use of English by non native English speaking controllers for an en-route traffic environment. ICAO documents were used as reference for a recommended ATC language.

3 Source of the Analysed Data

3.1 Technical Environment

For the recording of the data minor technical modification of the standard EEC real-time environment were made to ensure the data collection. The controller's headset was connected via an interface to the normal communication equipment instead directly. This interface STIF (Speech Techniques for sImulation Facilities' - EEC Note No. 25/96) is fully transparent for the controller communication. The PTT switch (Push To Talk) of the recorded position was connected to the STIF as well. The STIF interface serve for level adaptations of the audio data for the recording and for the transformation of the PTT information into an audio signal for recording. STIF interface and the audio DAT (Digital Audio Tape) recorder were place behind the controller working position.
As headset the HME 45 -KA from Sennheiser was used.
For recording a Sony DAT recorder DTC-60ES was employed. One channel were charged with the audio signal of the controller the other one record the PTT switch signal.

These recording were transcribed by mainly native English speaking students of an international business school. This option was preferred as transcription by our in house pseudo-pilots have given "nice phrases interpreted by a pilot" but not the real spoken controller utterances.

3.2 Recorded Real-time Simulation (S08 ANT-RVSM)

The aim of the 3rd continental real-time simulation S08 was to evaluate the concept of RVSM (Reduced Vertical Separation Minimum). ICAO has RVSM as an approved concept to reduce aircraft vertical separation from the conventional vertical separation minimum (CVSM) of 2000 ft to 1000ft. The chosen Swiss, French and German airspace represents the core area of Europe and simulates the interaction between control centres in 3 different countries with multiple conflict points.

As the presented study was limited on the use of English in ATC, only Swiss and German sectors have been recorded. By the reason that French is an official ICAO language the controller of Reims may use both, English and French.

The sectors SOL (Söllingen; ATCC Karlsruhe), ZU-2 (ATCC Zürich) and GE-4 (ATCC Geneva) have been recorded. From ATCC Geneva were a few exercises recorded only, by the same reason as for ATCC Reims.

Sector	Recording Date	Nbr. of Exercises	Recording Time
Söllingen	21/01/1997 - 31/01/1997	26	24:57
Geneva	04/02/1997 - 05/02/1997	5	4:32
Zürich	06/02/1997 - 13/02/1997	19	18:30
Total	21/01/1997 - 21/02/1997	**50**	**47:59**

Table 1: Exercises recorded

In general a simulation exercise was about 1.5 hours. The first half an hour (traffic initialisation phase) with little speech samples wasn't recorded.

3.3 Relation Speech Recording - Simulation Exercise

Speech recordings were made on the basis of a time table (see 3.2). Therefore the distribution of recorded exercises per sector in relation with different simulation difficulties (RVSM - traffic load) may not be comparable. By this reason detailed comparative statistical analysis is not made.

Sector	no RVSM	single RVSM	double RVSM	+ 35% traffic	+55% traffic	+65% traffic
Söllingen	6	9	11	17	9	0
Geneva	0	3	2	0	3	2
Zürich	2	8	9	0	8	11
Total	8	20	22	17	20	13

Table 2: Type of Exercises

Remark: "single RVSM" - flight levels are allocated one by one for the alternative directions, "double RVSM" FL are allocated two by two; + xx% traffic means - today's standard traffic increased by xx%.

3.4 Subjects

At the start of the recording period all subject were informed of the voice recording of the specific working position and the general propose (for speech recognition and analysis experiments).

Sector	Female	Male	Mean age	Nationality	Mother language
Söllingen	0	4	37.8	German	German
Geneva	1	3	28.0	Swiss	French
Zürich	3	0	27.3	Swiss	Swiss/German
Total	**4**	**7**	**31.0**		

Table 3: Subjects

They were asked to use their normal working behaviour. All controllers have had several years of experience (license) in ATC. The following table give the mean years of experience of the recorded controllers.

Sector	Years of Experience as controller (general)	Years of Experience as ACC* controller
Söllingen	14.8	11.0
Geneva	3.8	3.8
Zürich	6.0	4.3
Total	**8.2**	**6.4**

Table 4: Subjects Experience

* Area Control Centre

4 Definition of a Reference ATC Phraseology

ICAO is charged to co-ordinate research and development of an ATC phraseology and the publication of these studies. By this reason different ICAO documents (‘Rules of the Air and Air Traffic Services -Doc 4444’, ‘Aeronautical Telecommunications - Annex 10’ and ‘Manual of Radiotelephony, Doc 9432-AN/925’) were used to define a recommended ATC language.
Only the relevant words and phrases for an Area Control Centre (ACC) were included in the definition for this study. It is evident that this selection isn’t exclusive, but it will cover nearly all phrases employed in an ACC. See appendix A for details.

Aircraft call signs, numbers and alpha characters play an major role in this communication, therefore special care were employed on their definition and the way of their use.
Abbreviation in general are not permitted, exception in some special cases of aircraft call signs prescribed in ICAO documentation.

This reference phraseology were defined in mind of a possible implementation in a speech recogniser system, only.

5 Self Assessment of the Subjects in Relation to the recommended ICAO Phraseology

At the end of the simulation the subject had been interrogated on their meaning on their applied phraseology during the simulations. They were asked to estimate their own linguistic deviation from the language recommended by ICAO or equivalent national ATC language recommendations.

Sector	difference to ICAO recommend.					diff. to national recommend.				
	none	vli	li	la	vla	none	vli	li	la	vla
Söllingen	0	2	1	1	0	0	2	2	0	0
Geneva	0	1	3	0	0	0	2	2	0	0
Zürich	0	1	1	1	0	1	2	0	0	0
Total	0	4	5	2	0	1	6	4	0	0

Table 5: Subject's Statement of employed Phraseology (general)

Remark: vli (very little - range:<=10%);
li (little - range: >10% <=25%);
la (large - range: >25% <=35%);
vla (very large - range > 35%).

Another question were if their applied phraseology had to been different in simulation exercises with RVSM and conventional traffic samples.

Sector	Standard phraseology with conventional traffic samples	Standard phraseology with RVSM traffic samples
Söllingen	yes (all)	yes (all)
Geneva	yes/no (half/half)*	yes/no (half/half)*
Zürich	yes (all)	yes (all)

Table 6: Subject's Statement of employed Phraseology (conventional/RVSM traffic)

* Reason given: heavy workload

6 Global results

6.1 Manner of speaking

During 48 hours of RVSM-(Reduced Vertical Separation Minimum) simulation 9614 controller utterances were recorded. For the analyse the recordings have been transcribed. The aim of the RVSM simulation were findings for future capacity increase of the airspace. Therefore the results are given under these aspects too. The column “no RVSM” contains exercises based on today’s standard procedures, both other’s under specific RVSM conditions. On the right hand side the data are showed under an increased actual traffic outlook.

The following table gives interesting results for the global manner of controller’s speech.

	general	Sölling.	Geneva	Zürich	male	female	no RVSM	single RVSM	double RVSM	+35% traffic	+55% traffic	+65% traffic
Nbr. of spoken utt.:	9614	4551	1004	4059	5524	4090	1556	4053	4005	2949	3994	2671
utt. with 'repetitions':	1,3%	1,2%	1,2%	1,4%	1,4%	1,2%	1,1%	1,2%	1,4%	1,3%	0,9%	1,9%
utt. with 'hesitations':	2,7%	2,5%	1,6%	3,3%	2,5%	3,1%	2,9%	2,4%	3,0%	2,3%	3,0%	2,8%
utt. with 'disregard:	0,4%	0,5%	0,0%	0,4%	0,4%	0,3%	0,4%	0,3%	0,5%	0,4%	0,5%	0,2%
utt. with 'correction':	0,8%	0,7%	0,9%	1,0%	0,7%	1,0%	0,9%	0,9%	0,7%	0,6%	1,0%	0,9%
utt. with 'break':	0,2%	0,3%	0,4%	0,0%	0,3%	0,1%	0,2%	0,2%	0,1%	0,3%	0,2%	0,0%
utt. without AC-sign:	5,2%	3,8%	7,7%	6,1%	4,8%	5,7%	3,7%	4,9%	6,0%	3,5%	4,9%	7,5%
utt. in French:	1,6%	0,0%	15,4%	0,0%	1,7%	1,5%	0,0%	2,2%	1,6%	0,0%	2,8%	1,7%
utt. not used:	3,3%	2,6%	5,3%	3,6%	3,4%	3,3%	3,7%	2,6%	3,9%	2,7%	3,4%	3,9%
utt. valid:	95,0%	97,4%	79,3%	96,4%	94,9%	95,2%	96,3%	95,2%	94,5%	97,3%	93,8%	94,4%
Nbr. of valid utt.:	9138	4431	796	3911	5243	3895	1498	3857	3783	2869	3747	2522

Table 7: Global Manner of speaking

Controller utterances including the keyword “break” are treated like two separately made utterances. The ICAO standard “break break” has been used only once.

Over 5% of the controller messages have not included an AC-call-sign. ASR (Automatic Speech Recognition) without context knowledge can not interpret these utterances. Further 5% of the utterances are from the ‘spontaneous speech’ category (repetition, hesitation, disregard, correction). As actual recognisers are mainly trained for ‘continuous speech’ they may not be very well adapted to such a manner of speaking.

About 5% of the utterances have been eliminated from the further analysis of the speech corpus. The eliminated phrases were closely related with the conduction of the simulation or from private nature. All French utterances from the Geneva sector were skipped as well.

The following table show the same data based on subject level:

	general	subj.A	subj.B	subj.C	subj.D	subj.E	subj.F	subj.G	subj.H	subj.I	subj.J	subj.L
Nbr. of spoken utt.:	9614	1318	791	1108	1534	215	231	383	175	1608	615	1636
utt. with 'repetitions':	1,3%	1,3%	0,6%	1,3%	1,9%	1,4%	0,9%	1,0%	1,7%	1,2%	2,8%	0,7%
utt. with 'hesitations':	2,7%	2,0%	1,3%	4,1%	2,9%	2,3%	1,7%	1,8%	0,0%	3,2%	2,8%	3,2%
utt. with 'disregard:	0,4%	0,5%	0,3%	0,2%	0,9%	0,0%	0,0%	0,0%	0,0%	0,1%	0,2%	0,7%
utt. with 'correction':	0,8%	0,4%	0,4%	2,2%	0,0%	2,3%	0,0%	0,5%	1,1%	1,3%	0,2%	1,1%
utt. with 'break':	0,2%	0,0%	0,0%	0,4%	0,5%	0,5%	0,9%	0,3%	0,0%	0,0%	0,0%	0,1%
utt. without AC-sign:	5,2%	4,5%	1,3%	5,8%	4,6%	9,3%	6,1%	9,1%	4,6%	4,5%	8,9%	5,5%
utt. in French:	1,6%	0,0%	0,0%	0,0%	0,0%	6,5%	26,0%	16,7%	9,7%	0,0%	0,0%	0,0%
utt. not used:	3,3%	3,8%	1,3%	2,6%	3,1%	2,8%	1,3%	9,4%	4,6%	4,0%	3,6%	2,8%
utt. valid:	95,0%	96,2%	98,7%	97,4%	96,9%	90,7%	72,7%	73,9%	85,7%	96,0%	96,4%	97,2%
Nbr. of valid utt.:	9138	1268	781	1079	1487	195	168	283	150	1543	593	1591

Table 8: Manner of speaking per Subject

Remark: Some variations are important e.g. for utterance without AC-call-sign from 1,3% to 9,3%!

6.2 Controller instructions and courtesy forms

In the recommended ICAO phraseology for ATC commands, forms of politeness (“good morning”, “bye”, “please”, “thanks”, ...) are not foreseen. This rule seems to be ignored by a great majority of controllers and pilots. Mainly these courtesy forms are reduced to a reasonable minimum with “good morning” at entering and “bye, bye” at leaving the control sector.

Most of the controller’s shows a tendency to vary these courtesy forms by the time of the day and their knowledge of abroad languages and slang’s. So even the use of simple greetings end up in a huge number of different words of different languages.

	all utterances	utterances without courtesy forms		utterances with courtesy forms	
general	9138	5989	65,5%	3149	34,5%
Söllingen	4431	3456	78,0%	975	22,0%
Geneva	796	416	52,3%	380	47,7%
Zürich	3911	2117	54,1%	1794	45,9%

Table 9: Distribution of the Courtesy Forms

This table shows a tendency of national influence in the use of courtesy forms. A superposed male (Söllingen - male only) female (Zürich - female only) decency cannot be seen as Geneva is a mixed group with a male majority.

	all utt. with courtesy	transfer as key-w. in utt.	greetings as transf. key-w.	courtesy with other key-w.
general	3149	79,4%	20,5%	0,1%
Söllingen	975	96,2%	3,7%	0,1%
Geneva	380	67,6%	32,4%	0,0%
Zürich	1794	72,9%	27,0%	0,2%

Table 10: Utterances with Courtesy Forms

Nearly 80% of the utterances with a courtesy form were related directly with an explicit transfer message type. After nearer examination of the remaining we detected that in nearly all cases the recommended ICAO phraseology for the ‘transfer’ of an AC entering the sector (e.g. Lufthansa 5504 radar contact) have been replaced by standalone greetings (e.g. Lufthansa 5504 guten Morgen). In the further report these standalone greetings were counted as transfer message type. The last column of the previous table represents seldom the use of words like ‘please’ and ‘thank you’ in all other type of instructions.

6.3 Number of statements per controller utterance

A controller utterance framed by the pressed PTT switch may include one or more statements to the same AC. A statement represent all the different speeches a controller exchange with a pilot in the sense of an instruction (e.g. climb to FL 300), a request (e.g. report your heading) an acknowledgement/refuse of a pilot utterance (e.g. roger, negative) and a confirmation. In this report the expression ‘instruction’ is used in the global sense of all possible statements between controller and pilot.

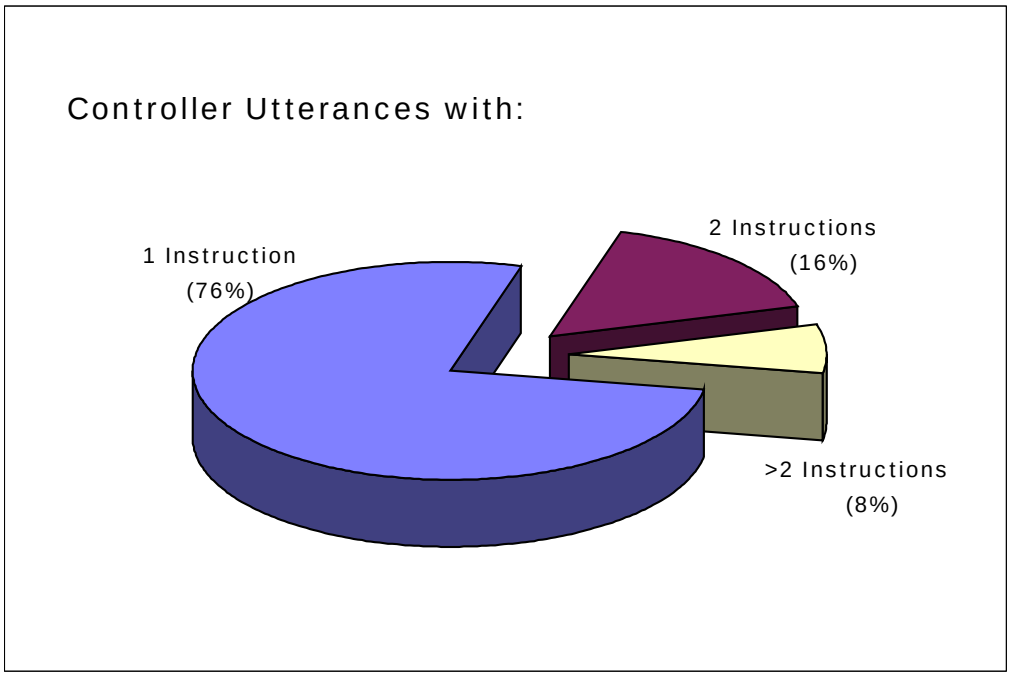


Figure 1: General Distribution of single and multiple- Instructions per utterance

In a small number of utterances (0,9%) the AC call-sign was used without any following instruction. In such a case the AC call-sign represents a positive acknowledgement instruction of the previous pilot utterance and may be understood in the context of the exchanged utterances only.

Controller utterances with more than 3 instructions have been very seldom (8 cases) and are treated like utterances with 3 instructions.

	general	Sölling.	Geneva	Zürich	male	female	no RVSM	single RVSM	double RVSM	+35% traffic	+55% traffic	+65% traffic
Nbr. of valid utt.:	9138	4431	796	3911	5243	3895	1498	3857	3783	2869	3747	2522
utt. with 0 instr. (AC-sign):	0,9%	0,5%	0,5%	1,5%	0,5%	1,5%	1,1%	1,2%	0,5%	0,6%	0,8%	1,5%
utt. with 1 instruction:	75,3%	86,4%	61,8%	65,5%	83,5%	64,3%	78,6%	72,8%	76,7%	86,5%	73,2%	65,7%
utt. with 2 instructions:	16,4%	11,2%	16,7%	22,2%	11,8%	22,7%	15,6%	18,3%	14,8%	11,1%	17,9%	20,3%
utt. with 3 or more instr.:	7,5%	2,1%	21,2%	10,8%	4,4%	11,6%	4,9%	7,9%	8,0%	2,0%	8,2%	12,5%
AC-instructions:	131,5%	115,6%	159,4%	143,8%	120,8%	145,9%	125,4%	134,4%	130,8%	115,3%	134,5%	145,3%
Nbr. of AC-instructions:	12012	5120	1269	5623	6331	5681	1879	5184	4949	3307	5041	3664

Table 11: Instructions per Controller Utterance (general)

	general	subj.A	subj.B	subj.C	subj.D	subj.E	subj.F	subj.G	subj.H	subj.I	subj.J	subj.L
Nbr. of valid utt.:	9138	1268	781	1079	1487	195	168	283	150	1543	593	1591
utt. with 0 instr. (AC-sign):	0,9%	0,2%	0,3%	0,6%	0,8%	0,0%	1,2%	0,4%	0,6%	2,1%	1,2%	1,2%
utt. with 1 instruction:	75,3%	90,1%	90,1%	84,0%	83,7%	63,1%	66,1%	59,1%	60,2%	59,6%	63,7%	69,0%
utt. with 2 instructions:	16,4%	8,4%	8,5%	14,3%	12,4%	15,4%	16,7%	18,3%	15,9%	25,3%	15,0%	23,6%
utt. with 3 or more instr.:	7,5%	1,3%	1,2%	1,5%	3,4%	22,1%	17,9%	22,2%	22,2%	13,0%	20,1%	6,3%
AC instructions:	131,5%	111,0%	110,8%	117,5%	119,7%	160,0%	154,2%	162,6%	159,1%	151,2%	155,1%	136,3%
Nbr. of AC-instructions:	12012	1407	865	1268	1780	312	259	418	280	2334	920	2169

Table 11: Instructions per Controller Utterance (subjects)

The number of instructions is far higher than the number of utterances. By this reason the percentage sum of the different instructions are higher then 100%.

6.3.1 Number of words per Utterance

The exploited utterances represents nearly 101 000 spoken words with about 510 000 characters. For the character count numbers were counted in their written form (e.g. 9 ➔ niner ➔ 5 characters), spaces are counted too.

	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
nbr. of utt.	9138	6959	1499	680	453
words per utt.	11,0	10,2	12,2	16,7	5,8
words per AC-sign part	4,1	4,2	3,9	4,4	0,0
words per instr. part	6,9	6,0	8,3	12,3	5,8

Table 12 : Mean Number of Words per Utterance (general)

Söllingen	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
nbr. of utt.	10,2	9,8	12,6	17,4	5,2
words per utt.	4,2	4,3	3,9	4,5	0,0
words per AC-sign part	6,0	5,5	8,7	12,9	5,2
words per instr. part	4433	3855	496	88	176
Geneva					
nbr. of utt.	12,1	11,2	11,5	15,1	6,7
words per utt.	4,0	4,0	3,5	4,1	0,0
words per AC-sign part	8,1	7,2	8,2	10,9	6,7
words per instr. part	794	495	135	168	60
Zürich					
nbr. of utt.	11,7	10,6	13,6	17,2	6,1
words per utt.	4,1	4,1	4,0	4,5	0,0
words per AC-sign part	7,6	6,5	9,6	12,7	6,1
words per instr. part	3911	2609	868	424	217

Table 13 : Mean Number of Words per Utterance (per sector)

6.3.2 Number of characters - duration of an utterance

The normal speaking speed of a controller is about 10 - 12 characters (space counted as a character) per second. Based on the figures from 6.3.1, the following estimations for the duration of an utterance have been calculated. A mean word is 5,05 characters long.

	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign	utt. AC-sign only
duration of a utt. (sec.)	5,0	4,7	5,6	7,7	2,7	1,9

Table 14 : Estimated duration of the spoken utterances

6.4 Distribution of instruction categories

For the reading of the following tables it have to been noticed that multiple instructions in the same utterance result in a multiple entrance of the tables. An example utterance "Alitalia 234 identified cleared Aosta, Saint Prex, Rollampont climb to flight level 300" will be counted for 'transfer', 'clearance' and 'level-change' and so the vertical percentage sum of all instruction types will be greater 100%.

	general	Sölling.	Geneva	Zürich	male	female	no RVSM	single RVSM	double RVSM	+35% traffic	+55% traffic	+65% traffic
nbr of valid utt.:	9138	4431	796	3911	5243	3895	1498	3857	3783	2869	3747	2522
transfer'	60,2%	64,0%	61,9%	55,5%	63,0%	56,4%	59,8%	59,1%	61,4%	63,5%	60,3%	56,2%
level-change'	26,8%	18,2%	40,1%	33,9%	21,0%	34,7%	22,1%	27,2%	28,3%	17,9%	28,8%	34,1%
clearance'	15,4%	9,2%	28,8%	19,6%	11,5%	20,6%	13,0%	17,0%	14,7%	8,8%	16,5%	21,1%
manoeuvre'	10,1%	10,7%	7,4%	10,0%	10,1%	10,2%	12,8%	10,5%	8,7%	11,0%	10,0%	9,3%
miscellaneous'	4,3%	3,5%	4,4%	5,1%	3,9%	4,8%	3,9%	4,4%	4,3%	3,5%	3,9%	5,7%
ident'	3,6%	0,1%	5,4%	7,2%	1,2%	6,8%	1,7%	4,6%	3,3%	0,1%	3,6%	7,4%
report'	2,7%	3,3%	3,1%	1,9%	3,3%	2,0%	3,4%	2,6%	2,5%	3,8%	2,3%	2,1%
speed'	0,3%	0,4%	0,1%	0,1%	0,4%	0,1%	0,5%	0,2%	0,3%	0,6%	0,1%	0,1%
cruising'	0,0%	0,0%	0,0%	0,1%	0,0%	0,1%	0,0%	0,1%	0,0%	0,0%	0,1%	0,0%
roger	4,2%	2,6%	4,4%	6,0%	2,9%	6,1%	4,6%	4,5%	3,8%	2,6%	5,0%	5,0%
confirm	0,7%	0,6%	0,6%	0,9%	0,7%	0,8%	0,5%	0,7%	0,8%	0,7%	0,6%	1,0%
affirm	0,4%	0,6%	0,8%	0,2%	0,7%	0,1%	0,3%	0,5%	0,5%	0,6%	0,4%	0,3%
negative	0,3%	0,3%	0,3%	0,2%	0,2%	0,3%	0,2%	0,2%	0,3%	0,3%	0,2%	0,2%

Table 15: Distribution of the different Instruction Types (general)

The Söllingen sector may be classified as pure 'horizontal sector'. It does not include geographically any civil international airport. Zürich and Geneva sector covers geographically major airports and have therewith horizontal and vertical traffic. This sector difference result in a significant unequal distribution of the controller instruction types and shows the inconsistency of the sector working methods.

The 'male – female' results are not significant as they are strongly related with the sectors (Söllingen male only).

Using RVSM increase level and clearance commands but reduce significantly the manoeuvre instructions.

Increasing traffic workload seems to result in significant change of the working methods. The controller reduce manoeuvring the aircraft and increase clearance and level change commands.

	general	subj.A	subj.B	subj.C	subj.D	subj.E	subj.F	subj.G	subj.H	subj.I	subj.J	subj.L
nbr of valid utt.:	9138	1268	781	1079	1487	195	168	283	150	1543	593	1591
transfer'	60,2%	65,7%	70,0%	62,9%	56,9%	62,6%	57,1%	66,5%	59,1%	57,4%	56,3%	55,3%
level-change'	26,8%	14,7%	15,2%	20,9%	20,7%	41,5%	35,1%	39,3%	44,3%	32,7%	44,4%	33,1%
clearance'	15,4%	7,0%	8,8%	10,4%	10,0%	26,2%	27,4%	28,4%	33,5%	24,6%	24,6%	14,5%
manoeuvre'	10,1%	10,6%	9,0%	6,5%	13,9%	7,7%	6,5%	10,1%	4,0%	11,0%	10,1%	9,8%
miscellaneous'	4,3%	4,1%	2,3%	4,0%	4,4%	5,6%	6,0%	4,3%	1,7%	5,1%	6,9%	3,6%
ident'	3,6%	2,1%	0,1%	0,1%	0,0%	5,1%	5,4%	5,8%	5,1%	7,4%	5,2%	6,9%
report'	2,7%	1,5%	1,8%	3,7%	5,6%	2,1%	6,5%	1,9%	2,8%	2,1%	2,0%	1,4%
speed'	0,3%	0,2%	0,0%	0,3%	1,1%	0,0%	0,6%	0,0%	0,0%	0,1%	0,0%	0,0%
cruising'	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,2%	0,0%	0,0%
roger	4,2%	1,7%	2,2%	4,4%	2,4%	4,6%	4,2%	3,1%	6,3%	6,2%	2,5%	7,5%
confirm	0,7%	1,5%	0,4%	0,6%	0,3%	0,5%	0,6%	0,8%	0,6%	0,8%	1,0%	0,7%
affirm	0,4%	0,6%	0,0%	0,2%	1,5%	1,5%	0,6%	0,4%	0,6%	0,2%	0,0%	0,0%
negative	0,3%	0,2%	0,0%	0,2%	0,5%	0,0%	1,2%	0,0%	0,0%	0,0%	0,5%	0,4%

Table 16: Distribution of the different Instruction Types (subject)

6.5 Distribution of single and multiple instructions in an utterance

The ICAO phraseology aloes the use of more than one instruction per utterance for the same AC. In this case the combined instructions were classified and analysed under the type of the first pronounced instruction type only.
If, by special reasons (busy environment), more than one AC have to be addressed in a single utterance the instructions have to be separated by the double word “break break”. During the recordings 16 times a single “break” were used to separate instructions for different AC and once the double “break break”. In the case of using the word “break” in an utterance the messages for the different AC have been treated like a second, new utterances.

A maximum of 4 instructions in an utterance for a single AC were used by the recorded controllers. However this was the case in 8 of the nearly 10 000 spoken utterances only. These cases have been ignored for analysis and treated like an utterance with 3 instructions.

The following graphs show the distribution (first, second or third instruction) of the different instruction categories within an utterance in general and for the specific sectors. No difference is made for single or multiple instructions (percentage is based on valid spoken utterances).

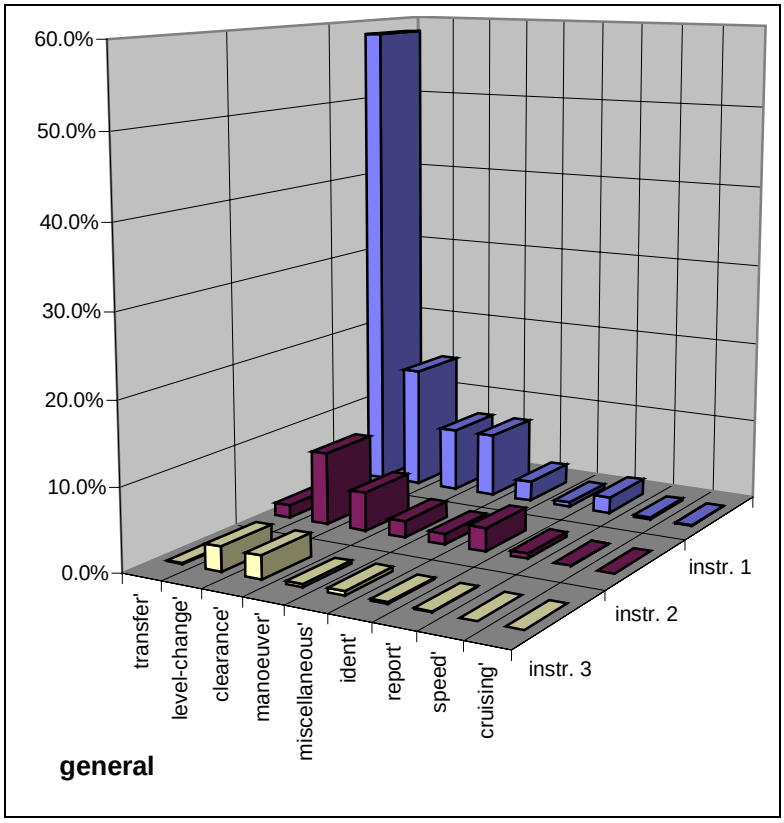


Figure 2: Distribution of Instruction types (general) in an Utterance

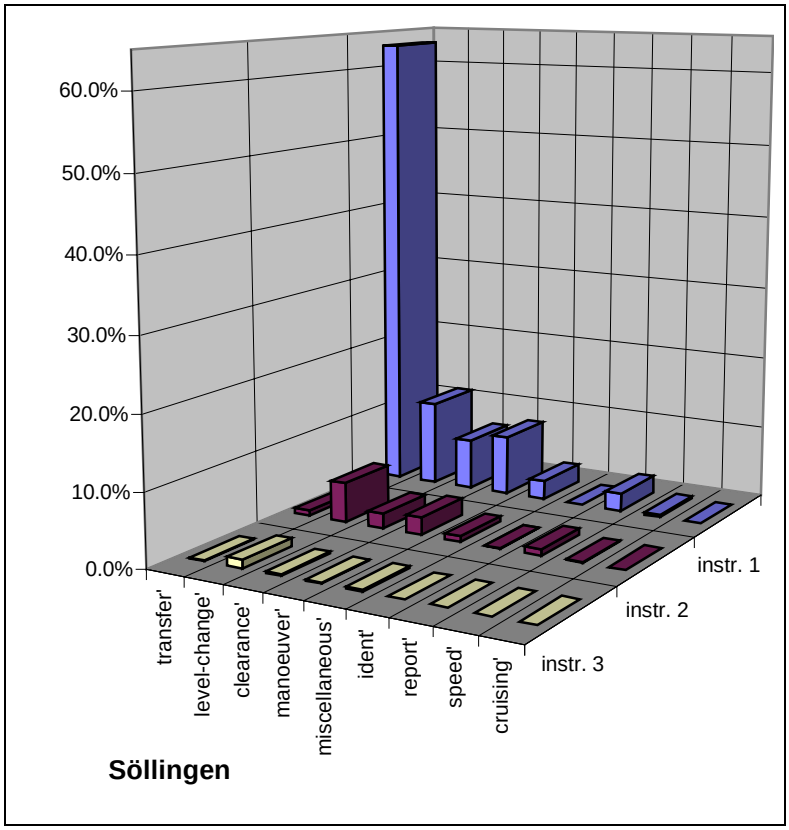


Figure 3: Distribution of Instruction types (Söllingen) in an Utterance

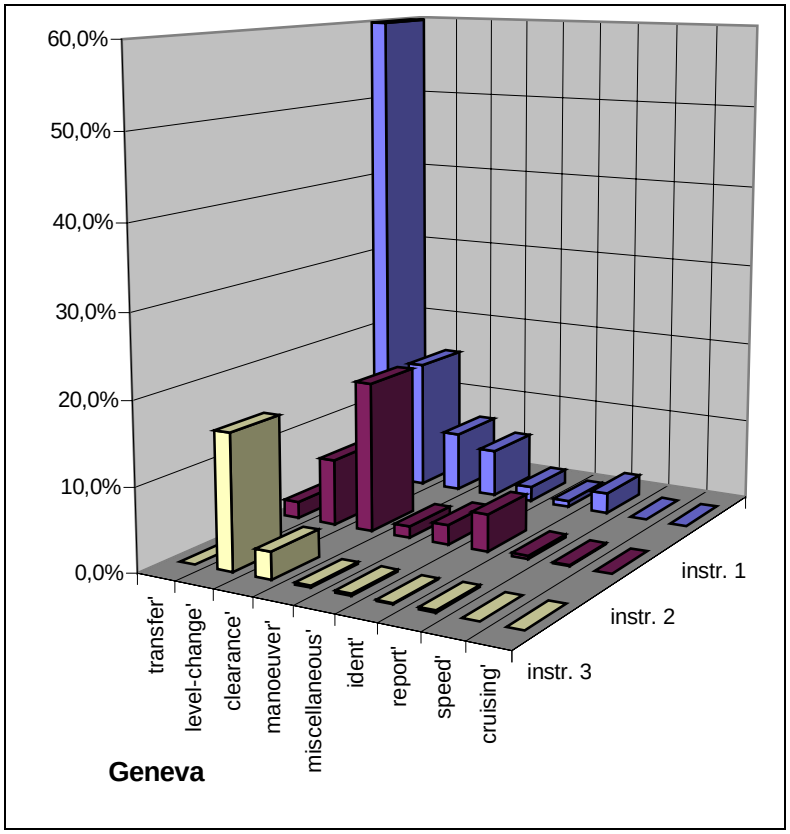


Figure 4: Distribution of Instruction types (Geneva) in an Utterance

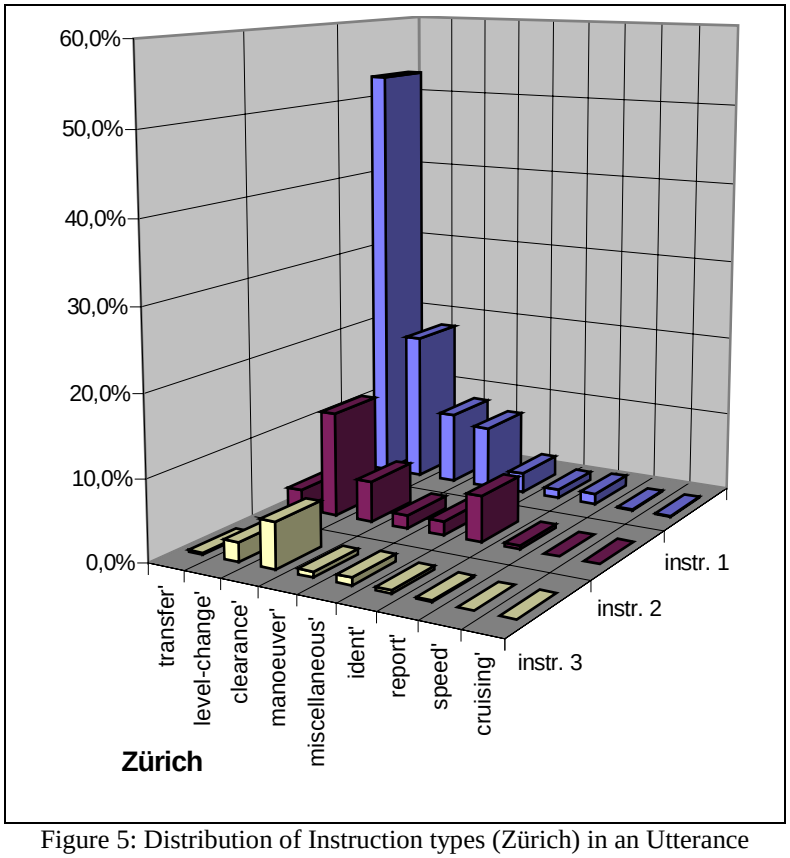


Figure 5: Distribution of Instruction types (Zürich) in an Utterance

The detailed distribution of instructions categories in relation to simulation aspects are shown in appendix B; to subjects are in appendix C.

7 Detailed Results

The frequency of some instruction types are very low. Only 3 ‘cruising’ instructions (of nearly 10 000 utterances) have be given, so this one is ignored in this chapter. Other instructions with common or opposite meaning have been assembled for the analyse. These have been the case for the types ‘confirm’ - ‘affirm’ and ‘roger’ - ‘negative’.

For these analysis the instructions are classified by the starting instruction of a controller utterance. I.e. the utterance; ‘Aerolloyd five niner zero Rhein Radar identified direct to Trasadingen climb flight level tree zero zero’ include 3 different instructions for the same AC and will be analysed as ‘transfer – in’ instruction. AC callsign are skipped for analysis. Utterances with missing AC callsign are treated as the previous ones but specified with a frequency number.

7.1 Transfer Instruction

When an AC is entering an ATC control sector in general the first controller message for this AC is may be “Speedbird one two three four radar contact”. The last controller message for the AC leafing the sector could be e.g. “Speedbird one two tree four contact Rhein Control frequency one three two decimal four”. These types of controller instructions we classified as transfer instructions. The recommended structures are given in appendix A3.1.

7.1.1 Courtesy forms in transfer instructions

As the ICAO recommendation’s are a specific command language no form of politeness is foreseen. It seems to be reasonable to accept a minimum of courtesy for transfer messages between AC and ATC centre. The first controller message for an AC entering his sector could be i.e. “Good morning Speedbird one two three four radar contact”.

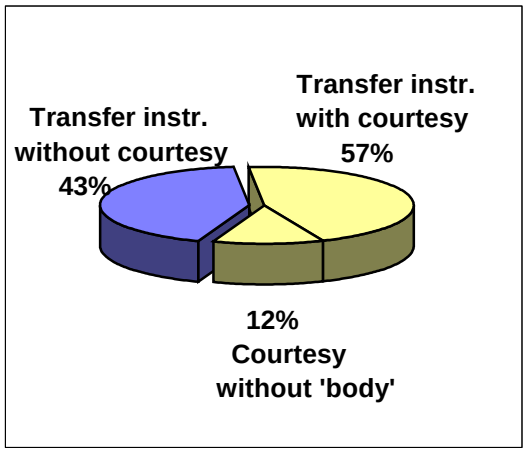


Figure 6: Distribution of Courtesy Forms

all utterances	9138
all utterances with transfer	5367
utt. with transfer and courtesy	3077

Table 17: Distribution of Courtesy Forms

all utterances with transfer	5367
transfer instr. without courtesy	42,9%
transfer instr. with courtesy	45,1%
courtesy without transfer 'body'	12,0%

Table 18: Transfer instructions and Courtesy Forms

In the recordings many times such a message was reduced to “Good morning Speedbird one two three four”. For this analysis all utterances with any formula of politeness (sense of ‘good morning’) were counted as a transfer instruction without ‘body’.

The following forms of politeness cover over 85% of all utterances with courtesy in the exploited simulation:

English: good afternoon, good day, good morning, morning, good bye, bye,
German/Swiss: guten Tag, guten Morgen, Tag, Morgen, tschüss, grützi,
French: bonjour, au revoir,

Controllers show a tendency to use greetings in the language of the country where the AC is coming.

7.1.2 Instructions attached to a Transfer Instruction

For an ACC sector, the 'transfer' is the message with the highest frequency (mean 60,2%). Therefore it is given mainly isolated in an single utterance.

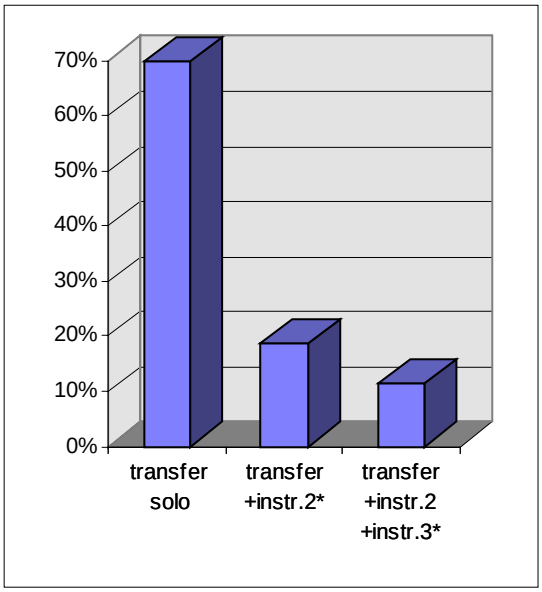


Figure 7: Transfer and instr. per utterance (general)

all transfer messages	5367	
transfer solo	3757	70,0%
transfer +instruction2*	995	18,5%
transfer +instr.2+instr.3*	615	11,5%

Table 19: Transfer and instr. per utterance (general)

* Remark: the number 'transfer +instruction2' does not include the number of 'instr.2' of the line 'transfer +instr.2 +instr.3', but this last one include the 15 utterances with 4 instructions.

The previous graph and table gives a general idea of the relation of the transfer instruction and other types of instruction in the same utterance. As the "Good Morning" may replace the 'body' (12% of all transfer instr. see fig. 6) of the transfer instruction the following two graphs split the previous one under this aspect.

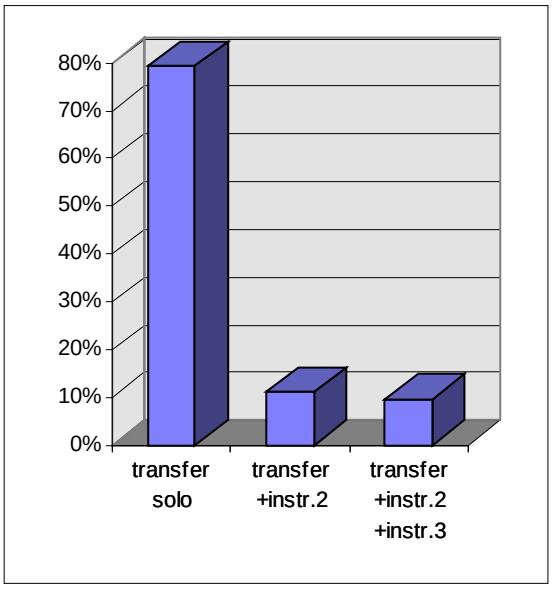


Figure 8: Transfer and instr./utt. (with body)

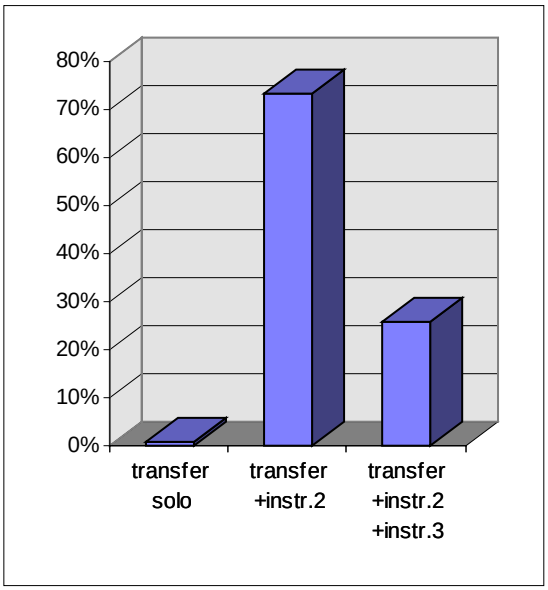


Figure 9: Transfer and instr./utt. (without body)

Fig. 9 shows that in nearly all cases (over 99%) in which the courtesy form stands for a transfer 'body' one or more instructions are following. If the transfer 'body' (with or without courtesy) is present (fig.8) in nearly 80% no other instruction follows.

The next three graphs gives details on the type of instructions attached to a transfer type instruction at the first place of an utterance. They represent the same aspects as the previous three.

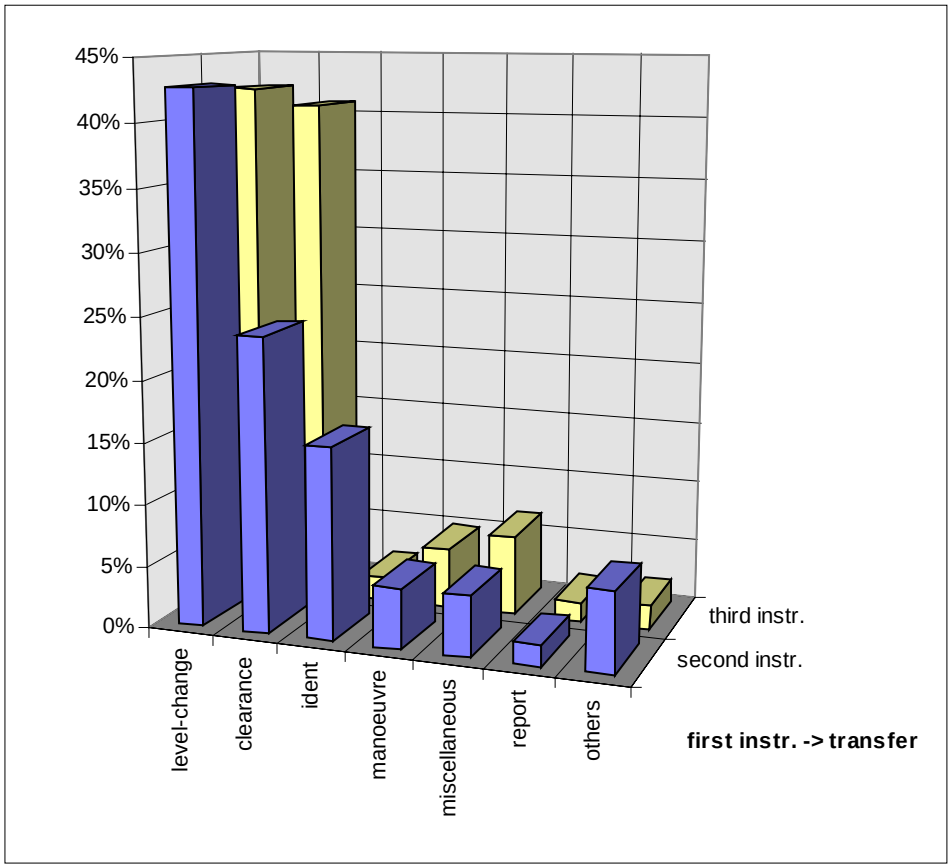


Figure 10: Distribution of instr. types in an utterance with transfer as first instr. (general)

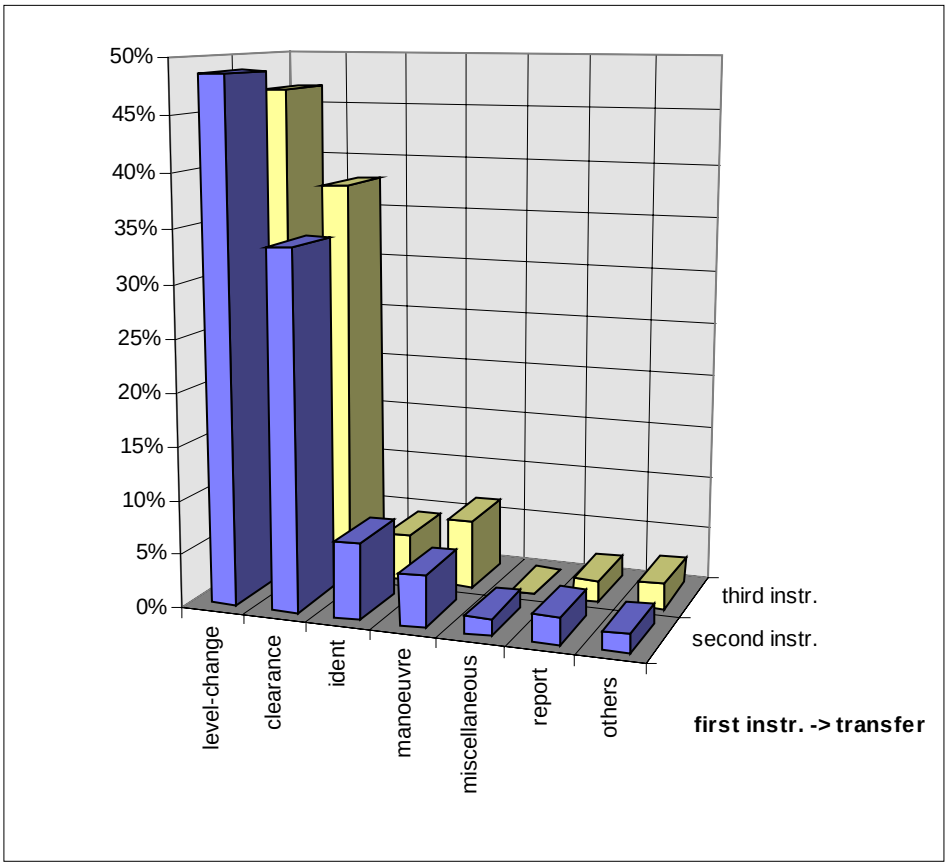


Figure 11: Distribution of instr. types in an utterance with transfer as first instr. (with body)

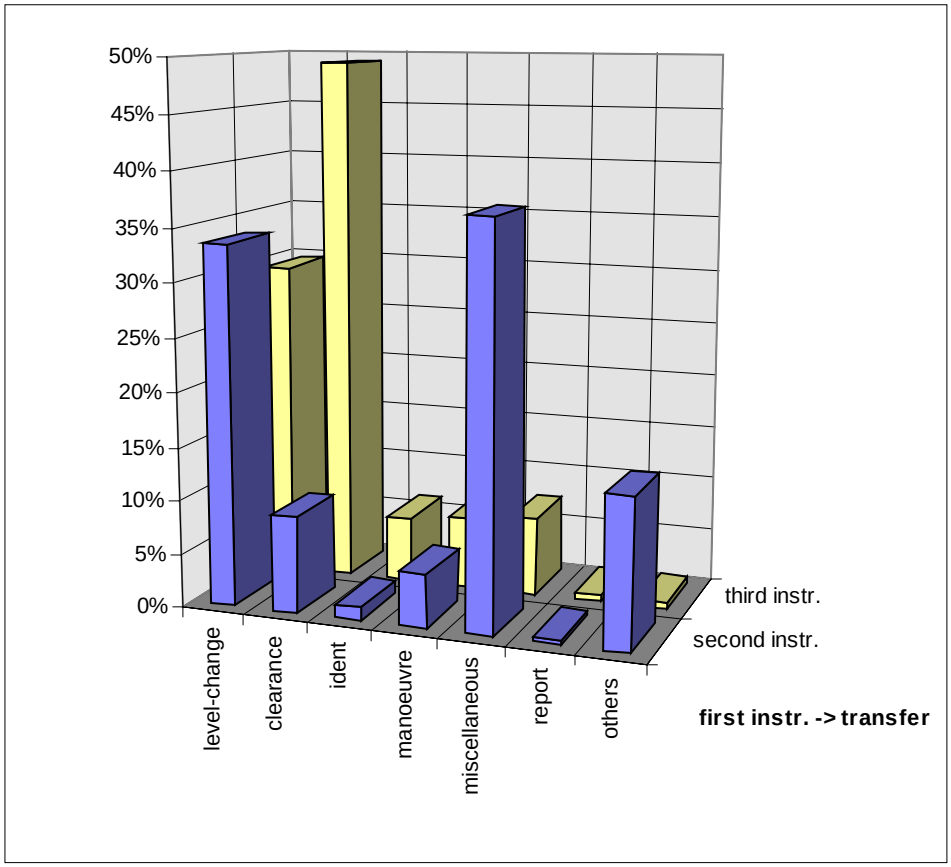


Figure 12: Distribution of instr. types in an utterance with transfer as first instr. (without body)

7.1.3 Number of words per 'transfer' utterance

all transfer-utt.	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
nbr. of utt.	5367	3757	995	615	67
words per utt.	11,7	10,7	12,3	16,7	8,0
words per AC-sign part	4,3	4,3	4,4	4,5	0
words per instr. part	7,3	6,3	7,9	12,3	8,0
with transfer-'body'					
nbr. of utt.	4725	3750	525	450	-
words per utt.	11,7	10,7	13,2	17,5	-
words per AC-sign part	4,3	4,3	4,4	4,5	-
words per instr. part	7,2	6,3	8,8	13,0	-
without transfer-'body'					
nbr. of utt.	642	6	471	165	*
words per utt.	12,1	6,5	11,2	14,7	-
words per AC-sign part	4,3	4,5	4,3	4,4	-
words per instr. part	7,8	2,0	6,9	10,3	-

Table 20 : Mean number of words per 'transfer' utterance

*Remark: The number of 'transfer' utterances without transfer 'body' was to small (3) to calculate values.

7.1.4 Mean duration of a 'transfer' utterance

Based on the values from 6.3.2 the estimation for the mean duration of speaking a 'transfer' utterance (including the AC call-sign) can be calculated:

	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
duration of a utt. (sec.)	5,4	4,9	5,7	7,7	3,7

Table 21 : Estimated duration of a spoken 'transfer' utterances

7.1.5 Transfer phraseology

To analyse the controller utterance the transcript phrases have been normalised. The AC callsign at the begin of an utterance was replace by an indicator field – yes or no – AC callsign present. A callsign at any other place of the phrase was replaced by the text '<callsign>'. Courtesy forms mentioned in 7.1.1 have been eliminated. All other sector specific names for navigation points, control centre names and their communication frequencies have been replaced by placeholders (<nav-point>, <station>, <frq-nbr>). No difference for a navigation point e.g. 'NTM', was made if the expression 'November Tango Mike' or 'Nattenheim' was pronounced. Similar for the frequencies (correct or only partly). All other numbers have been replaced by a placeholder '<nbrX>'. 'X' is indicating the number of digits used for this placeholder. Words for AC manoeuvres like 'left', 'right', 'climb' or 'descend' are replaced by the placeholders <left-right> or <climb-descend>.

Example:
'Lufthansa three five five six good morning Rhein Radar identified turn right by one five degrees and climb flight level two niner zero'
will be normalised as:
'<station> Radar identified turn <left-right> by <nbr2> degrees and <climb-descend> flight level <nbr3>'.

For the normalisation of the other types of instruction (level change, manoeuvre, ….) the same placeholder typology will be used.

Up to now the message category transfer including controller phrases for AC entering and leaving a sector. For the detailed analyse controller's transfer utterances are spliced in two categories:

- messages to AC entering the sector are called 'transfer (in),
- messages to AC leaving the sector are called 'transfer (out)'.

7.1.5.1 Transfer (in) utterances

	all transfer	transfer (solo)	tra. with 1 instr.	tra. with >1 instr.	utt. without AC-sign
Nbr. of transfer (in) utt.	2834	1228	991	615	6

Table 22 : Number of 'transfer (in)' utterances

For the 'transfer (in) solo' category we isolated 53 different ways of saying. And 667 different phrases if one or more instructions are attached to the transfer (in) utterance. For more details please see annex D.

The following normalised utterance (transfer solo) are the most used one with a frequency of more than 1%.

- identified
- radar contact
- <station> radar identified
- is identified
- <station> identified
- is in radar contact
- <station>
- in radar contact

transfer (solo) messages	1228	
10 most frequent	1135	95,1%
20 most frequent	1159	97,2%

Table 23: Frequency of transfer (in) solo utterance

The 10 most used normalised utterance (transfer with attached one or more instruction) have a frequency of more than 2%. The transfer (in) instruction may be based on 'greetings' suppressed by the normalisation.

- squawk <nbr4>
- roger
- <climb-descend> to flight-level <nbr3>
- radar contact <climb-descend> flight-level <nbr3>
- is identified <climb-descend> to flight-level <nbr3>
- radar contact maintain flight-level <nbr3> <nav-point> <nav-point>
- maintain flight-level <nbr3> <nav_point> <nav_point>
- <station> radar identified <climb-descend> flight-level <nbr3>
- identified <climb-descend> flight-level <nbr3>
- identified cleared <nav-point> <nav-point> flight-level <nbr3>

transfer + >1 instr.	991	
10 most frequent	547	56,0%
20 most frequent	649	66,4%

Table 24: Frequency of transfer (in) utterance including other instructions

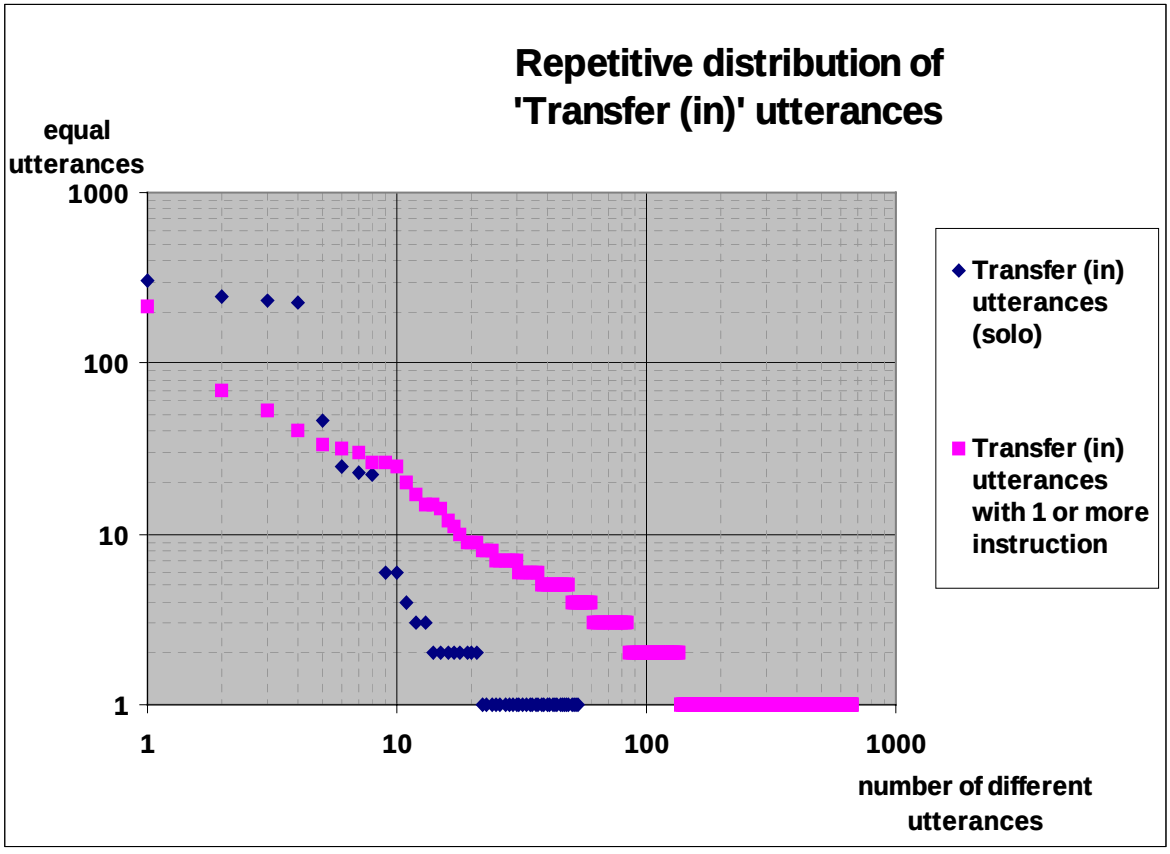


Figure 13: Repetitive distribution of 'Transfer (in) utterances

7.1.5.2 Transfer (out) utterances

	all transfer	transfer (solo)	tra. with 1 instr.	tra. with >1 instr.	utt. without AC-sign
Nbr. of transfer (out) utt.	2533	2529	4	0	55

Table 25 : Number of 'transfer (out)' utterances

Instructing the pilots to contact another ATC centre was very seldom accomplished by a further message, but we counted 135 different ways of saying. More details in annex D.

The following normalised utterance (transfer solo) are the most used one with a frequency of more than 1%.

- contact <station> <frq-nbr>
- <station> <frq-nbr>
- contact <station> on <frq-nbr>
- contact <station> radar <frq-nbr>
- call <station> on <frq-nbr>
- <station> radar <frq-nbr>
- call <station> <frq-nbr>
- contact <station> control on <frq-nbr>

transfer (solo) messages	2529	
10 most frequent	2259	89,8%
20 most frequent	2366	94,1%

Table 26: Frequency of transfer (out) solo utterance

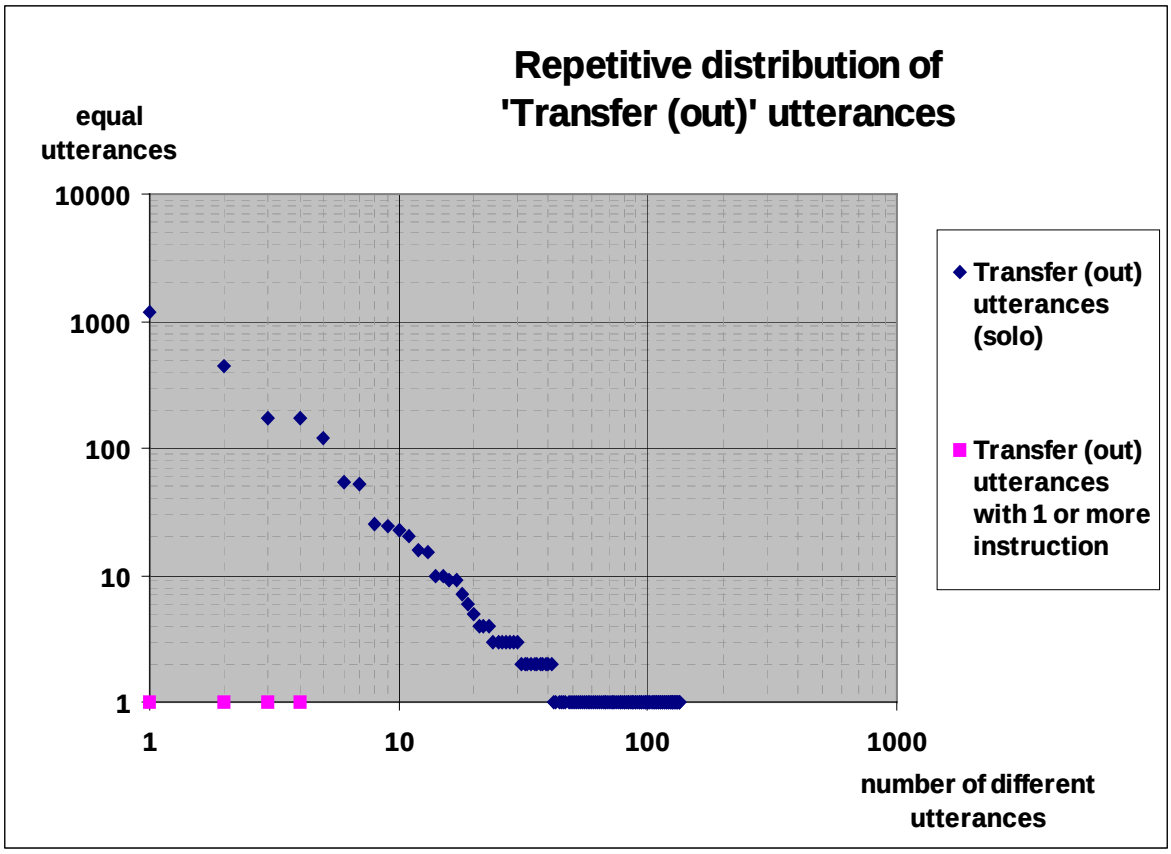


Figure 14: Repetitive distribution of 'Transfer (out) utterances

7.2 Change Flight Level Instruction

7.2.1 Instructions attached to a Change Flight level Instruction

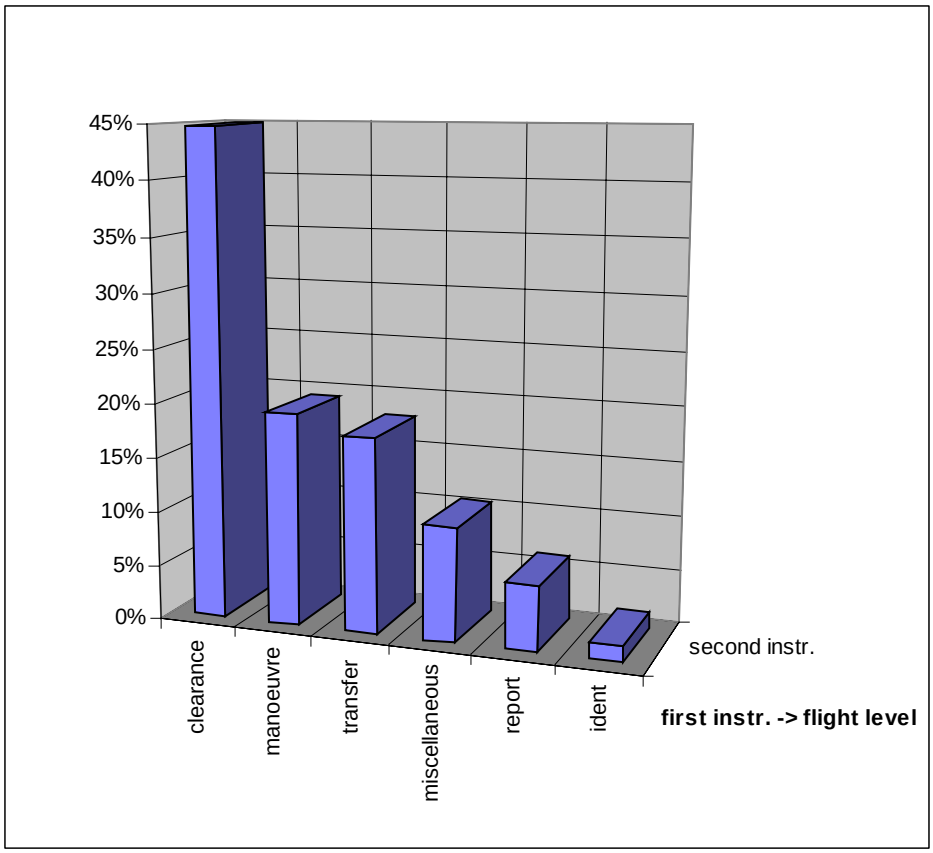


Figure 15: Distribution of instructions types in an utterance with change 'fight level' as first instr.

7.2.2 Number of Words per Change Flight Level Instruction

all flight level-utt.	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
nbr. of utt.	1365	1282	80	3	18
words per utt.	11,9	11,6	16,1	18,7	8,8
words per AC-sign part	4,3	4,3	4,3	4,6	0
words per instr. part	7,6	7,3	11,8	14,1	8,8

Table 27 : Mean number of words per change 'flight level' utterance

7.2.3 Mean duration of a Change Flight Level Instruction

Based on the values from 6.3.2 the estimation for the mean duration of speaking a change 'flight level' utterance (including the AC call-sign) can be calculated:

	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
duration of a utt. (sec.)	5,5	5,3	7,4	8,6	4,0

Table 28 : Estimated duration of a spoken change 'flight level' utterances

7.2.4 Change Flight Level Instruction Phraseology

The normalisation of the utterance was done similar to under 7.1.5 described.

	all flight level	flight level (solo)	lev. with 1 instr.	lev. with >1 instr.	utt. without AC-sign
Nbr. of flight level utt.	1365	1282	80	3	18

Table 29 : Number of 'change flight level' utterances

For the controller to pilot instruction to change the AC flight level we counted 211 different ways of doing. The following utterance are the most one used with an frequency of ten at least. More details in annex D.

- <climb-descend> to flight level <nbr3>
- <climb-descend> flight level <nbr3>
- <climb-descend> now flight level <nbr3>
- <climb-descend> now to flight level <nbr3>
- continue <climb-descend> to flight level <nbr3>
- <climb-descend> to level <nbr3>
- continue <climb-descend> flight level <nbr3>
- <climb-descend> <nbr3> now

Change flight level msg.	1282	
10 most frequent	1019	79,5%
20 most frequent	1059	82,6%

Table 30: Frequency of change flight level (solo) utterance

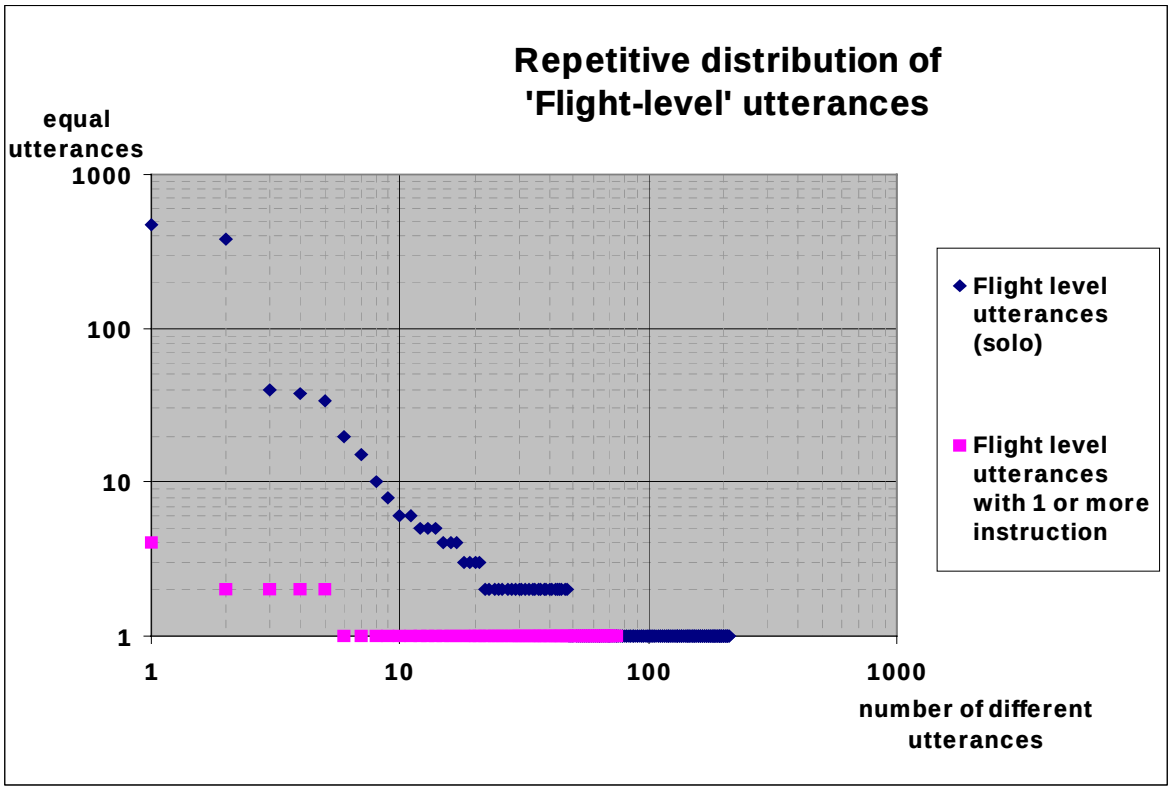


Figure 16: Repetitive distribution of 'Change Flight Level' utterances

7.3 Clearance Instruction

7.3.1 Instructions attached to a Clearance Instruction

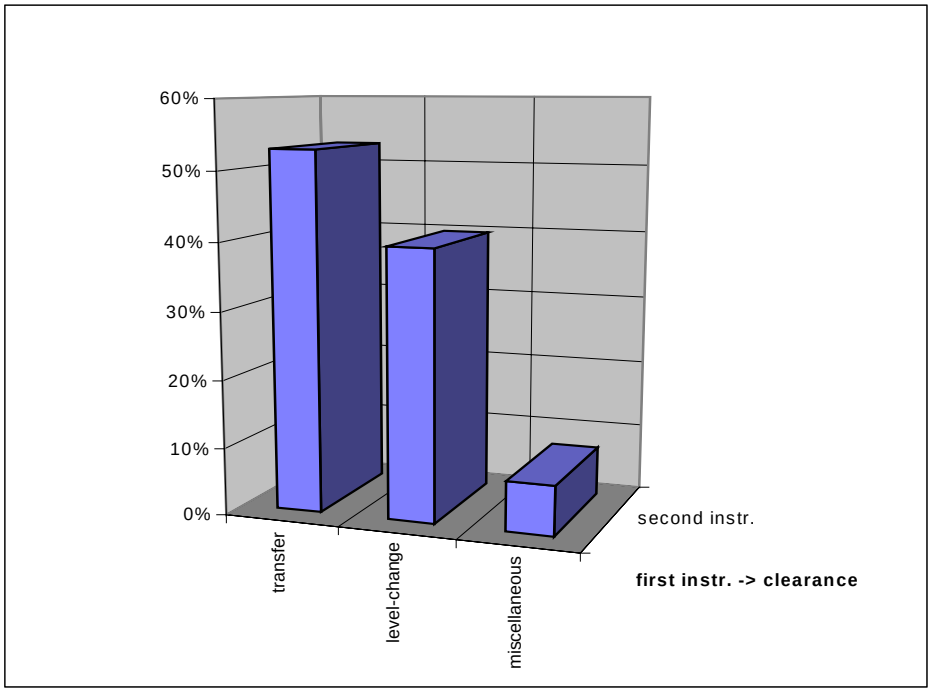


Figure 17: Distribution of instructions types in an utterance with 'clearanc' as first instr.

7.3.2 Number of Words per Clearance Instruction

all clearance-utt.	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
nbr. of utt.	721	650	71	0	16
words per utt.	9,4	8,7	16,2	0	6,9
words per AC-sign part	4,2	4,2	4,0	0	0
words per instr. part	5,1	4,5	12,7	0	6,9

Table 30 : Mean number of words per 'clearance' utterance

7.3.3 Mean duration of a Clearance Instruction

Based on the values from 6.3.2 the estimation for the mean duration of speaking a 'clearance' utterance (including the AC call-sign) can be calculated:

	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
duration of a utt. (sec.)	4,3	4,0	7,5	0	3.2

Table 31 : Estimated duration of a spoken 'clearance' utterances

7.3.4 Clearance Instruction Phraseology

The normalisation of the utterance was done similar to under 7.1.5 described.

	all clearance	clearance (solo)	clr. with 1 instr.	clr. with >1 instr.	utt. without AC-sign
Nbr. of clearance utt.	721	650	71	0	16

Table 32 : Number of 'clearance' utterances

Give a clearance to the pilot we counted 168 different ways of doing (clearance solo). The following utterance are the most one used with an frequency of two percent at least. More details in annex D.

- proceed direct to <nav-point>
- direct <nav-point>
- direct to <nav-point>
- set course direct to <nav-point>
- all navigation <nav-point>
- set course to <nav-point>
- proceed to <nav-point>
- own navigation to <nav-point>
- set course direct <nav-point>
- on navigation to <nav-point>
- proceed direct <nav-point>
- all navigation to <nav-point>

Clearance message.	650	
10 most frequent	361	55,5%
20 most frequent	445	68,5%

Table 33: Frequency of clearance (solo) utterance

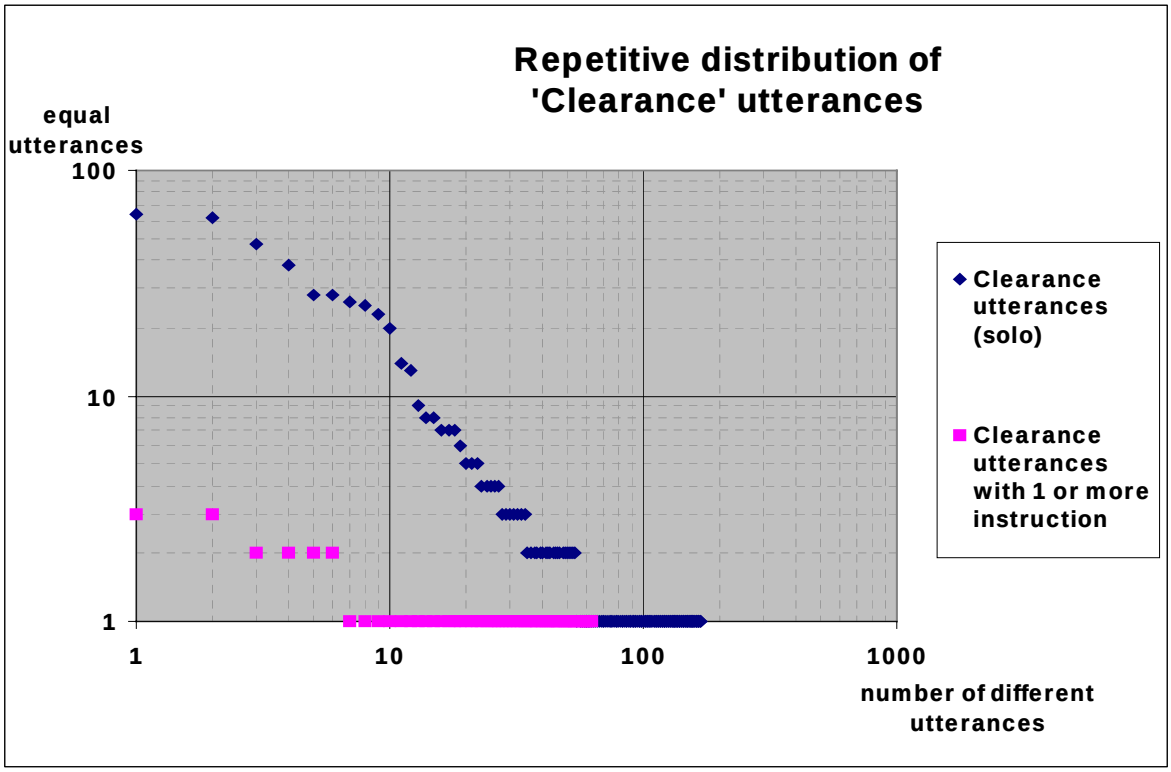


Figure 18: Repetitive distribution of 'Clearance' utterances

7.4 Manoeuvre Instruction

7.4.1 Instructions attached to a Manoeuvre Instruction

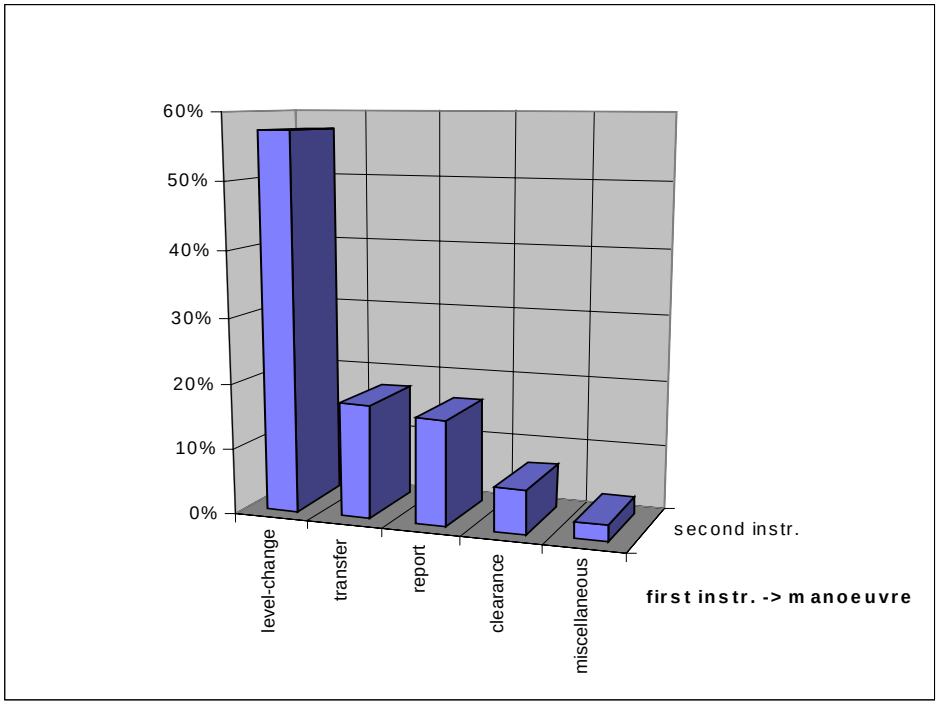


Figure 19: Distribution of instructions types in an utterance with 'manoeuvre' as first instruction

7.4.2 Number of Words per Manoeuvre Instruction

all manoeuvre-utt.	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
nbr. of utt.	715	634	76		9
words per utt.	10,4	9,9	15,3		6,5
words per AC-sign part	4,2	4,2	4,2		0
words per instr. part	6,3	5,7	11.1		6,5

Table 34 : Mean number of words per 'manoeuvre' utterance

7.4.3 Mean duration of a Manoeuvre Instruction

Based on the values from 6.3.2 the estimation for the mean duration of speaking a 'manoeuvre' utterance (including the AC call-sign) can be calculated:

	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
duration of a utt. (sec.)	4,8	4,6	7,0		3,0

Table 35 : Estimated duration of a spoken 'manoeuvre' utterances

7.4.4 Manoeuvre Instruction Phraseology

The normalisation of the utterance was done similar to under 7.1.5 described.

	all manoeuvre	manoeuvre (solo)	man. with 1 instr.	man. with >1 instr.	utt. without AC-sign
Nbr. of manoeuvre utt.	715	634	76	5	9

Table 36 : Number of 'manoeuvre' utterances

To manoeuvring an AC we counted 168 different phrases (manoeuvre solo). The following utterance are the most one used with an frequency of ten at least. More details in annex D.

- turn <left-right> to <nav-point>
- turn <left-right> heading <nbr3>
- turn <left-right> <nbr2> degrees
- turn <left-right> by <nbr2> degrees
- fly heading <nbr3>
- <left-right> heading <nbr2> degrees
- <left-right> turn to <nav-point>
- heading of <nbr3>
- turn <left-right> to <nav-point> <nav-point>
- <left-right> turn <nbr2> degrees

manoeuvre message.	634	
10 most frequent	347	54,7%
20 most frequent	404	63,7%

Table 37: Frequency of manoeuvre (solo) utterance

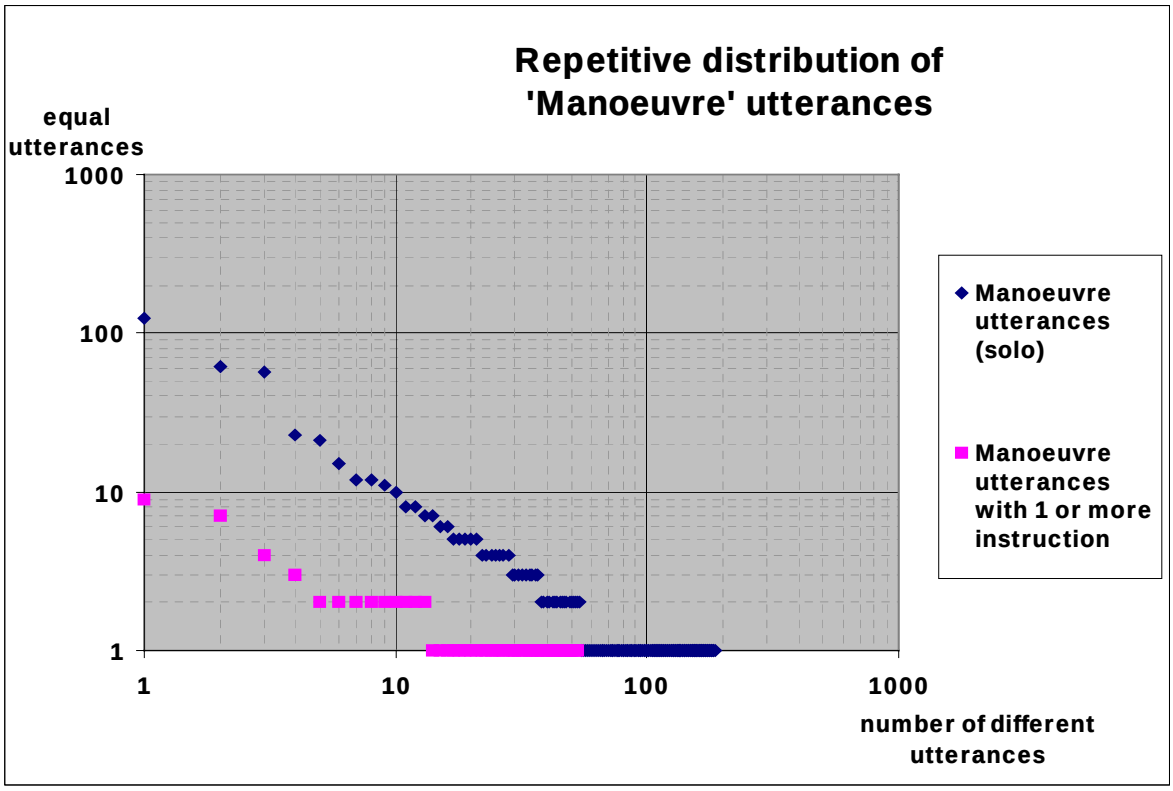


Figure 20: Repetitive distribution of 'Manoeuvre' utterances

7.5 Miscellaneous Instruction

7.5.1 Number of Words per Miscellaneous Instruction

all miscellaneous-utt.	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
nbr. of utt.	223	209	14	0	75
words per utt.	7,7	6,8	17,7	0	4
words per AC-sign part	2,4	2,4	3,3	0	0
words per instr. part	5,2	4,4	14,4	0	4

Table 38 : Mean number of words per 'miscellaneous' utterance

Remark: This instruction type shows an excessive number of utterances without attached AC callsign (over 1/3 of all utterances). This explain the variation the mean length of the AC-sign part with other instruction types.

7.5.2 Mean duration of a Miscellaneous Instruction

Based on the values from 6.3.2 the estimation for the mean duration of speaking a 'miscellaneous' utterance (including the AC call-sign) can be calculated:

	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
duration of a utt. (sec.)	3,5	3,1	8,1		1,8

Table 39 : Estimated duration of a spoken 'miscellaneous' utterances

7.5.3 Miscellaneous Instruction Phraseology

The normalisation of the utterance was done similar to under 7.1.5 described.

	all miscellaneous	miscellaneous (solo)	mis. with instr.	utt. without AC-sign
Nbr. of miscellaneous utt.	223	209	14	75

Table 40 : Number of 'miscellaneous' utterances

The following utterance are the most one used with an frequency of three at least. More details in annex D.

- say again
- thank you
- <only the call-sign>
- calling
- okay
- correct
- I call you back
- say again your callsign
- <station>
- <station> radar do you read
- are you on frequency
- stand by

miscellaneous message.	223	
10 most frequent	73	32,7%
20 most frequent	95	42,6%

Table 41: Frequency of miscellaneous (solo) utterance

7.6 Squawk Instruction

7.6.1 Number of Words per Squawk Instruction

all squawk-utt.	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
nbr. of utt.	47	47			3
words per utt.	9,1	9,1			4,7
words per AC-sign part	4,0	4,0			0
words per instr. part	5,2	5,2			4,7

Table 42 : Mean number of words per 'squawk' utterance

7.6.2 Mean duration of a Squawk Instruction

Based on the values from 6.3.2 the estimation for the mean duration of speaking a 'squawk' utterance (including the AC call-sign) can be calculated:

	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
duration of a utt. (sec.)	4,2	4,2			2,2

Table 43 : Estimated duration of a spoken 'squawk' utterances

7.6.3 Squawk Instruction Phraseology

The following utterance are the most one used with an frequency of two at least.

- squawk <nbr4>
- squawk now <nbr4>

squawk message.	47	
10 most frequent	46	97,9%
20 most frequent	47	100%

Table 44: Frequency of squawk (solo) utterance

7.7 Report Instruction

7.7.1 Number of Words per Report Instruction

all report-utt.	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
nbr. of utt.	180	174	6		8
words per utt.	8,3	8,2	13,5		4,9
words per AC-sign part	4,1	4,2	4,4		0
words per instr. part	4,2	4,0	11,2		4,9

Table 45 : Mean number of words per 'report' request utterance

7.7.2 Mean duration of a Report Instruction

Based on the values from 6.3.2 the estimation for the mean duration of requesting a 'report' (including the AC call-sign) can be calculated:

	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
duration of a utt. (sec.)	3,8	3,8	5,2		2,3

Table 46 : Estimated duration of a spoken 'report' request utterances

7.7.3 Report Instruction Phraseology

The normalisation of the utterance was done similar to under 7.1.5 described.

	all report	report (solo)	rep. with 1 instr.	utt. without AC-sign
Nbr. of report utt.	180	174	6	8

Table 47 : Number of 'report' utterances

To request an AC report we counted 54 different ways of doing (report solo). The following utterance are the most one used with an frequency of ten at least. More details in annex D.

- report your heading
- report your mach number
- report heading
- report your rate of <climb-descend>
- your heading

report message.	180	
10 most frequent	124	68,9%
20 most frequent	140	77,8%

Table 48: Frequency of report (solo) utterance

7.8 Speed Instruction

The number of utterances with a speed instruction at the first place was 19. More phraseology details in annex D.

7.9 Cruising Instruction

The number of utterances with a cruising instruction at the first place was 3.

7.10 'Roger/Negative' Instruction

7.10.1 Instructions attached to a 'Roger/Negative' Instruction

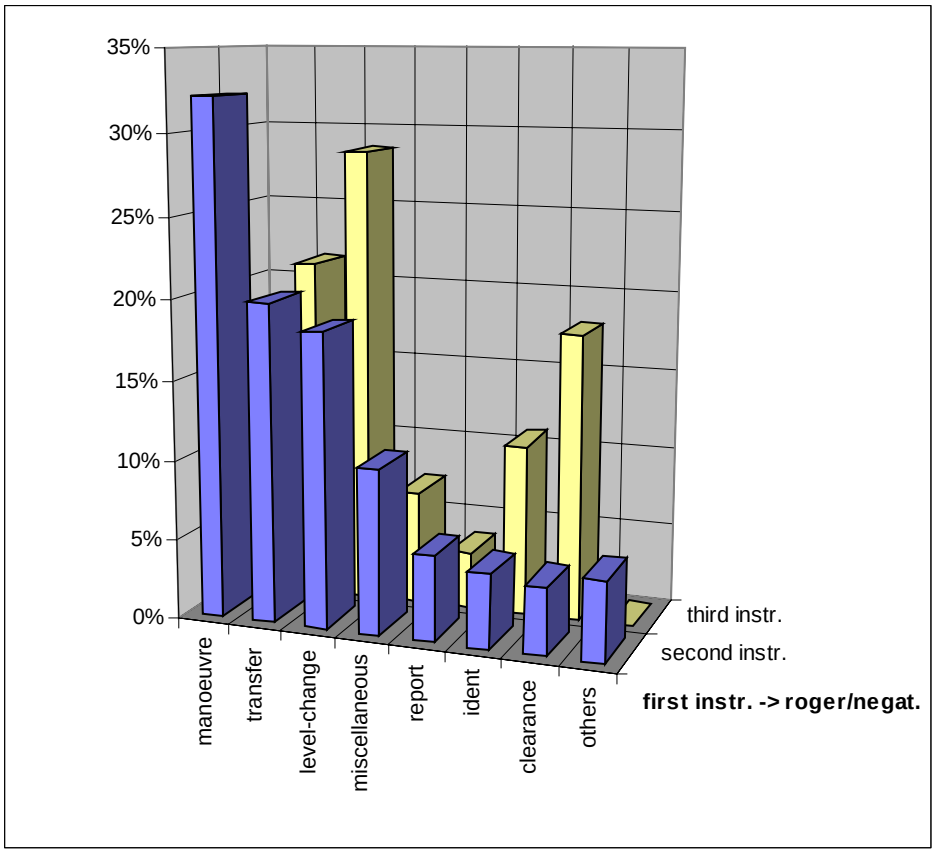


Figure 21: Distribution of instructions types in an utterance with roger/negative as first instr.

7.10.2 Number of Words per 'Roger/Negative' Instruction

all roger/negative-utt.	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
nbr. of utt.	324	63	228	33	106
words per utt.	8,0	2,3	8,7	15,2	5,9
words per AC-sign part	1,5	1,2	2,4	2,4	0
words per instr. part	6,5	1,1	6,2	12,8	5,9

Table 49: Mean number of words per 'roger/negative' utterance

Remark: This instruction type shows an excessive number of utterances without attached AC callsign (nearly 1/3 of all utterances). This explain the variation the mean length of the AC-sign part with other instruction types.

7.10.3 Mean duration of a 'Roger/Negative' Instruction

Based on the values from 6.3.2 the estimation for the mean duration of speaking a change 'flight level' utterance (including the AC call-sign) can be calculated:

	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
duration of a utt. (sec.)	3,7	1,1	4,0	7,0	2,7

Table 50 : Estimated duration of a spoken 'roger/negative' utterances

7.10.4 'Roger/Negative' Instruction Phraseology

Under this instruction category utterances starting with 'roger' for a confirmation of a previous pilot statement or 'negative' for the interdiction of a previous pilot statement are classified. Both keywords don't permit to conclude the utterance sense without knowledge of the previously exchanged pilot - controllers utterances. An attached instruction may not necessarily have the sense of instruction repetition. Therewith the isolated context analysis of these utterances are very difficult. With context knowledge several utterances of this category may have been classified in other instruction groups and may be an error in that sense. But the overall number of utterances of this 'roger – negative' category is rather small (324) representing about 3% of all analysed utterance and will so influence very little the results of the other instruction categories. No difference was maid if the roger/negative was in front of the callsign or after it.

The normalisation of the utterance was done similar to under 7.1.5 described.

	all roger/neg.	roger/neg. (solo)	rog-neg with 1 instr.	rog-neg with >1 inst	utt. without AC-sign
Nbr. of roger/negative utt.	324	63	228	33	106

Table 51 : Number of 'roger/negative' utterances

The following utterance are the most one used with an frequency of four at least. More details in annex D.

- <rog-neg>
- <rog-neg> contact <station> <frq-nbr>
- <rog-neg> turn <left-right> <nbr3>
- <rog-neg> <climb-descend> to flight-level <nbr3>
- <rog-neg> squawk <nbr4>
- <rog-neg> identified
- <rog-neg> maintain
- <rog-neg> fly heading <nbr2> degrees
- <rog-neg> radar contact
- <rog-neg> call you back
- <rog-neg> <frq-nbr>

roger/negative message.	228	
10 most frequent	136	59,7%
20 most frequent	161	70,6%

Table 52: Frequency of roger - negative utterance including one other instruction

7.11 Affirm/Confirm Instruction

7.11.1 Number of Words per Affirm/Confirm Instruction

all affirm/confirm-utt.	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
nbr. of utt.	82	65	17		13
words per utt.	7,6	6,3	12,4		3,4
words per AC-sign part	2,3	1,9	3,9		0
words per instr. part	5,2	4,4	8,5		3,4

Table 53 : Mean number of words per 'affirm/confirm' utterance

7.11.2 Mean duration of a Affirm/Confirm Instruction

Based on the values from 6.3.2 the estimation for the mean duration of speaking a change 'flight level' utterance (including the AC call-sign) can be calculated:

	general	utt. with 1 instr.	utt. with 2 instr.	utt. with 3 instr.	utt. without AC-sign
duration of a utt. (sec.)	3,5	2,9	5,7		1,6

Table 54 : Estimated duration of a spoken 'affirm/confirm' utterances

7.11.3 Affirm/Confirm Instruction Phraseology

The normalisation of the utterance was done similar to under 7.1.5 described.

	all affirm/conf.	affirm/conf. (solo)	aff/conf. with instr.	utt. without AC-sign
Nbr. of affirm/confirm utt.	82	65	17	13

Table 55 : Number of 'affirm/confirm' utterances

To request an AC to report an affirmation or a confirmation for a given instruction we counted 51 different ways of doing. The following utterance are the most one used with an frequency of ten at least. More details in annex D.

- <affirm-confirm>
- <affirm-confirm> level <nbr3>
- <affirm-confirm> contact <station> radar <frq-nbr>
- <affirm-confirm> <climb-descend> to <nbr3>

20 most frequent	49	59,8%

Table 56: Frequency of report (solo) utterance

Affirm/confirm message.	82	
10 most frequent	39	47,6%

7.12 AC callsign solo utterance

7.12.1 Number of Words per AC callsign utterance

all AC callsign-utt.	general
nbr. of utt.	91
words per utt.	3,9
words per AC-sign part	3,9
words per instr. part	0

Table 57 : Mean number of words per 'AC callsign' utterance

Remark: We can see a tendency to shorten the callsign (e.g.: 1554 instead of Airfrance 1554, VJI instead of GBVJI, …) if it is used as the only to an statement of the AC.

7.12.2 Mean duration of a AC callsign utterance

Based on the values from 6.3.2 the estimation for the mean duration of speaking an AC call-sign utterance can be calculated:

	general
duration of a utt. (sec.)	1,8

Table 58 : Estimated duration of a spoken 'AC callsign' utterances

8 Conclusion

The aim of this is to support ASR with detailed knowledge of controllers humans speech behaviour. Preliminary studies (Guilhem Grondin, Dévelopment d'un système expert d'analyse des résultats de la reconnaissance vocal) on using some kind of artificial intelligence to increase ASR results have been successfully. But they showed as well that the results with the current state of the art technology are still far away from which could be expected from our human customers in ATC real-time simulator. So that at the end of 1998 the EEC stopped its ASR activities. But as controllers phraseology is little documented I think the presented technical analyse may be useful to other domains as well.

The variation from the real used controller phraseology and our reference ICAO phraseology (see 4 Definition of a reference ATC phraseology) is very large. Less than 20% of the phrases have been in detail conform with the used reference phraseology, but controllers state that 85% of their utterance follow ICAO standard phraseology. The human pilot has no problem with this deviation but an ASR system will fail often. This result is supported from the EEC practical experiments (Comparative Experiments with Speech Recognisers for ATC Simulations, Horst Hering, EEC Note No. 09/98) where the recogniser based on stochastic word distribution shows much better results as another one with fixed tree-based grammar structure.
ASR systems are able to recognise **only** ASR system known words! Any strange word (not implemented word) will guide to an (for humans understanding) arbitrary selection of an ASR system known word. Only partly spoken words, unpronounced syllables, repetitions and hesitations, classified as spontaneous speech, will stress ASR's similar to strange words. We encountered about 4% of the phrases with such a manner of human speaking which cannot be solved by actual available state of the art continuous voice speech recognisers.

The analysis of recorded Speech samples point out significant influence of specific simulation parameter on controllers speaking behaviour. Environment variables with strong influence are the structure of the sector and the traffic workload. The sector structure influence the use of the different instruction types. A sector with mainly horizontal traffic flow (i.e. Söllingen) have a higher part of 'transfer' instruction and less manoeuvring instructions for the AC. An upper airspace sector including access to a major international airport (i.e. Zürich) will use much more manoeuvring ('level-change', 'clearance', 'manoeuvre') instructions.
Controllers with comfortable workload show a tendency to prefer elegant economic problem solutions with horizontal AC manoeuvres. With increasing traffic load horizontal manoeuvres are reduced and the use of 'change-level' and 'clearance' instructions are highly increase.
However about 76 % of all controller utterance are given as single instruction to one AC. The distribution of multiple instruction per utterance depend on the sector structure and traffic load also. Increasing traffic increase the number of controller utterances with multiple instructions

The four most one used instruction types are ‘transfer’, ‘level-change’, clearance and to ‘manoeuvre’ an AC. A transfer instruction (AC entering or leaving a sector) is present in more as 60% (mean, min. 55%, max. 64%) of all controller utterances. The frequency of ‘level-change’ was nearly 27%, ‘clearance’ 15% and manoeuvres 10% in mean. Increasing traffic was resulting in important positive variation for ‘level-change’ and ‘clearance’ instructions and reducing ‘manoeuvre’ and ‘transfer’ instructions. Other instructions like ‘indent’, report’, ‘roger’ and ‘miscellaneous’ have each a frequency of 3..4% only. ‘Speed’, cruising’, ‘confirm’, ‘affirm’ instruction types have an frequency of less than 1% each.

The most used instruction s type ‘transfer’ is another source of problems for ASR systems
Many times humans use courtesy forms for new entering AC or for AC leafing the sector are. It may be placed at the start, middle or end of the controller utterance, may vary with the time of the day (morning, afternoon, night) and controller’s knowledge of abroad greetings. More than 34% of all phrase included such from the ICAO recommendations not foreseen ‘greetings’.

Chapter 7 may give answers on many detailed questions like:

- how many words are spoken for an specific instruction type,
- how many time takes it to speak this instruction,
- if an utterance has more than one instructions, what kind of instruction follows as second and third instruction,
- what’s the real used syntax for this instruction,
- what’s the frequency of the specific syntax.

These aspects may be helpful for the development of ASR expert systems and as well from interest for other ATC domains. Several other aspect could be derived from the available speech base.

9 Acknowledgements

Treating the transcribed controller utterances with nearly 100 000 words was not always very simple. Many thanks for the excellent support of my college Gilbert Coatleven without his help probably this report had never been terminated.

10 Bibliography

Analyse du langage employé dans les communications d'un système de contrôle,
Eric Janet, INRIA 12/82

Procedures for Air Navigation Services - Rules of the Air and Air Traffic Services,
Document 4444, ICAO 1984

International Standards, and Recommended Practice and Procedures for Air Navigation Services - Aeronautical Telecommunications - Annex 10 to the Convention on International Civil Aviation; Volume II, ICAO 1995

Manual of Radiotelephony, Doc 9432-AN/925, ICAO 1984

STIF Speech Techniques for sImulation Facilities,
Horst Hering, EEC Note No. 25/96

S08 ANT-RVSM 3rd Continental Real-Time Simulation - Visitor Guide,
Diena Seeger & Roger Lane, EEC 1997

3rd Continental RVSM Real-Time Simulation,
Roger Lane, Robin Deransy, Diena Seeger, EEC Report No. 315, 1997

Comparative Experiments with Speech Recognizers for ATC Simulations,
Horst Hering, EEC Note No. 09/98

Dévelopment d'un système expert d'analyse des résultats de la reconnaissance vocal,
Guilhem Grondin, Diplome d'Ingenieur, Conservatoire National des Arts et Métiers IIE

Appendix

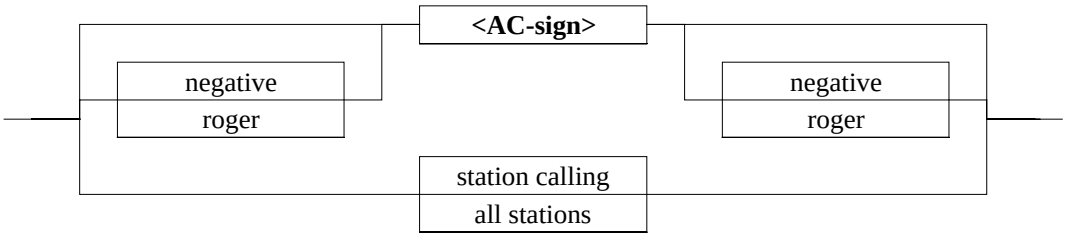
11 Appendix A

The following ATC language structure was built by coping all ACC relevant phrases from the ICAO documents, sorting them into categories and finding significant common parts for same kind of a simple grammar. So if the reader is missing utterances, this means only, there are no example phrases for this case in the ICAO documentation.

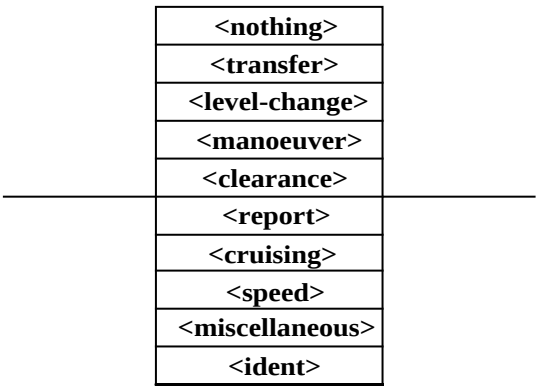
The utterances are shown with branches in a graphical way. The propose of this was to get a simple programmable structure of valid controller phrases. So it is evident that not all possible branches of a structure will give meaningful utterances. The branches has to be read in a straight forward manner (left to right). Real spoken words are in normal letters, expressions in brackets '<>' are 'variables' (place holders) and has to be replaced by one or more spoken words of the adequate sense (e.g. <AC-sign> may be replaced by a spoken "Lufthansa eight two six eight").

11.1 Basic structure of a ATC utterance

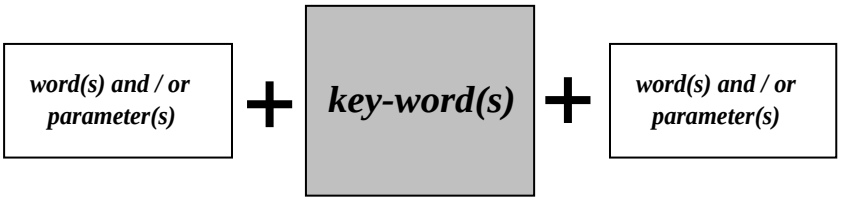
11.2 Structure of <AC-call>



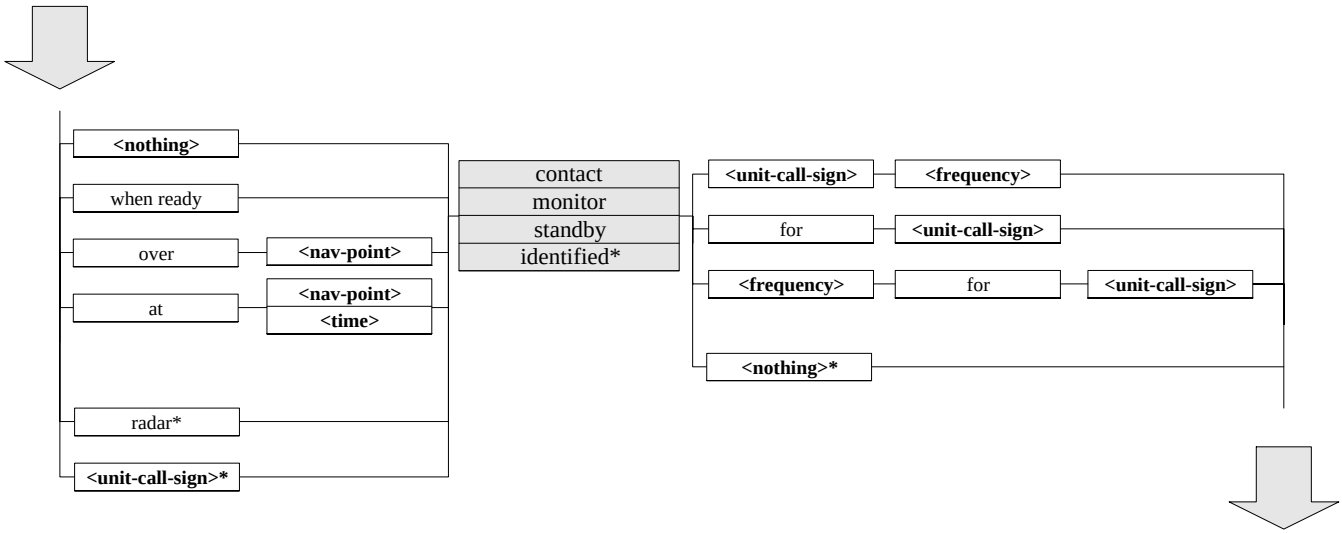
11.3 Structure of <command>



The basic structure of each **<command>** is:

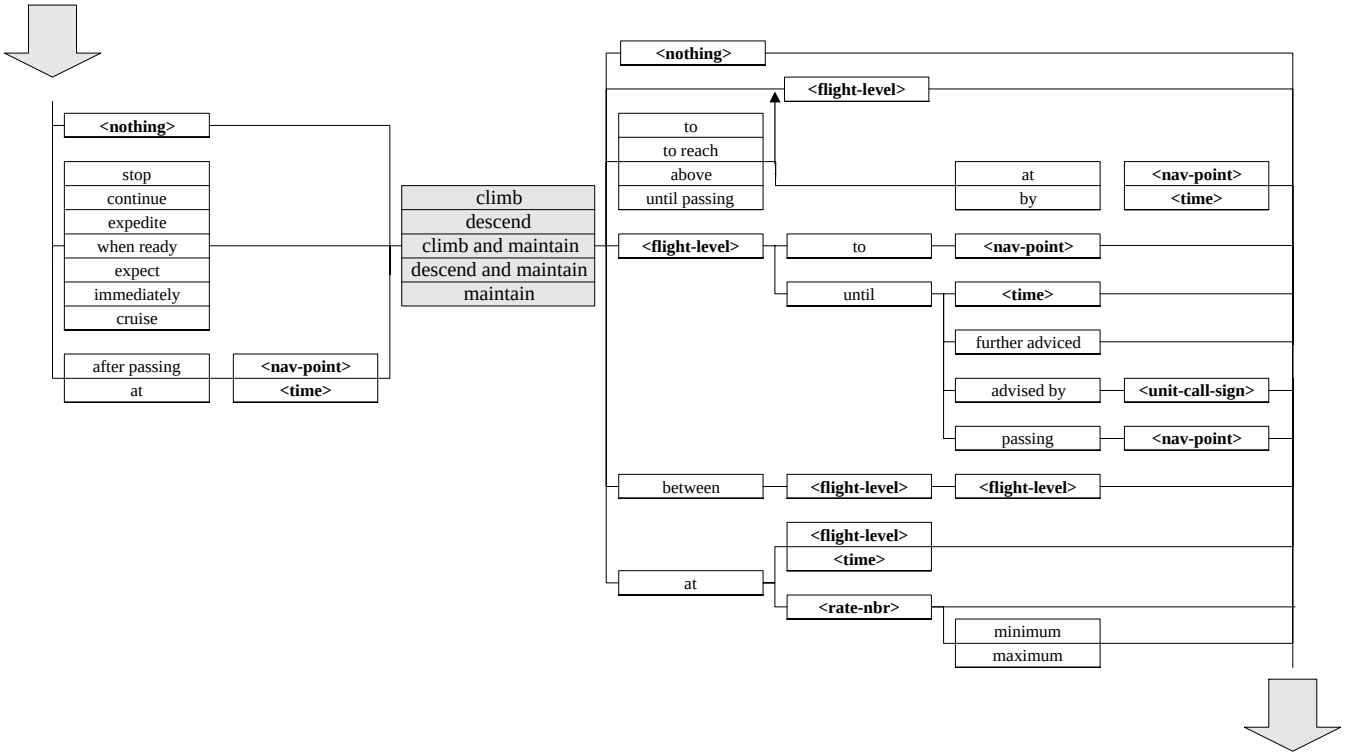


11.3.1 Structure of <transfer>

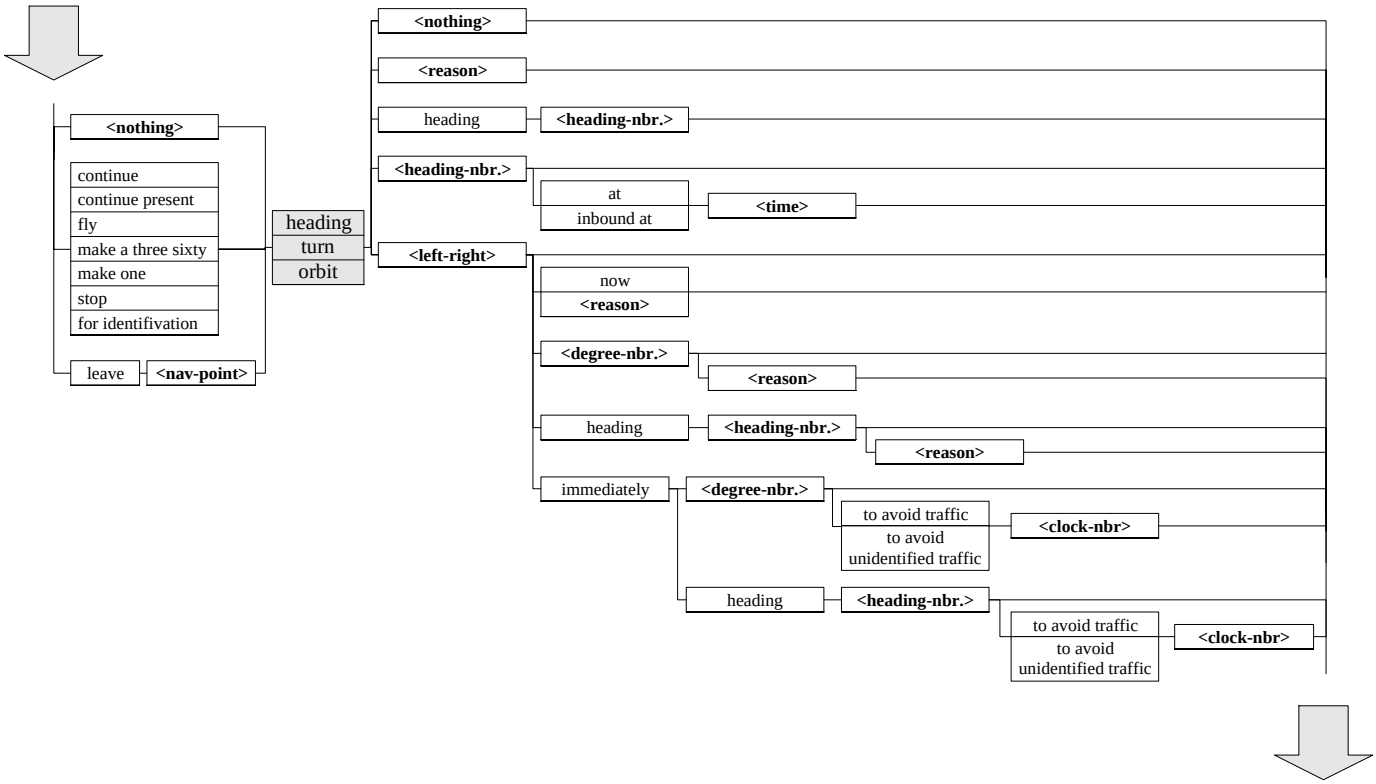


*** Non ICAO recommendation**

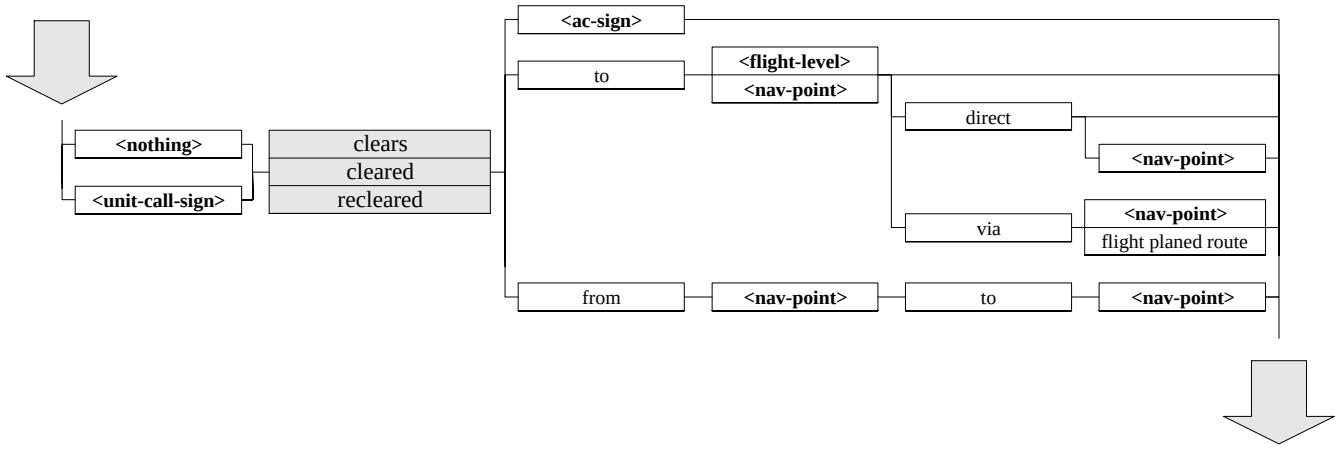
11.3.2 Structure of <level-change>



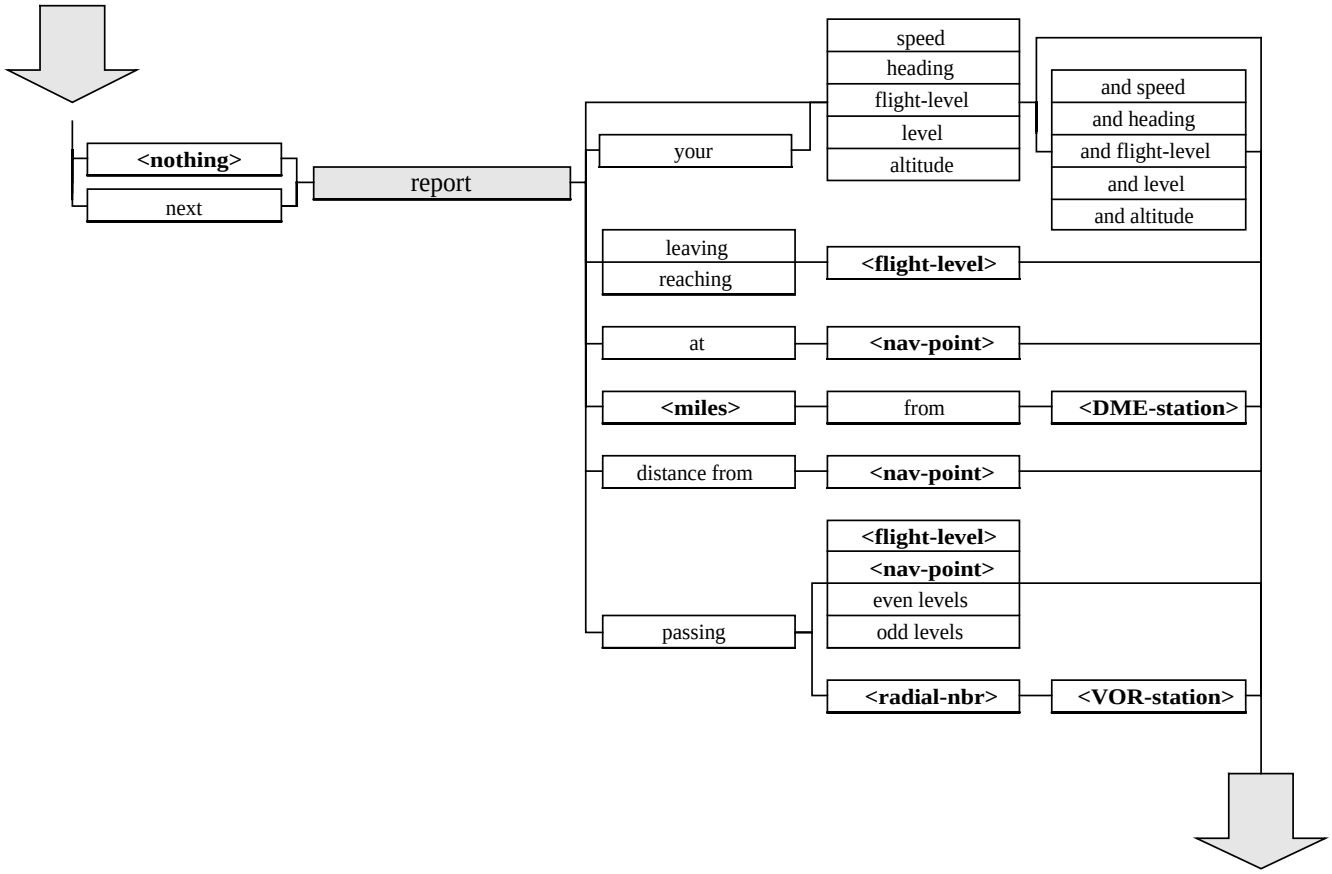
11.3.3 Structure of <manoeuvre>



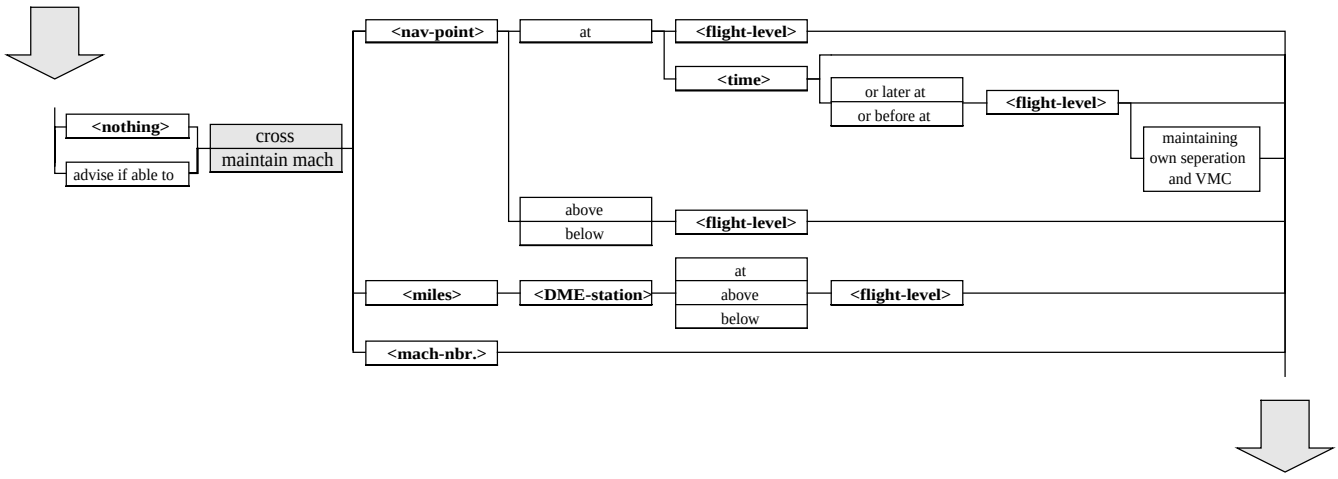
11.3.4 Structure of <clearance>



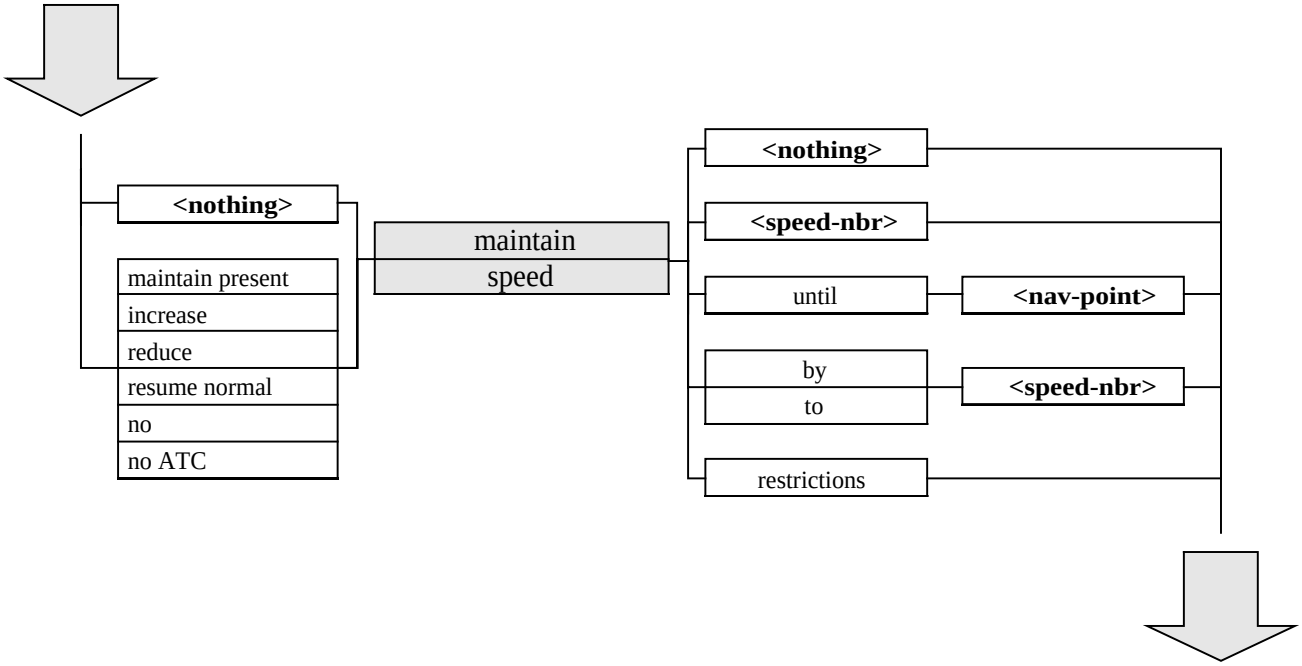
11.3.5 Structure of <report>



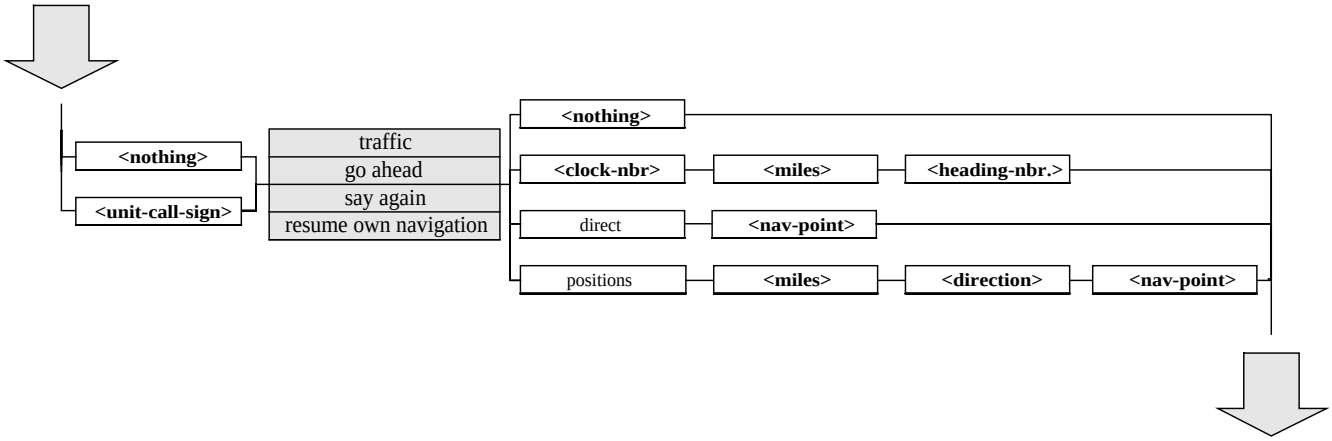
11.3.6 Structure of <cruising>



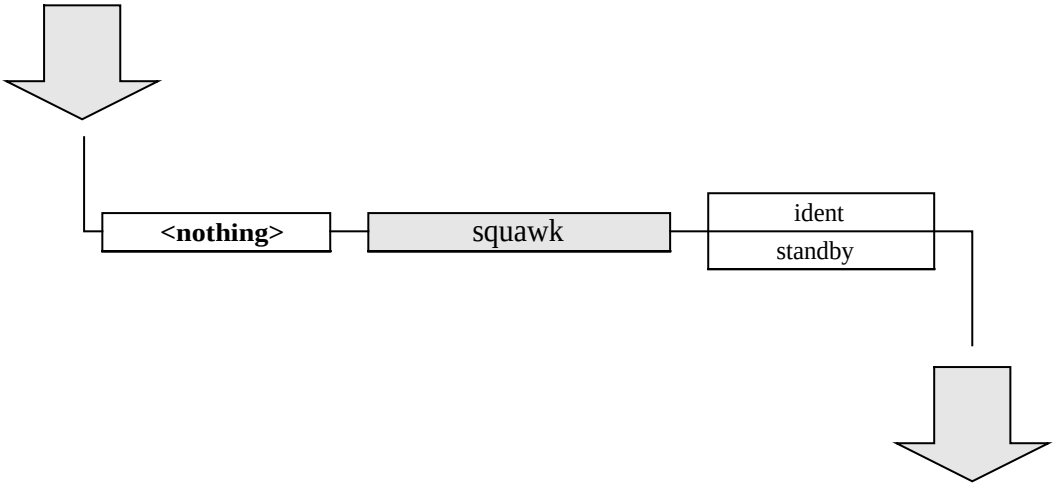
11.3.7 Structure of <speed>



11.3.8 Structure of <miscellaneous>



11.3.9 Structure of <ident>



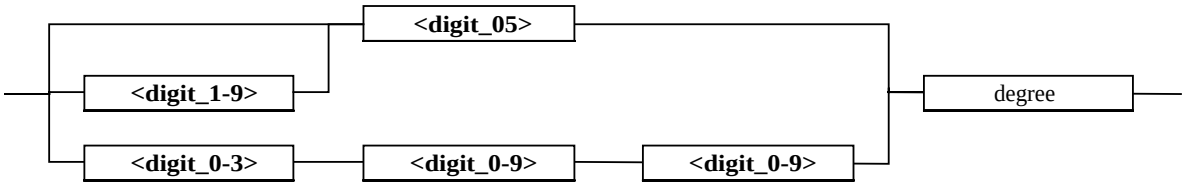
11.3.10 Structures of the '<variables>'

11.3.10.1 Structure of miscellaneous simple <variables>

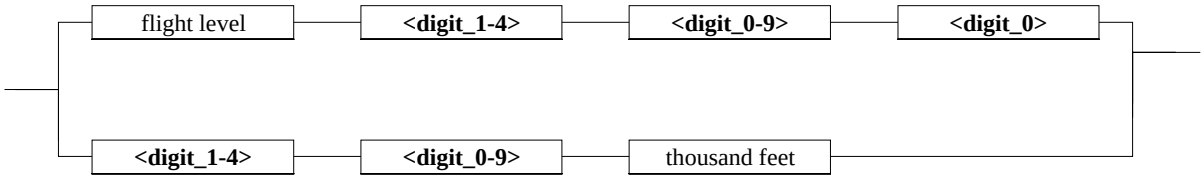
Remarks: The sign '|' represents a logical 'OR' and the '&' means logical 'AND'.

<abc>	{alpha | bravo | charlie | delta | foxtrot | golf | kilo | india | .....}
<atc-station>	{Rhein | Zurich | Geneva | Milan | Aix | .....}
<clock-nbr>	{**<digit_1-12>** & o'clock}
<digit_0>	{0 | 'letter O'}
<digit_5>	{5}
<digit_05>	{**<digit_0>** | **<digit_5>**}
<digit_0-2>	{**<digit_0>** | 1 | 2}
<digit_0-3>	{**<digit_0-2>** | 3}
<digit_0-5>	{**<digit_0-3>** | 4 | **<digit_5>**}
<digit_0-9>	{**<digit_0-5>** | 6 | 7 | 8 | 9}
<digit_1-4>	{1 | 2 | 3 | 4}
<digit_1-9>	{**<digit_1-4>** | **<digit_5>** | 6 | 7 | 8 | 9}
<digit_1-12>	{**<digit_1-9>** | 10 | 11 | 12}
<direction>	{north | north-west | north-east | south | south-west | south-east | ...}
<DME-station>	**<nav-point>**
<heading-nbr>	{**<digit_0-3>** & **<digit_0-9>** & **<digit_0-9>**}
<left-right>	{left | right}
<mach-nbr>	{**<digit_0>** & decimal & **<digit_1-9>**}
<reason>	{for traffic | for spacing | for separation | for delaying action | .....}
<speed-nbr>	{**<digit_1-9>** & **<digit_0-9>** & **<digit_0-9>** & **miles}**
<teleph-name>	{Lufthansa | Air Frans | Speedbird | Sabena | Swissair | .....}
<VOR-station>	**<nav-point>**

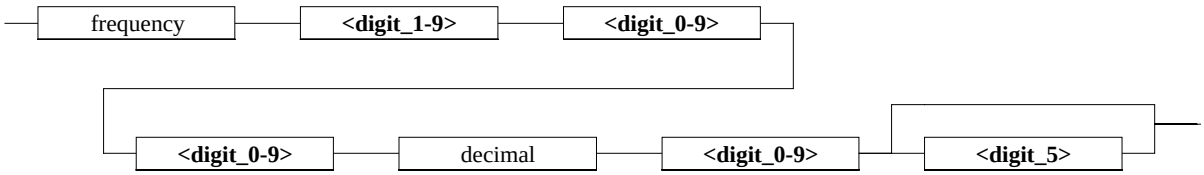
11.3.10.2 <degree-nbr>



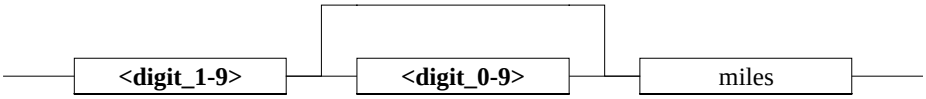
11.3.10.3 <flight level>



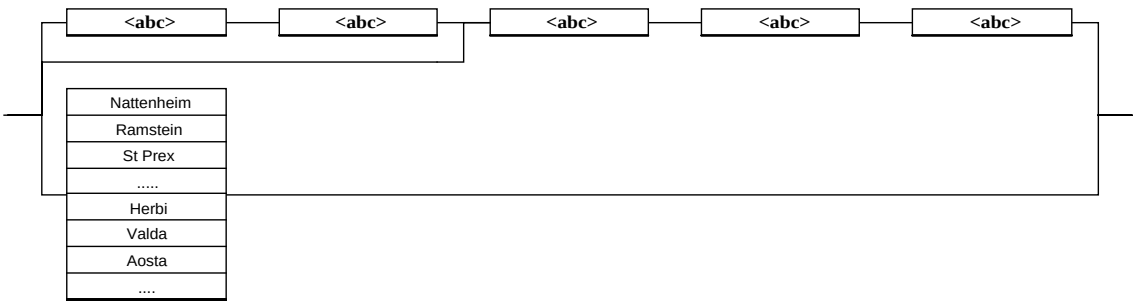
11.3.10.4 <frequency>



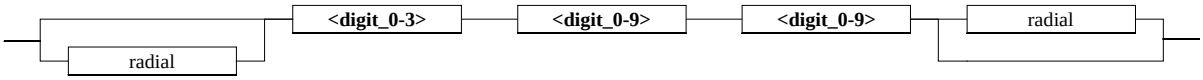
11.3.10.5 <miles>



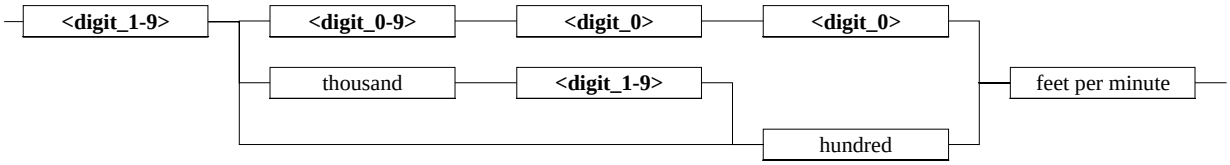
11.3.10.6 <nav-point>



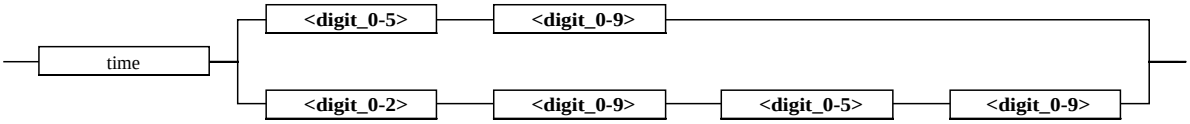
11.3.10.7 <radial-nbr>



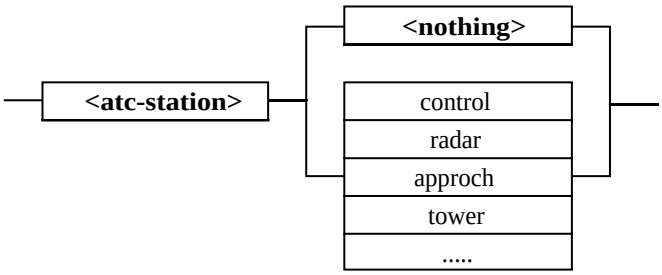
11.3.10.8 <rate-nbr>



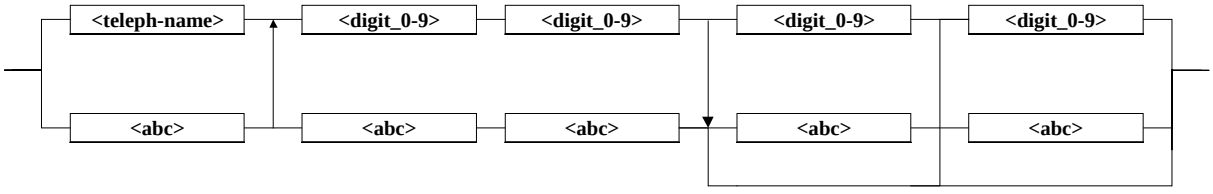
11.3.10.9 <time>



11.3.10.10 <unit-call-sign>



11.3.10.11 <ac-sign>



12 Appendix B

The following tables show the relation between different simulation aspects and the order of the given instructions categories:

1st instruction	general	Sölling.	Geneva	Zürich	male	female	no RVSM	single RVSM	double RVSM	+35% traffic	+55% traffic	+65% traffic
Nbr. of valid utt.	9138	4431	796	3911	5243	3895	1498	3857	3783	2869	3747	2522
transfer'	51,4%	62,4%	44,5%	40,5%	59,2%	41,0%	53,5%	47,8%	54,3%	62,1%	49,8%	41,8%
level-change'	17,3%	12,2%	19,6%	22,6%	13,2%	22,7%	13,5%	18,1%	17,9%	11,8%	18,3%	22,0%
clearance'	8,4%	7,0%	12,7%	9,2%	7,8%	9,3%	8,9%	9,5%	7,2%	6,8%	9,3%	9,0%
manoeuvre'	7,9%	8,2%	5,8%	7,8%	7,8%	7,9%	10,5%	8,0%	6,7%	8,6%	7,8%	7,2%
miscellaneous'	2,8%	2,6%	3,3%	2,9%	2,9%	2,6%	2,5%	2,9%	2,8%	2,5%	2,4%	3,7%
ident'	3,1%	0,0%	5,3%	6,1%	1,1%	5,8%	1,1%	4,2%	2,7%	0,1%	3,1%	6,5%
report'	2,0%	2,5%	2,6%	1,4%	2,4%	1,4%	2,3%	1,9%	2,0%	2,8%	1,7%	1,5%
speed'	0,2%	0,3%	0,0%	0,1%	0,3%	0,1%	0,4%	0,1%	0,2%	0,5%	0,1%	0,1%
cruising'	0,0%	0,0%	0,0%	0,1%	0,0%	0,1%	0,0%	0,1%	0,0%	0,0%	0,1%	0,0%
roger	4,2%	2,6%	4,4%	6,0%	2,9%	6,0%	4,6%	4,5%	3,8%	2,6%	5,0%	4,8%
confirm	0,5%	0,5%	0,4%	0,6%	0,5%	0,5%	0,5%	0,5%	0,6%	0,5%	0,4%	0,7%
affirm	0,4%	0,6%	0,8%	0,2%	0,7%	0,1%	0,3%	0,5%	0,5%	0,6%	0,4%	0,3%
negative	0,3%	0,3%	0,3%	0,2%	0,2%	0,3%	0,2%	0,2%	0,3%	0,3%	0,2%	0,2%

2nd instruction	general	Sölling.	Geneva	Zürich	male	female	no RVSM	single RVSM	double RVSM	+35% traffic	+55% traffic	+65% traffic
Nbr. of valid utt.	9138	4431	796	3911	5243	3895	1498	3857	3783	2869	3747	2522
transfer'	1,6%	0,7%	2,0%	2,5%	0,9%	2,4%	2,1%	1,5%	1,5%	0,8%	1,9%	2,0%
level-change'	7,1%	4,9%	9,2%	9,1%	5,5%	9,2%	7,9%	7,3%	6,6%	5,1%	8,2%	7,6%
clearance'	5,0%	2,0%	15,1%	6,3%	3,5%	7,1%	2,3%	5,5%	5,6%	1,8%	4,8%	9,0%
manoeuvre'	2,0%	2,4%	1,6%	1,7%	2,2%	1,8%	2,0%	2,2%	1,8%	2,3%	2,0%	1,7%
miscellaneous'	1,1%	0,7%	0,8%	1,5%	0,7%	1,5%	0,8%	1,2%	1,0%	0,7%	1,2%	1,2%
ident'	0,5%	0,0%	0,1%	1,0%	0,1%	1,0%	0,5%	0,4%	0,5%	0,0%	0,5%	0,9%
report'	0,6%	0,8%	0,3%	0,4%	0,7%	0,4%	0,9%	0,6%	0,5%	0,9%	0,5%	0,4%
speed'	0,1%	0,1%	0,1%	0,0%	0,1%	0,0%	0,1%	0,1%	0,1%	0,1%	0,1%	0,0%
cruising'	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
roger	0,0%	0,0%	0,0%	0,1%	0,0%	0,1%	0,0%	0,1%	0,1%	0,0%	0,0%	0,1%
confirm	0,2%	0,2%	0,1%	0,2%	0,2%	0,2%	0,1%	0,2%	0,2%	0,2%	0,2%	0,2%
affirm	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
negative	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%

3rd instruction	general	Sölling.	Geneva	Zürich	male	female	no RVSM	single RVSM	double RVSM	+35% traffic	+55% traffic	+65% traffic
Nbr. of valid utt.	9138	4431	796	3911	5243	3895	1498	3857	3783	2869	3747	2522
transfer'	0,1%	0,1%	0,0%	0,2%	0,1%	0,2%	0,1%	0,2%	0,1%	0,1%	0,1%	0,2%
level-change'	2,5%	1,1%	11,3%	2,2%	2,2%	2,8%	0,7%	1,9%	3,8%	0,9%	2,2%	4,6%
clearance'	1,9%	0,2%	1,0%	4,1%	0,3%	4,2%	1,8%	2,0%	1,9%	0,3%	2,4%	3,1%
manoeuvre'	0,3%	0,1%	0,0%	0,5%	0,1%	0,5%	0,2%	0,3%	0,3%	0,2%	0,3%	0,4%
miscellaneous'	0,4%	0,2%	0,3%	0,7%	0,2%	0,6%	0,6%	0,2%	0,5%	0,2%	0,3%	0,8%
ident'	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,1%	0,0%	0,0%	0,0%	0,0%	0,0%
report'	0,1%	0,1%	0,3%	0,1%	0,1%	0,1%	0,3%	0,1%	0,1%	0,1%	0,1%	0,1%
speed'	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
cruising'	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
roger	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
confirm	0,1%	0,0%	0,1%	0,1%	0,0%	0,1%	0,0%	0,1%	0,1%	0,0%	0,0%	0,1%
affirm	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
negative	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%

13 Appendix C

The following tables show the relation between subjects and the order of the given instructions categories:

1st instruction	general	subj. A	subj. B	subj. C	subj. D	subj. E	subj. F	subj. G	subj. H	subj. I	subj. J	subj. L
Nbr. of valid utt.	9138	1268	781	1079	1487	195	168	283	150	1543	593	1591
transfer'	51,4%	64,5%	65,7%	62,1%	55,8%	39,0%	48,2%	49,1%	38,7%	45,9%	48,7%	32,5%
level-change'	17,3%	9,3%	12,3%	15,1%	12,7%	23,1%	17,3%	19,4%	18,0%	16,1%	23,9%	29,3%
clearance'	8,4%	5,8%	8,1%	9,2%	5,7%	15,4%	8,3%	10,6%	18,0%	11,1%	5,9%	8,9%
manoeuvre'	7,9%	9,0%	7,7%	2,8%	11,3%	6,2%	4,2%	4,2%	10,0%	8,2%	7,6%	8,1%
miscellaneous'	2,8%	3,5%	1,5%	2,2%	3,8%	3,1%	5,4%	2,8%	2,0%	1,8%	3,7%	2,8%
ident'	3,1%	1,9%	0,1%	0,0%	0,0%	4,6%	5,4%	4,2%	8,0%	5,8%	3,2%	6,7%
report'	2,0%	1,3%	1,7%	2,9%	3,8%	2,1%	6,0%	1,8%	1,3%	1,2%	1,5%	1,1%
speed'	0,2%	0,2%	0,0%	0,1%	0,9%	0,0%	0,0%	0,0%	0,0%	0,1%	0,0%	0,0%
cruising'	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,2%	0,0%	0,0%
roger	4,2%	1,7%	2,2%	4,4%	2,4%	4,6%	4,2%	5,3%	2,7%	6,2%	2,4%	7,4%
confirm	0,5%	1,3%	0,1%	0,3%	0,3%	0,5%	0,0%	0,4%	0,7%	0,4%	0,7%	0,6%
affirm	0,4%	0,6%	0,0%	0,2%	1,5%	1,5%	0,6%	0,7%	0,0%	0,2%	0,0%	0,0%
negative	0,3%	0,2%	0,0%	0,2%	0,5%	0,0%	1,2%	0,0%	0,0%	0,0%	0,5%	0,4%

2nd instruction	general	subj. A	subj. B	subj. C	subj. D	subj. E	subj. F	subj. G	subj. H	subj. I	subj. J	subj. L
Nbr. of valid utt.	9138	1268	781	1079	1487	195	168	283	150	1543	593	1591
transfer'	1,6%	1,1%	0,6%	0,6%	0,6%	1,0%	1,2%	2,8%	2,7%	3,8%	1,7%	1,5%
level-change'	7,1%	4,7%	2,9%	5,4%	5,6%	12,3%	4,2%	8,5%	12,0%	15,4%	9,3%	3,7%
clearance'	5,0%	1,1%	0,5%	1,2%	4,0%	10,8%	17,3%	18,7%	11,3%	5,8%	13,8%	4,8%
manoeuvre'	2,0%	1,6%	1,2%	3,6%	2,6%	1,5%	2,4%	1,4%	1,3%	1,9%	1,5%	1,6%
miscellaneous'	1,1%	0,3%	0,5%	1,5%	0,6%	2,1%	0,6%	0,0%	0,7%	2,3%	1,5%	0,9%
ident'	0,5%	0,2%	0,0%	0,0%	0,0%	0,5%	0,0%	0,0%	0,0%	1,5%	2,0%	0,3%
report'	0,6%	0,2%	0,1%	0,8%	1,7%	0,0%	0,6%	0,0%	0,7%	0,7%	0,3%	0,2%
speed'	0,1%	0,0%	0,0%	0,2%	0,1%	0,0%	0,6%	0,0%	0,0%	0,0%	0,0%	0,0%
cruising'	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
roger	0,0%	0,1%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,2%	0,1%
confirm	0,2%	0,2%	0,3%	0,3%	0,0%	0,0%	0,0%	0,4%	0,0%	0,4%	0,0%	0,1%
affirm	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
negative	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%

3rd instruction	general	subj. A	subj. B	subj. C	subj. D	subj. E	subj. F	subj. G	subj. H	subj. I	subj. J	subj. L
Nbr. of valid utt.	9138	1268	781	1079	1487	195	168	283	150	1543	593	1591
transfer'	0,1%	0,0%	0,0%	0,0%	0,3%	0,0%	0,0%	0,0%	0,0%	0,1%	0,5%	0,3%
level-change'	2,5%	0,6%	0,0%	0,5%	2,4%	6,2%	13,7%	15,9%	6,7%	1,2%	11,1%	0,1%
clearance'	1,9%	0,2%	0,3%	0,0%	0,3%	0,0%	1,8%	1,4%	0,7%	7,6%	4,9%	0,9%
manoeuvre'	0,3%	0,1%	0,1%	0,2%	0,1%	0,0%	0,0%	0,0%	0,0%	0,8%	1,0%	0,1%
miscellaneous'	0,4%	0,3%	0,3%	0,3%	0,1%	0,5%	0,0%	0,0%	0,7%	1,0%	1,7%	0,0%
ident'	0,0%	0,0%	0,0%	0,1%	0,0%	0,0%	0,0%	0,0%	0,0%	0,1%	0,0%	0,0%
report'	0,1%	0,0%	0,0%	0,0%	0,2%	0,0%	0,0%	0,7%	0,0%	0,2%	0,2%	0,1%
speed'	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
cruising'	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
roger	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
confirm	0,1%	0,1%	0,0%	0,0%	0,0%	0,0%	0,6%	0,0%	0,0%	0,1%	0,3%	0,0%
affirm	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
negative	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%

14 Appendix D

14.1 Utterance frequency transfer (in) solo

21 of 53 (all transfer in solo utterance) more than once used phrases.

301	identified
245	radar contact
233	<station> radar identified
228	is identified
46	<station> identified
25	is in radar contact
23	<station>
22	in radar contact
6	<greatings-only>
6	non RVSM radar contact
4	<station> radar
3	<station> radar you are identified
3	is identified break
2	correction <callsign> identified
2	is in radar contact now
2	non RVSM <station> radar identified
2	non RVSM identified
2	non RVSM is identified
2	non-RVSM radar contact
2	you are identified
2	you're identified

14.2 Utterance frequency transfer (in) including other instructions

37 of 667 (all transfer in utterance including another instruction) more than five times used phrases. The transfer (in) instruction may be based on ‘greetings’ suppressed by the normalisation.

212	squawk <nbr4>
70	roger
53	<climb-descend> to flight-level <nbr3>
40	radar contact <climb-descend> flight-level <nbr3>
33	is identified <climb-descend> to flight-level <nbr3>
32	radar contact maintain flight-level <nbr3> <nav-point> <nav-point>

30 maintain flight-level <nbr3> <nav_point> <nav_point>
26 <station> radar identified <climb-descend> flight-level <nbr3>
26 identified <climb-descend> flight-level <nbr3>
25 identified cleared <nav-point> <nav-point> flight-level <nbr3>
20 <climb-descend> flight-level <nbr3>
17 identified <climb-descend> to flight-level <nbr3>
15 is identified proceed to <nav-point> <climb-descend> to flight-level <nbr3>
15 radar contact continue <climb-descend> flight-level <nbr3>
14 maintain level <nbr3> <nav_point> <nav_point>
12 <station> radar squawk <nbr4>
11 identified clear <nav-point> <nav-point> flight-level <nbr3>
10 radar contact maintain level <nbr3> <nav-point> <nav-point>
9 cleared direct <nav_point> flight-level <nbr3>
9 radar contact <climb-descend> to flight-level <nbr3>
9 radar contact direct <nav-point>
8 is identified <climb-descend> flight-level <nbr3>
8 is identified proceed direct to flight-level <nav-point>
8 radar contact <nav-point> <nav-point>
7 cleared <nav_point> <nav_point> flight-level <nbr3>
7 <station> radar identified maintain level <nbr3> <nav-point> <nav_point>
7 radar contact maintain flight-level <nbr3> proceed <nav_point> <nav-point>
7 is identified report your heading
7 continue <climb-descend> to flight-level <nbr3>
7 maintain flight-level <nbr3>
6 is identified fly <nbr3> <climb-descend> flight-level <nbr3>
6 identified <nav-point> <nav-point> maintain flight-level <nbr3>
6 radar contact maintain flight-level <nbr3> <nav-point> <nav_point> <nav-point>
6 identified report your heading
6 <station> squawk <nbr4>
6 radar contact flight plain route
6 radar contact proceed <nav-point> <nav-point>

14.3 Utterance frequency transfer (out) solo

41 of 135 (all transfer out solo utterance) more than once used phrases.

1172 contact <station> <frq-nbr>
438 <station> <frq-nbr>
175 contact <station> on <frq-nbr>
174 contact <station> radar <frq-nbr>
122 call <station> on <frq-nbr>
54 <station> radar <frq-nbr>
52 call <station> <frq-nbr>
25 contact <station> control on <frq-nbr>
24 contact <station> frequency <frq-nbr>
23 contact now <station> <frq-nbr>

20	<station> on <frq-nbr>
16	contact radar <frq-nbr>
15	<frq-nbr>
10	<station> control <frq-nbr>
10	contact <station> control on frequency <frq-nbr>
9	contact radar on <frq-nbr>
9	for further climb <station> <frq-nbr>
7	likewise <station> <frq-nbr>
6	as well <station> <frq-nbr>
5	contact now <station> radar <frq-nbr>
4	<station> frequency <frq-nbr>
4	contact now <station> on <frq-nbr>
4	further climb clearance contact radar <frq-nbr>
3	also <station> <frq-nbr>
3	contact <station> <frq-nbr> correction <frq-nbr>
3	contact <station> <station> <frq-nbr>
3	contact <station> radar on <frq-nbr>
3	contact now <station> control on <frq-nbr>
3	likewise <station> radar <frq-nbr>
3	now call <station> on <frq-nbr>
2	<station> <frq-nbr> ... <frq-nbr>
2	at <station> <frq-nbr>
2	call <station> sector <frq-nbr>
2	call us on <frq-nbr>
2	contact <frq-nbr>
2	contact <station> on <frq-nbr> correction <frq-nbr>
2	correct call <station> <frq-nbr>
2	further climb contact radar on <frq-nbr>
2	further contact <station> <frq-nbr>
2	non RVSM contact <station> <frq-nbr>
2	report your heading to <station> <frq-nbr>

14.4 Utterance change flight level solo

21 of 211 (all change flight level solo utterance) more than twice used phrases.

466	<climb-descend> to flight level <nbr3>
382	<climb-descend> flight level <nbr3>
40	<climb-descend> now flight level <nbr3>
38	<climb-descend> now to flight level <nbr3>
34	continue <climb-descend> to flight level <nbr3>
20	<climb-descend> to level <nbr3>
15	continue <climb-descend> flight level <nbr3>
10	<climb-descend> <nbr3> now
8	continue <climb-descend> to flight <nbr3>
6	<climb-descend> to flight level <nbr3> initially

6 for separation <climb-descend> flight level <nbr3>
5 <climb-descend> initially to <nbr3>
5 <climb-descend> is <nbr2> or more
5 <climb-descend> to <nbr3>
4 <climb-descend> now <nbr4> feet per minute or more
4 <climb-descend> to flight <nbr3>
4 due to traffic <climb-descend> to <nbr3>
3 <climb-descend> <nbr3> final level
3 <climb-descend> flight level <nbr3> rate <nbr4> or more
3 <climb-descend> flight level <nbr3> rate at least <nbr4>
3 continue <climb-descend> level <nbr3>

14.5 Utterance change flight level including other instructions

5 of 74 (all change flight level including other instructions utterance) at least twice used phrases.

4 <climb-descend> flight level <nbr3> set coast to <nav-point>
2 <climb-descend> flight level <nbr3> contact <station> <frq-nbr>
2 <climb-descend> to flight level <nbr3> all navigation <nav-point>
2 <climb-descend> to flight level <nbr3> and contact <station> <frq-nbr>
2 <climb-descend> to flight level <nbr3> contact <station> <frq-nbr>

14.6 Utterance clearance solo

34 of 168 (all clearance solo utterance) more than twice used phrases.

64 proceed direct to <nav-point>
62 direct <nav-point>
47 direct to <nav-point>
38 set course direct to <nav-point>
28 all navigation <nav-point>
28 set course to <nav-point>
26 proceed to <nav-point>
25 own navigation to <nav-point>
23 set course direct <nav-point>
20 on navigation to <nav-point>
14 proceed direct <nav-point>
13 all navigation to <nav-point>
9 all navigation direct to <nav-point>
8 proceed on navigation to <nav-point>
8 resume all navigation direct <nav-point>
7 clear direct <nav-point>
7 proceed now to <nav-point>

7 resume all navigation to <nav-point>
6 proceed now direct to <nav-point>
5 cleared direct <nav-point>
5 proceed direct to <nav-point> <nav-point>
5 proceed to <nav-point> <nav-point>
4 all navigation direct <nav-point>
4 direct to <nav-point> <nav-point>
4 direct to <nav-point> now
4 on navigation <nav-point>
4 resume all navigation direct to <nav-point>
3 after <nav-point> direct to <nav-point>
3 navigation to <nav-point>
3 now proceed direct to <nav-point>
3 on navigation <nav-point> <nav-point>
3 own navigation direct to <nav-point>
3 proceed now all navigation to <nav-point>
3 set coast direct to <nav-point>

14.7 Utterance clearance including other instructions

5 of 64 (all clearance including other instructions utterance) at least twice used phrases.

3 all navigation <nav-point> <station> <frq-nbr>
3 on navigation <nav-point> contact <station> <frq-nbr>
2 direct <nav-point> contact <station> <frq-nbr>
2 on navigation direct <nav-point> contact <station> <frq-nbr>
2 proceed direct to <nav-point> <climb-descend> <nbr3>
2 proceed to <nav-point> climb to <nbr3>

14.8 Utterance AC manoeuvring solo

37 of 185 (all manoeuvre solo utterance) more than twice used phrases.

124 turn <left-right> to <nav-point>
62 turn <left-right> heading <nbr3>
57 turn <left-right> <nbr2> degrees
23 turn <left-right> by <nbr2> degrees
21 fly heading <nbr3>
15 <left-right> heading <nbr2> degrees
12 <left-right> turn to <nav-point>
12 heading of <nbr3>
11 turn <left-right> to <nav-point> <nav-point>
10 <left-right> turn <nbr2> degrees
8 continue present heading

8 turn now <left-right> to <nav-point>
7 turn <left-right> heading of <nbr2> degrees
7 turn <left-right> heading of <nbr3>
6 fly heading of <nbr3>
6 turn to <nav-point>
5 flight heading <nbr3>
5 fly now heading <nbr3>
5 heading <nbr2> degrees
5 heading <nbr3>
5 turn <left-right> <nbr3> for separation
4 continue on present heading
4 due to traffic continue present heading
4 fly heading <nbr3> until advised
4 heading of <nbr2> degrees
4 turn <left-right> heading <nbr2> degrees
4 turn <left-right> to <nav-point> intersection
4 turn further <left-right> <nbr3>
3 <left-right> turn <nav-point>
3 continue heading of <nbr3>
3 continue present heading until advise
3 turn <left-right> <nbr2> degrees due traffic
3 turn <left-right> <nbr2> degrees radar vector to <nav-point>
3 turn <left-right> for <nav-point>
3 turn <left-right> in bound <nav-point> <nav-point>
3 turn <left-right><nbr1> degrees
3 turn further <left-right> <nbr2> degrees

14.9 Utterance AC manoeuvring including other instructions

13 of 53 (all manoeuvre including other instructions utterance) at least twice used phrases.

9 turn <left-right> direct to <nav-point>
7 turn <left-right> <nbr2> degrees report new heading
4 turn <left-right> by <nbr2> degrees <climb-descend> <nbr3>
3 turn <left-right> <nbr2> degrees <climb-descend> flight-level <nbr3>
2 continue heading contact <station> <frq-nbr>
2 continue present heading <climb-descend> to flight-level <nbr3>
2 fly heading <nbr3> <climb-descend> level <nbr3>
2 fly heading <nbr3> continue <climb-descend> to <nbr3>
2 maintain heading <climb-descend> flight-level <nbr3>
2 turn <left-right> <nbr2> degrees <climb-descend> to flight-level <nbr3>
2 turn <left-right> heading <nbr3> <climb-descend> to <nbr3>
2 turn <left-right> direct <nav-point>
2 turn <left-right> to <nav-point> <climb-descend> to flight-level <nbr3>

14.10 Miscellaneous utterance for AC solo

26 of 128 (all miscellaneous solo utterance) more than once used phrases.

14	say again
13	thank you
11	<only call-sign>
8	calling
8	okay
5	correct
4	I call you back
4	say again your callsign
3	<station>
3	<station> radar do you read
3	are you on frequency
3	stand by
2	<station> radar stand by for identification
2	call you back
2	expect higher over <nav-point> in <nbr1> minutes
2	expect higher west <nav-point> in about <nbr1> minutes
2	say again callsign
2	say again please
2	say again that call sorry
2	still on the frequency ?
2	still with me
2	that is fine
2	what is your call sign
2	who was that please
2	yeah
2	yes correct

14.11 Requesting utterance an AC report solo

16 of 54 (all report solo utterance) more than once used phrases.

62	report your heading
17	report your mach number
11	report heading
10	report your rate of <climb-descend>
6	your heading
4	report position
4	what is your mach number ?
4	your rate of <climb-descend>

3 report rate of <climb-descend>
3 say your position
2 request heading
2 request your heading
2 what is your position
2 what is your rate of <climb-descend> ?
2 what's your position
2 what's your rate of <climb-descend>

14.12 Utterance modifying AC speed

18 of 19 all speed instructions utterances.

2 can you <increase-decrease> to decimal <nbr2> or <more-less>
1 and make it decimal <nbr2> or <more-less>
1 can <increase-decrease> to decimal <nbr2> ?
1 can you <increase-decrease> your speed to decimal <nbr2> or <more-less> ?
1 can you reduce your speed to decimal <nbr2> or <more-less> ?
1 <increase-decrease> to decimal <nbr2> or <more-less>
1 <increase-decrease> your speed to decimal <nbr2> or <more-less>
1 maintain your speed decimal <nbr2> or <more-less>
1 maintain your speed mach point <nbr2> or <more-less>
1 no further speed instructions
1 no speed instructions
1 reduce to decimal <nbr2>
1 reduce to decimal <nbr2> or <more-less>
1 reduce your speed to decimal <nbr2> or <more-less>
1 set your speed to mach decimal <nbr2> or <more-less>
1 speed at your convenience contact <station> <frq-no-deci>
1 speed up to mark decimal <nbr2>
1 your speed is to your convenience

14.13 Utterance roger/negative including other instructions

14 of 172 (all roger/negative utterances) at least three times used phrases.

63 <rog-neg>
17 <rog-neg> contact <station> <frq-nbr>
13 <rog-neg> turn <left-right> <nbr3>
10 <rog-neg> <climb-descend> to flight-level <nbr3>
8 <rog-neg> squawk <nbr4>
6 <rog-neg> identified
5 <rog-neg> maintain
5 <rog-neg> fly heading <nbr2> degrees
5 <rog-neg> radar contact
4 <rog-neg> call you back
4 <rog-neg> <frq-nbr>
3 <rog-neg> your rate of <climb-descend> at least <nbr4>
3 <rog-neg> for separation turn <left-right> <nbr3>
3 <rog-neg> turn <left-right> <nbr2> degrees

14.14 Utterance affirm/confirm request instructions

4 of 51 all affirm/confirm request utterances at least once used.

28 <affirm-confirm>
3 <affirm-confirm> level <nbr3>
2 <affirm-confirm> contact <station> radar <frq-nbr>
2 <affirm-confirm> <climb-descend> to <nbr3>