Repairs as the last orderly provided defense of safety in aviation

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Abstract

We analyze the multi-dimensional organization of action in aviation, focusing on the repairs that derive from parties’ orientation to several sources of knowledge in which current information provides corrections for errors occurring earlier at the organizational and local levels. We suggest that the analysis of the coordination of talk and action can inform us about the multi-dimensional nature of the organization of action in complex environments. We note that repairs and corrections in naturally-occurring activities inform participants and researchers about troubles that do not, however, cause incidents or accidents thanks to these corrective practices. The multi-dimensional organization of actions provides a number of corrective resources against emerging incidents. Our video-taped data comes from two environments, air traffic control centers and simulated Airbus flights, including more than 70 hours of data in all. The sequential analysis of talk and action is based on conversation analysis (CA), ethnomethodology (EM), and ethnographic field work. The theoretical aims of the study concern the explication of organization of complex multimodal activities in which talk, action and technical resources are interwoven. In practical terms, the study aims at making the emergence and management of errors in complex activities transparent, providing a basis for improving safety procedures.

Keywords: ethnomethodology, interaction, intersubjectivity, organization of repair, multimodality, aviation

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1 Introduction

Contrary to common sense, aviation has become increasingly safe, as the decreasing trend in the relative number of accidents shows. In the US, for example, traffic has grown substantially over time, but the relative number of accidents has decreased dramatically (Table 1).
<table>
<thead>
<tr>
<th>Year</th>
<th>Traffic volume in millions of passengers</th>
<th>Fatal accidents per 100 million passenger miles flown</th>
</tr>
</thead>
<tbody>
<tr>
<td>1930</td>
<td>0.4</td>
<td>28.2</td>
</tr>
<tr>
<td>1939</td>
<td>1.5</td>
<td>12.0</td>
</tr>
<tr>
<td>1960</td>
<td>57.9</td>
<td>1,504</td>
</tr>
<tr>
<td>1970</td>
<td>171.7</td>
<td>0.298</td>
</tr>
<tr>
<td>1980</td>
<td>296.9</td>
<td>0.034</td>
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<tr>
<td>1990</td>
<td>465.6</td>
<td>0.121</td>
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<tr>
<td>1995</td>
<td>547.4</td>
<td>0.053</td>
</tr>
<tr>
<td>2000</td>
<td>665.5</td>
<td>0.040</td>
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Table 1. Air carrier volumes and flight safety (airlines) in the US 1930-2005. (Leary 1995 for the 1930 and 1939 figures, and US Department of Transportation 2001.)

The record seems to imply that aviation has managed to maintain and improve its safety, contradicting the predictions about systems of this kind. Perrow (1984) has argued that the increase in complexity and close connections between components will eventually lead to system accidents or “normal accidents”. Aviation seems however to have managed to increase its volume and decrease the proportion of accidents despite the growth in complexity.\(^1\) In this article, we address some of the practices through which agents in aviation counteract the emerging potential hazards through corrective practices that are part of the organization of aviation, and point out corrective measures that remedy potential and evolving hazards. We address the actions in interaction that contribute to the elimination of incidents, arguing that the aviation industry – air traffic control and aircraft carrier flight operations – involves organized ways of coordinating technically assisted teamwork that counteracts potentially hazardous errors and safety gaps. We focus on the multi-dimensional work practices of controllers and pilots in invoking new resources, information sources, and procedures or tools for repairing problems as they emerge.

The characteristics of aviation have to be taken into account in exploring its interactional practices. First, aviation consists of interwoven social and technological systems. People define situations, act accordingly, accomplish and coordinate their actions and decisions using technologies. Actions are both socially and technologically structured. Organizations set up rules and procedures that guide and enable actions and institute divisions of labor between people. In practice, technical, social and organizational aspects of action are inseparable parts of multifaceted activities. Second, aviation is based on a complex division of labor between interlinked parties, being distributed between professions and organizations and in time and space, since the management of flight requires real-time co-ordination and cooperation within a spatially and socially distributed network. Third, communication processes, which connect both distant and proximate parties, are crucial to the co-ordination of the aviation network. In face-to-face teamwork, not only talk but also gestures, gaze directions and bodily

\(^1\) It would be interesting to compare the degree to which other large and complex socio-technical systems, such as the railway system, marine transport, the automobile system and nuclear power industry, have been successful in improving their relative safety record.
postures form part of the intersubjective orientation of the communicative actions. Gestures like pointing allow a party to highlight a salient aspect of the endless, ongoing information flow for the shared focus of action. In particular, potential problems are pointed out through gestures to form an intersubjective orientation toward the trouble in question so that it can be defined and resolved. In our article, we will demonstrate how gestures and bodily coordination form an inseparable part of air traffic control and flight crew operations teamwork.

Earlier research has shown that complex systems involve inherent dangers that are reflexively linked to the management of the complexity and hazards of technologies (Perrow, 1984). Recent studies have pointed out many ways in which the risks can be managed, both through redesign or re-organization and influencing attitudes or interactional practices (see Weick and Roberts, 1993; Schulman, 1993; Rochlin, 1997). Relatively little, however, is still known about how the agents coordinate actions together in complex socio-technical systems (cf. Heath and Luff, 2000; Goodwin, 1995). Suchman (1993) initiated research on teamwork in systems coordinating geographically distant settings, such as air traffic control and aircraft carrier flight operations. These different settings impose a number of common requirements that are handled using particular communicative practices, work models and organizational structures. Suchman called these settings “centers of coordination”, pointing out three general concerns that also characterize our aviation materials:

1. Centers of coordination handle distributed activities in which one set of participants is responsible for providing services for another. This requires that each and every set engage and cooperate within itself and with other sets.

2. The activities being managed are influenced by and vulnerable to a range of troubling contingencies. The setting is either charged with handling these contingencies or they arise during the course of action so that the operators must be able to accomplish their task in spite of them.

3. Each setting is concerned with connecting people and activities together over time and space according to an overall ordering principle, such as a time-table or the emerging demands of a time-critical situation. (Suchman, 1993.)

In these settings, participants have to achieve a common orientation to the task in hand, which makes them capable of acting according to the relevant ordering principle. There is a widespread division of and corresponding coordination of activities among the people involved both within the control room (cockpit or air traffic control team) and those outside. They need to keep track of action to respond to normal, natural troubles and difficulty in maintaining schedules and coordinating activities in complex settings. They must know the system as a whole and their role in it; for example, know what differences their actions make (Suchman, 1993).

To catch the pilots’ and the controllers’ work on tracing and simultaneously weaving a rich network on dependencies across the aviation mobility system2, we draw on Reason’s (1990) model of accident causation that broadened the investigations to latent aspects of the system. For our part, we complement Reason’s model by addressing the order at the level of work practices, and the reflexive tie between work interaction and the broader mobility system (see Koskela et al. forthcoming). In particular, we focus on the

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2 We want to thank anonymous referees for a number of excellent analytic formulations.
organization of repair as the last structurally provided defense of aviation safety, thereby opening up for investigation a new neglected dimension of order in the aviation.

1.1 The Swiss cheese model

Reason’s model (1990) illustrates how people contribute to the breakdown of complex, interactive and well-protected systems to produce an accident. In the aviation context, well-guarded refers to strict rules, high standards and sophisticated monitoring. Thanks to progress in technology and defense systems, accidents seldom originate exclusively from the errors of operational personnel (front-line operators) or as a result of equipment failures, resulting instead from the interactions of a series of failures or prevalent flaws in the system. Many of these failures are not immediately visible, and may have delayed consequences.

Failures can be of two types, depending on the immediacy of their consequences. An active failure has an immediate adverse effect. Such errors are usually made by the front-line operators. A pilot raising the landing gear lever instead of the flap lever exemplifies this failure type. A latent failure may lie dormant for a long time. Such failures usually originate with the decision-makers, regulators or a line management far removed in time and space from the event. A decision to merge two companies without providing training to standardize operating procedures illustrates a latent failure. The failures can also be introduced at any level of the system by human conditions such as poor motivation or fatigue.

Latent failures, which originate from questionable decisions or incorrect actions are not harmful in isolation, but can create a window of opportunity for a pilot, an air traffic controller or mechanic to commit an active failure that breaches the defenses and results in an accident. The front-line operators inherit system defects. They have to deal with situations in which technical problems, adverse conditions or their own actions activate the latent failures. A well-guarded system will have defenses that act against interacting latent and active failures. When the defenses work, the result is only an incident; otherwise, it is an accident (Figure 1.).
Figure 1. The Swiss cheese model of accident causation (Reason, 1990).

2 Theoretical background

The increasing role of technology in work practices, communication and social interaction make the intersection between technology and the social organization of activity an important research topic (Heath and Luff, 2000; Luff et al., 2000; Arminen, 2005a). Technology in action poses new challenges for research. Talk may still be the primordial site at and through which the actors express their understanding of their situated agencies and negotiate their division of roles for participation in action (Heritage, 1984), but communication is increasingly technically assisted. Hence, communication, technology and action are not separate plenums, talk and other forms of communication being the media for orchestrating activities through emerging agencies made available by the organized set of technical resources. In spoken interaction, talk and action also inform each other in the ongoing accomplishment of the task they contribute to. It is not talk as such, but the coordination of talk and action that establishes the sense of the ongoing action (Goodwin, 2000). This is especially important in technical environments, in which multimodality dominates. In multimodal interactions multiple communicative modes – language, gestures, gazes, material objects and technical artefacts – are in play in different ways (Norris, 2004). In technical environments, such as aviation or centres of coordination, media other than talk are not just complementary but necessary for the achievement of action. We address collaborative actions in which participants coordinate a range of tasks and use various tools to respond to troubles. The study shows how intersubjectivity, the shared understanding of ongoing action, is accomplished and mended by multiple modes of communicative resources; i.e., verbal and non-verbal practices in interaction and technology use.
Our work trades on the anthropology of science and technology and workplace studies (Suchman, 1987; Goodwin, 1995; Heath and Luff, 2000; Luff et al., 2000). These traditions, drawing on a combination of methods from ethnomethodology, CA and ethnography, form a naturalistic approach committed to the detailed study of social and work practices, disclosing the reasoning and procedures through which tasks are carried out. This research considers the production and coordination of social action in real-time through talk and visual conduct. Much of this research concerns problems, routine or other, and troubles in the resolution of problems (Suchman, 1987; Goodwin, 1996; Goodwin and Goodwin 1996; Garcia and Jacobs, 1998; Nevile and Walker, 2005; Arminen, 2005a). The technical and social resources that enable smooth coordination of activities also allow socially-situated reasoning which may prove to be erroneous. Technically-improved access to distant objects through radar, etc., engenders a fabricated participation framework in which ‘reciprocity of perspectives’, i.e., the presupposition of a common frame of reference (Schutz, 1967), is not guaranteed and intersubjectivity may be challenged (see Heath & Luff, 2000). Technical facilitation of perceptions thus is a level of possible human error, in addition to ‘errors’ in mundane processes of language and communication (Schegloff, 1979). Repair practices also provide agents with defenses of intersubjectivity (Schegloff, 1992). In mobility systems, they allow parties to transcend the boundaries of the system by being prospectively and retrospectively organized, forming the last organized defense against accidents in action.

2.1 The organization of repair

The term repair refers to the practices for dealing with problems in speaking, hearing and understanding talk in a conversation (Schegloff, 1979; Jefferson, 1987; Drew, 1997), practices which form an orderly organization of repair (Schegloff et al., 1977). The episodes of repair activity are composed of repair initiation marking possible disjunction with the prior talk and the production of repair, solving or abandoning the problem. The problematic talk which the repair addresses is referred to as the trouble-source or repairable. The organization of repair becomes understandable through two basic dimensions. The first concerns who initiates repair, which may be initiated by the speaker of the problematic talk or by some recipient – self-initiation and other-initiation respectively. The second dimension concerns the sequential location of repair initiation. Virtually all repair initiations are launched in a window of opportunity following the trouble source. Self-initiated repairs start in three main positions: within the same turn as their trouble source, in the trouble-source turn’s transition space or in the third turn from the trouble source turn. The other-initiated repairs are mainly started in the turn subsequent to the trouble source turn. Another way of referring to them is the next-turn repair initiations or NTRIs. (Schegloff et al., 1977.)

The means of repair initiation are organized so as to favour self-initiated self-repair. In spite of the empirical preponderance of self- over other-correction, the latter do occur in conversation. When the other-correction is done it is often modulated in form. It may be downgraded through uncertainty markers or the question format. The other-corrections may also be modulated with the usage of form “Y means X” where X is a possible correction or replacement word. The “Y means X” form may also be used to check understanding; i.e., the recipient tests his/her appreciation of the turn. The modulated other-corrections and understanding checks are not asserted but proffered for
acceptance or rejection. The other-corrections which are not modulated are frequently done in the turn after an understanding check or a modulated other-correction. The regular format used in the production of un-modulated other-correction is “No” plus correction. Overall, the other-corrections tend to be specifically marked or positioned, exhibiting an orientation to their dispreferred status in conversation (Schegloff et al., 1977: 375 – 379).

The vast majority of problems in speaking, hearing and understanding are dealt with immediately in talk. There is still a set of circumstances in which the troubles in comprehension are repaired in the third position from the trouble-source turn (Schegloff 1992). The simplified example below describes the use of third position repair in an airline cockpit interaction:

A: And will you give me the checklist from there (T1)
B: The checklist ((brings the normal checklist into view)) (T2)
A: No. I mean the emergency checklist ←

In third position (←), speaker A undertakes to address the trouble by engaging in a repair operation relative to the talk in T1. In the sequential context of repair after next turn, the third position repair supplies and is dedicated to “the last structurally provided defence of intersubjectivity in conversation” (Schegloff, 1992).

The studies on repairs have initially been concerned with problems in speaking, hearing and understanding talk, but participants in interaction also encounter other kinds of trouble. Corrective practices may also target interactants’ physical actions, interactive multimodal semiotic facilities and the interactive actions of parties with their environment, with or without verbal activities. Goodwin has studied intersubjective order and the problems of parties engaged in physical actions in a wide range of settings from an educational interaction on an archaeological site to young girls playing hopscotch (Goodwin, 1994; 2000; 2001). These cases include corrective episodes in which a person was deterred from undertaking a physical course of action that was considered inappropriate by their co-participant.

The problems in human-machine interactions and computer supported co-operative work have recently been addressed through insights gained from research on human face-to-face interaction. Suchman (1987) pioneered the field with her study on the intersubjective problems emerging in users’ interactions with a photocopier. She noticed that the users took the unresponsiveness of the machine as evidence of trouble in their performance of the action taken. To resolve the problem, the users re-inspected instructions on the machine’s display, re-identified the object of the instruction and repaired their action. The analysis of the troubles in photocopying is valuable since it discloses work required to comprehend the machine’s behaviour. By studying what things look like when they are unfamiliar and troublesome for the user, Suchman improves our understanding of the mastery of technology.

Spagnolli et al. (2002) have studied failures in the users’ material and virtual interactions with the virtual library, analyzing the particular breakdown episodes where the user was forced to abandon a projected course of action and mobilize resources to obtain a more effective one. They argue that the breakdowns in interaction with an
artefact expose the aspects of a system-in-use that hamper the successful completion of an action.

Nevile (2004a) has opened airline cockpit interaction up for research. His study also touches upon the problematic understandings in routine flights, revealing some cases in which airline pilots were having trouble in the production of verbal and/or physical conduct during actual flights, and pointing out their repair practices (see also Nevile and Walker 2005). Harper and Randall (1992) have analyzed resolution of conflict between civil and military Air Traffic Control operations consisting of repairable courses of action that were resolved in an unfolding collaborative interaction.

2.2 Data and Methods

The methodological contribution consists of uniting the analysis of visual actions with the study of spoken interaction so that the mutually constitutive role of talk and action can be examined. Talk is studied with the help of CA transcription conventions and methods and visual actions are inspected along with the stream of speech to disclose the sequential flow of activities as an organized whole. These studies reverse engineer the building blocks of the intersubjective understanding of social practices in action in which the parties’ coordination of their activities itself displays their sense of practice.

The methodological tools consist of ethnomethodology, conversation analysis (CA) and ethnography (Hutchby and Wooffitt, 1998; ten Have, 2004; Arminen, 2005a). Ethnographic materials provide a background for more detailed scrutiny of videotaped (inter)actions. Ideally, the use of several data sources leads to a hermeneutic circle in which the details of interaction are interpreted vis-à-vis their ethnographic context, the sense of which is elucidated by reference to the details of interaction. Video recordings allow the testing of the validity of ethnographic insights and provide reportable evidence on the practices studied.

The video-taped research data was gathered from two environments, an Airbus (A320) flight simulator and Area Control in Finland. In the flight simulator, the airline pilots trained for the various abnormal and emergency situations such as fire in a cabin, technical failure in the aircraft’s hydraulic systems and crossing traffic. These biannual training sessions are part of their compulsory updating of flying skills. The simulated flight data consists of 60 hours of recordings of which nearly half (about 30 h) is used for scientific purposes. The transcript follows CA conventions (see Hutchby and Wooffitt, 1998; ten Have, 2004; Arminen, 2005a).

The air traffic control data represents teamwork between the Executive Controller and the Planning Controller collected January-April 2003 in real work situations. The data consists of 10 hours of recorded settings of the air traffic control teamwork. Area Control, which is responsible for producing the air traffic flight information and communication services and managing airspace coordination and supervision while aircraft move in its area, handles flights when they are en route in Finnish airspace. Work in Area Control is organized into teams consisting of two members: the Executive Controller (EC) and the Planning Controller (PLC). The executive controller’s duty is to talk to flight crews and control the aircraft actively through radar and flight strips, while the Planning Controller carries out coordination, plans the task in the longer perspective, makes strip notes and supports the Executive Controller in her/his monitoring.
3 Cockpit interaction

The airline cockpit is a socio-technical setting in which the pilots coordinate their talk and non-talk activities to perform the tasks necessary to fly the plane (Nevile, 2004a; Auvinen, 2009 forthcoming). The term socio-technical indicates that the participants interact as they use and respond to a complex technical system that may link mechanical, electronic and computerized components (see Hutchins, 1995). In socio-technical settings, team members collaborate with each other to perform tasks, assess situations, make decisions, recognize and resolve problems, and so on. In addition to mutual interaction, the pilots also interact with a number of participants outside the cockpit, such as ramp agents, air traffic controllers and cabin crew members.

The pilots always have two formal roles in the cockpit: The first is that of an official rank like Commander (CDR) or Co-pilot (COP), of which the former is usually more experienced and trained crew member. The second is to be either Pilot-flying (PF) or Pilot-not-flying (PNF). The PF controls (flies) the aircraft, making the immediate inputs to control the performance of the plane and taking responsibility for routine planning and decisions for the flight. The PNF typically assists the PF by setting up instruments, reading charts, communicating with the air traffic control (ATC) and monitoring the PF’s performance. Irrespective of which pilot is at the controls of the aircraft, the CDR is always responsible for the major strategic and tactical decisions.

The pilots’ talk-in-interaction mainly orients to the performance of the flight tasks in the cockpit – the pilots seldom engage in casual conversation. A task can be defined as piece of work in which participants conduct talk and non-talk activities in collaboration with each other to achieve an intended and agreed outcome, such as executing a checklist, performing an approach briefing or transferring control and navigation duties during the flight. The cockpit talk is highly scripted and economical. The flight crew operating manuals and standard operating procedures include formal descriptions of what the airline pilots should say on the flight, when exactly to say it and who is responsible for saying it. The salient non-talk activities in an airline cockpit include rotating and pushing knobs, monitoring displays, moving levers, reading checklists, charts and manuals, writing notes, looking out of the window and the like (Nevile, 2001; 2004a).

For safety reasons, the airline pilots need to perform the tasks and the talk and non-talk activities required for them in a strict sequence. The airline cockpit is a multi-task setting in which the performance of a particular task becomes relevant and appropriately next only after other tasks have been completed and specified circumstances prevail (see Nevile, 2002; 2004a; 2006). One large-scale task can be considered to consist of many sub-tasks that are to be performed in predefined order. For example, completing the takeoff task provides at the very least that the pilots release the brakes, start the engines, extend the flaps, taxi to the assigned runway, receive clearance and the necessary information from the air traffic control, accelerate down the runway, achieve the required speed and raise the aircraft’s nose-wheel off the runway in order for the aircraft to become airborne (see Nevile, 2006). Whilst the performance of flight tasks is based on sequences, each pilot must frequently perform a number of tasks concurrently in the course of even the most routine flights (Loukopoulos et al., 2003; see also Dismukes and Nowinski, 2006).
3.1 Intersubjective problems in cockpit interaction

The pilots occasionally face intersubjective problems in the performance of flight tasks. They may momentarily have diverging understandings of what tasks they have completed, what they are doing or supposed to do next. These problems are usually routinely resolved. We address the repair practices intended to locate and resolve the problems of intersubjectivity in cockpit interaction. In all three cockpit examples, the crews are conducting an emergency landing at Arlanda Airport, Stockholm due to fire in a cabin lavatory.

In the first case, an intersubjective problem occurs when the Co-Pilot (COP) misrecognizes the referent of the Commander’s (CDR) request. The CDR then engages in the third position repair to clarify his request. The trouble and its repair make diverging sets of organized knowledge particular to this setting relevant. The consequent repairs at lines 10 and 12 differ in terms of their specificity; the latter includes knowledge specific to the type of aircraft (Airbus) that both the trouble source and the first repair had lacked. As a safety procedure, the pilots have checklists for normal, abnormal and emergency situations. During an emergency, the pilots have to execute an appropriate emergency checklist to recover the situation as quickly as possible. At lines 8 - 9, the COP seems to misunderstand which checklist the CDR is requesting at line 6; at line 10, the CDR addresses the misunderstanding and engages in repair.

(1) (COP=Co-pilot/PF=Pilot-flying, CDR=Commander /PNF=Pilot-not-flying, Crew 5: 0:46)

01 ((Cop is entering data onto the Flight Management System, FMS))

02 COP:  *Ii äl äs*³ ((ILS)) zero one left,
         *Ai el eš* ((ILS)) zero one left,

03 ((Cop is entering data onto the FMS; (10.5) ))

04 CDR:  *Ja*,
         *And*,

05 (1.0)

06 → CDR:  *annatko tsekkilistan sieltä.* hh  
        will you give me the checklist from there. hh

³ English and Finnish are the main languages used by the Finnish airline pilots and air traffic controllers at work. When the participants speak Finnish, the transcripts follow a two-line format including the original Finnish version and the vernacular English translation. What is specific to our data is that the participants may use both English and Finnish (or a mixture of them) within a single turn at talk. In order to discern the occurrence of code-switching, i.e., the alternations between two languages, the words (or syllables/letters) produced in Finnish are italicized in the transcripts.
((Cop completes entering data onto the FMS; (1.2)))

((Cop brings the normal checklist into view; (0.7)))

((COP has a normal checklist in his right hand))

((Cop moves the normal checklist away))

((Cop is seeking the QRH; (3.4)))

((Cop gives the QRH to Cdr))
At lines 1 – 7, the COP is entering flight data specific to Arlanda Airport onto the Flight Management System. After that, at line 8, the COP responds to the CDR’s request with an understanding check by repeating its referent. As soon as the COP reaches up the checklist (line 9), the CDR launches a repair consisting of the initiation “e:i”, “n:o”, the repair marker “siis”, “I mean” and the specification of the referent, “sen imergensi”, “the emergency” at line 10 (cf. Schegloff, 1992). Through his repair, the CDR distinguishes the emergency checklist from the normal checklist. The repair is designed to recast the COP’s understanding to provide for another opportunity to fulfil the request. The CDR also orients toward the COP through posture, gazing directly at him (Illustration 1.).

The COP, however, does not meet the request, despite the clarification of the referent, and a gap of 1.5 seconds ensues. After the pause in talk, the CDR reformulates his repair by revising the description of the referent using the acronym QRH at line 12. QRH stands for the Quick Reference Handbook containing checklists for various abnormal and emergency situations. After a 2.2 second pause, the COP produces a new understanding check, which he then repeats with the acknowledgement “joo”, “yeah” at line 14. The repetition of the understanding check followed by the acknowledgement seems to reveal his change of state in that the meaning of the request has now become clear to him. Simultaneously with his talk, the Co-pilot puts back the normal checklist (14 - 15). During the succeeding 3.4 seconds he seeks the QRH, which he then gives to the CDR concurrently with the area controller’s call (lines 16 – 18, Illustration 2.).

Here an active failure of terminology occurred as the CDR made his request without specifying which checklist he meant. The sequential coordination of interaction also involved an active failure: the CDR appears to have tried to initiate the emergency procedure on his request, i.e., going through the emergency checklist, while the COP was still entering data onto the FMS, and was not ready to engage in a new action. So the issue here is monitoring others’ conduct for coordinating joint activity; that is, pilots should appropriately attend to one another’s readiness, display readiness to one another, etc. The COP’s inability to meet the request there and then points to a latent failure, since the COP and the CDR were not oriented to the same sequential phase of flight; otherwise the COP would have recognized the `checklist´ as that for an emergency despite the terminological looseness. Finally, a latent, organizational failure appears to have been relevant for the distribution of knowledge between the parties. The terminologies for checklists vary between aircraft types. Within the Airbus family, the emergency checklists are called QRH abbreviated from the Quick Reference Handbook. The QRH
abbreviation is not used in other aircraft types, emergency checklists being called emergency checklists. The various aircraft types are composed of different semiotic fields involving slightly but significantly differing systems of classification for items like checklists (cf. Goodwin, 2000). The crew in question differed in terms of flight experience\(^4\) in various aircraft. The COP had probably flown Airbus jets only, whereas the CDR had flown other types as well. The COP had no referent for emergency checklist in his register, while the CDR for his part did not orient to the Airbus semiotic field in making his request; only after the COP had failed to respond to his first repair did the CDR seem to come back to the Airbus semiotic field by adapting to its particular terminology. To sum up, the trouble took place when the CDR and the COP had momentarily lost their intersubjective sense of the referential meaning of the `checklist´, the appropriate coordination of action, the sequential phase of the activity and an orientation to the same semiotic field; that is, the trouble emerged when two active failures intertwined with two latent failures. The repair then brought the parties back to the common world of meanings, the sequential stage of the activity and semiotic field.

In the second case, three different safety holes glided together. Again imprecise terminology contributes to the referent recognition problem. The sequential coordination of the interaction also seems to contribute to the emergence of the trouble. Only after the understanding problem has been resolved does it turn out that pilots have a differing view of the sequential stage of the flight because of the interruption of briefing that seems to have escaped the COP’s mind. The exercise scenario is again the same, but the crew is different. The CDR makes an inquiry concerning the approach briefing that is conducted on each flight to ensure that the pilots have a shared understanding of the approach and landing procedure (c.f. Nevile, 2004b). In the approach briefing process, the Pilot-flying inserts all the flight data relevant for the approach and landing (the runway in use, approach type and terminal weather conditions and so on) into the Flight Management System (FMS) and informs the Pilot-not-flying of the data.

The briefing operations conducted by the COP had been interrupted three times for various reasons prior to the beginning of this instance.\(^5\) In the extract, the COP initiates a repair twice. The first repair initiation at line 6 relates to the prior turn at line 4 while the second, at line 15, relates to the prior turn at line 13. The repairs get completed by the CDR at lines 13 and 16 respectively. The ensuing conversation between the CDR and approach controller, which is a separate inserted sequence at lines 7 - 12, is omitted from the transcript.

(2) (COP=Co-pilot/ PNF=Pilot-not-flying, CDR=Commander/PF= Pilot-flying, Crew 2: 0:50)

01 COP:  Passing [( ) (teen)] thousand feet,

02 CDR     [( ) ( )],

\(^4\) Total flight hours: COP (500 h), CDR (9000 h). Along with Airbus jets, the CDR had experience of flying with some if not all of the following aircraft: DC9, MD80, DC10 and MD11.

\(^5\) The briefing process was interrupted, firstly because of insufficient flight data, i.e., the COP had not entered the weather information into the FMS, so that the crew discontinued the actual briefing and the COP went back to enter the omitted data; secondly, because of the technical problem in the cockpit simulator requiring immediate action from the crew; thirdly, because of the Instructor’s intervention with his indirect suggestion for the crew to proceed to the execution of the emergency descent checklist.
03 (4.0)

04 → CDR: *Mites se sanoo se sun< ö ♦briiffaus homma siellä.*
How is it that your< uh ♦briefing job there.

05 (0.5)

06 → COP: *Mitä,?*
What,?

((six lines of talk between approach control and the CDR is omitted ))

13 → CDR: *äd:: se ♦briiffaus (. ) homma.*
e:: the ♦briefing (. ) job.

14 (1.2)

15 → COP: *M::=:mikä briiffaus homma,=
W::=:what briefing job,=

Illustration 3.
COP:” W::=:what briefing job,=”
((COP glances at CDR))

16 → CDR: =ö:  [tämä, (. ) o:nks [ (se valmis jo),   ]
=e:  [this, (. ) i:s   [ (it done already),]  

17  

18 → COP:  [Siin on se >mato >mato ] laatikko
[There is the >worm] box

19 → COP:  eikö vaa<, (. ) [se on valmis,
right<, (. ) it’s done,

20  

Illustration 4.
CDR: “This,”
((CDR points to the ‘wormbox’))

(((Cdr points to the Cop’s FMS))

16 → CDR:  [tämä, (. ) o:nks [ (se valmis jo),   ]
=e:  [this, (. ) i:s   [ (it done already),]  

17  

18 → COP:  [Siin on se >mato >mato ] laatikko
[There is the >worm] box

19 → COP:  eikö vaa<, (. ) [se on valmis,
right<, (. ) it’s done,
Illustration 5. COP: “It’s done,”
((COP points to the ‘wormbox’))

21 (.)

22 CDR: Okei.
      Okay.

At line 1, the COP informs the cabin crew about the aircraft’s current altitude. Next the CDR makes an inquiry about the briefing (line 4). A syntactic redirection and hesitation display a word search, since the CDR has difficulty in finding the proper wording. He ends up with the verbalization “briefing job”, “briefaus homma” after the word search. The possessive adjective “your” locates the referent in the COP’s territory and the deictic expression “there” suggests its proximity to the COP. The pronoun “se”, “it” marks the referent known to the recipient (see Laury, 1991). The COP responds with the open repair initiation “what” at line 6 (Drew, 1997). The interaction is then disrupted by the approach control’s callout (omitted from the extract). At line 13, the CDR returns to his inquiry, thereby producing a correction for the COP’s repair initiation. The CDR seems to consider the COP’s problem as having been hearing rather than understanding the talk. After a pause, the COP re-initiates a repair by locating the trouble source in the referent of the prior turn and turning toward the CDR (Illustration 3).

At line 16, the CDR produces a repair with the demonstrative pronoun “this”, simultaneously with a pointing gesture towards the COP’s FMS (line 17, Illustration 4.). After the ostensive clarification of the referent, the CDR reformulates his inquiry as concern about whether the FMS data input has been done. The question reveals that the CDR does not know whether the data entry on the FMS has been completed. The COP first displays that he has understood the referent by stating its nickname⁶ and then answers the question at lines 18 – 19, while the COP simultaneously points towards the FMS (line 20, Illustration 5.). Subsequently, the CDR acknowledges the COP’s answer that the data has already been entered on the FMS (line 22). The momentary loss of intersubjective understanding has been repaired.

The CDR’s expression briefing thing was equivalent to approach briefing. There seems to be terminological looseness concerning the item in question, the Flight

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⁶ ‘Worm-box’ is a nickname for the Flight Management System.
Management System, or FMS, as well. These terminological problems contribute to a problem in recognizing the referent. The CDR’s trouble source turn was delivered after the execution of emergency descent checklist. An unexpected return from this checklist back to the approach briefing amounts to a sequential co-ordination trouble contributing to the COP’s difficulties. Further, the CDR’s inquiry revealed the pilots’ differing understanding of the completion of the approach briefing. The COP no longer oriented to briefing operations as an open topic as he did not seem to recall that the approach briefing was unfinished. For him, the briefing operations were already completed and known to be so by both pilots, making the CDR’s inquiry incomprehensible to him. Again the trouble came to the surface when active and latent problems were joined.

The pilots’ understanding differed over whether they had completed the task of data entry on the FMS. It seems that the safety procedure here contributed toward elimination of risk by opening up communication that made pilots aware of their lack of shared understanding of the flight phase. To fly their plane, the pilots need to regularly perform concurrent tasks with diverse temporal continuities. When both pilots are not aware of where they are in terms of task performance (e.g., whether some particular task has been completed or not), problems of intersubjective understanding may arise. Since the COP had forgotten, as his actions display, that the approach briefing was still unfinished, the CDR had no way of knowing if the task of data entry was completed or not.

The third case shows how the pilots augment standard callouts (here, ‘Your controls’ – ‘My controls’) with interactive back-ups of repairs as a safety mechanism (cf. augmentations of scripted financial interactions, Knorr-Cetina & Bruegger, 2002). The pilots are discussing the transfer of control and navigation duties. The COP, who is in control, is giving these to the CDR at line 5. The CDR first accepts the duties at line 6, but then allocates them back to the COP at lines 8 and 10 with a repair activity. Also in this case, an active error and two latent troubles coincide.

(3) (COP=Co-pilot/PF=Pilot-flying, CDR=Commander /PNF=Pilot-not-flying, STE= Steward, Crew 4: 0:47)

01 STE: *Selvä no sitte me pannaan hösseliks*, ((idiom))
   Right well then we start to work flat out.  

02 (0.5)

03 CDR: *Kyllä*,
   Yes,

---

7 The pilots’ use of a second language as the official prescribed language seems to lead to a number of interesting code-switches between English and Finnish. Here *briiffaus* is a loan from English, which is adapted to Finnish. *Matolaatikko* is the Finnish nickname for the auxiliary device. Code-switches would deserve their own study.

8 More work would be needed to analyze timely places for interruption of activities or sudden shifts in action. In any case, unexpected moves impose interactional complication, even where these moves were due to the flight operations and safety. This is a catch twenty-two.

9 To work flat out, as hard and fast as you possibly can, is roughly the sense of *panna hösselksi*. 
04  (3.2)

05  →  COP:  *Se on your controls taas,*=
      It is your controls again,*=

06  →  CDR:  =My controls,

07  ((CDr starts to shift his gaze and hand to the FMS; (0.5 ))

Illustration 6. ((CDR starts to shift his gaze and hand to the FMS))

Illustration 7. CDR: “Or wait a minute”
((CDR raises his index finger))

08  →  CDR:  *tai hetkine >otas vielä<,*
      or wait a minute >keep it still<,*

09  .

10→  CDR:  *pidä [vielä jonkun  aika]a nii mä*
      keep [it still for a while] so I’ll

11  COP:  [(aː] >minä pidän) controls< ],
      [(aː] >I’ll keep) the controls< ],

Illustration 8. CDR: “Keep it still for a while”
((CDR points toward COP))
At the beginning, the CDR completes his conversation with the Steward about the emergency on board (lines 1 - 3). The COP then hands the control and navigation duties to the CDR at lines 4 - 5. According to the standard operating procedures, the prescribed wording for the PF/PNF duties transfer is “your controls”. The COP orients to the norms of interaction by embellishing his talk with “se on... taas”, “it is...again”. The CDR accepts immediately, taking the control and navigation duties with the official wording “my controls” at line 6. The CDR then shifts his gaze and hand towards the FMS (line 7, Illustration 6).

Following his gaze and hand movement, the CDR initiates a repair with “or” and suspends the ongoing activity of duties transfer with “wait a minute” at line 8 (see Illustration 7). At his repair proper, the CDR asks the COP to “keep” the controls “for a while”, which the COP accepts in overlap at lines 9 – 11 (see Illustration 8). Next, the CDR accounts for his change of mind (lines 10, 13). Simultaneously with his talk, the CDR is bodily oriented to his FMS (lines 13 - 14). The CDR then orients to the data insertion at the same time reading the approach data to the COP.

In terms of the sequence, the CDR’s repair at line 8 focuses on his prior turn at line 6: formally, it is a self-initiated self-repair produced in the turn next to the trouble source. In sequential terms, the action is complex: the CDR’s turn is delivered in relation to the COP’s prior turn at line 5 being functionally other-initiated other-repair by the CDR. That is, it is an other-repair (done as a self-repair) that reverses the role allocation suggested by the other party.10

Further, it is occasioned by the particulars of the socio-technical setting as a constraint on the ongoing activity. Before the repair, the CDR moves his gaze towards the FMS (lines 7 - 8) displaying his orientation at that moment. He also mentions the data-entry task as his account for his reorientation (lines 10, 13 and 16). The visual glimpse of the FMS seems to have reminded the CDR of the task. At his repair, the CDR allocates the control and navigation duties back to the COP in order to ensure input of the data into

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10 The use of a repair here may have the benefit of avoiding a disagreement. If the CDR had refused the COP’s order, there would have resulted an open disagreement at least momentarily.
the system. The CDR’s repair is twofold: it both corrects the COP’s prior talk and also restores the sequential order of action in the cockpit.

In this case, the COP ordered the control and navigation duties to the CDR who first accepted the duties himself but then requested the COP to resume flying. An active failure in the sequential coordination of interaction occurred here; as shown, the processing of flight data turned out to be still incomplete when the COP oriented to the duties transfer. The latent failure was that the pilots lacked a shared understanding of the sequential phase of flight: The COP thought that the closure of the conversation between the CDR and Steward was a sequentially appropriate environment for the duties transfer. Initially, the CDR aligned with the COP’s view of the sequential stage of the flight but then questioned it. Another latent failure was that the standard operating procedures limit the range of responses to callouts such as ‘your controls’. The flight procedures script wording only for the affirmative response (c.f. Knorr-Cetina & Bruegger, 2002). The standardized response to ‘Your controls’ is ‘My controls’, exactly as the CDR said. The scripted wordings do not include a callout that would enable the airline pilot to formally refuse to take on the control and navigation duties. The standard operating procedures also aim to standardize the pilots’ actions by restricting responses to callouts. When standardized responses to standard callouts are inappropriate, pilots may need to remedy the scripted wordings with practices from ordinary talk, such as repairs or pre-sequences.

In cases 1 and 2, which focused on the organization of talk-in-interaction, the pilots were identifying and resolving problems in hearing or understanding the cockpit talk. However, in their talk-in-interaction, the pilots were also oriented to the ongoing sequential phases of tasks during flight. An analytical consequence is that the sequences of talk produced in an airline cockpit and other socio-technical settings should be analyzed as part of the sequential order of action-in-progress. In the third case, the pilots specifically dealt with the problem of establishing and maintaining the sequential order of action in the cockpit. This case concerned the relative positioning of moves, utterances and actions, i.e., the organization of talk-and-action-in-interaction (see Arminen, 2005b). Interestingly, the shared understanding about the positioning of particular action was returned in the cockpit through the practices of talk-in-interaction. This illuminates the close relationship between language and action; it is fallacious to treat the language system as distinct from action. As these cockpit cases and the following case on air traffic control show, language and action are juxtaposed, mutually elaborating each other (Goodwin, 2000).

4 Air traffic control teamwork

Air traffic control consists of complex, distributed time critical activities. The controllers are charged with connecting people and activities over time and space according to a canonical time-table and situated demands. The activities are accomplished through interaction based on shared knowledge and professional practices of cooperation and coordination (Arminen, 2000). Coordination takes place both within the air traffic control centre and between the centre, flight crews and other centres.

In air traffic control, an aircraft is controlled from different centres of coordination. The control tower takes over and handles the aircraft at the airport during take-off and landing. Approach controllers are responsible for the airspace around the
airport and, finally, the area controllers manage the traffic while it is en route. To facilitate this, the controllers constantly need to coordinate their work, which is both stipulated by procedures and supported by a number of artefacts.

Procedures involve the division of airspace into sectors, agreements between sectors concerning standard routes and flight levels (altitude) for handling the aircraft over sectors, etc. These procedures are a resource that enables the controllers to gain essential information about upcoming situations such as when, where and at what altitude to expect a particular flight. The controllers can thus anticipate upcoming situations and deal with irregularities.

Several artefacts support air traffic control. Some, such as the radar, enable awareness of the situation in the sky, whereas others are designed to reduce the time to perform recurrent tasks, such as the speed dial panel for the telephone. To cope with the distributed nature of the setting, there are also artefacts designed to facilitate coordination of the activities between control rooms, such as the flight plan database and its printouts. Both the flight strips and the closed-circuit television system display parts of controllers’ workspaces to other controllers.

Air traffic control is intended to produce an orderly flow of traffic, the controllers’ work being based on a division of labour that has to be managed in interaction and maintained through shared orientation. This orientation concerns cooperation and collaboration, the individual controllers having to attend to the whole situation, including how their picture and plans fit into the pictures and plans of colleagues, other control centres and flight crews. Common understanding is a spatially and temporally situated product of juxtaposing the individual picture and a grasp of the orientations of the other controllers involved. It is based on training, individual experiences and communicative practices providing a framework for interpreting individual actions (Palukka and Auvinen, 2005).

4.1 Recognizing and solving problems

The goal of air traffic control is to handle large volumes of traffic both safely and efficiently. The work is characterized by the redundancy which can provide back-ups in case of possible errors. There is a need for shared understanding of the system and what each individual is doing in relation to others. This understanding may be gained through overlapping knowledge of each other’s tasks. In the following case, the participants are dealing with institutional problems emerging on the level of interaction. This case includes a latent problem that manifests another one: the departure airport pilot briefing has accepted a requested, faulty flight level, which manifests lack of co-ordination between departure and area control. The problem then manifests itself in the interaction between the controllers. We will see how the participants, the Executive Controller (EC) and the Planning Controller (PLC), manage to achieve shared understanding and correct the error.

This case shows how the EC and PLC constantly establish and maintain a shared understanding of the traffic flow. The mutual orientation towards handling the aircraft occurs through the talk, gestures, bodily postures and technical artefacts, including the radar, closed-circuit television system, airspace map, flight plan data and its printouts,
called strips. The multimodality of action is realized through talk-in-interaction and physical coordination oriented to the materialized artefacts in the local environment.

(4) (EC=Executive Controller, PLC= Planning Controller)

01 PLC: =Kattos kun (       ) kiipee [aika
       =Look how (       )is climbing[quite

[Image 9. PLC: Look how is climbing quite @ swifly@
((EC shifts his gaze toward the radar screen.))]

02 PLC: [((EC shifts his gaze toward the radar screen))

03 PLC: @rappana [sti@
       @swift [ly @ (   ) (   )

04 EC: [Se vetää ihan rouheesti =mä odotan
       [ It’s pulling up quite fiercely=I’ll wait

05 EC: että mä katton tohon sataan yhdeksänkymppiin
       that I check it to hundred ninety((190))

06 EC: sitten vedän sen tohon SAS:n ylitte
       then I’ll pull it there over SAS

07 EC: mutta tot[a
       but e|r

08 PLC: [ni
       [ye

09 (1.0)

11 An aircraft of Scandinavian Airlines
Melkein sille sen (0.2) nelj kolkyt ((430))
one could almost that (0.2) four thirty ((430))

vois sitten (0.7) ty[kittää]
throw (0.7) to [it

((PLC shifts his gaze toward the strip board))

(0.5)

PLC: >Neljä sataa<, ((400))
>Four hundred<,

Onks se neljä sataa,
Is it four hundred,

=Ei kun neljä kolme [kytä ((430)) o’right
=No it’s four thirty ((430)) o’right

((PLC looks at the strip board and taps his pen against the flight strip))

(0.5)

PLC: Jesu[s

((EC shifts his gaze toward the close circuit television))

[Sehän] [menee RVSM:n
[y’know it]goes

((PLC shifts his gaze toward the closed circuit television))

((coughs))

((coughs))

mukaan tonne,
according to RVSM there,

(1.2)
Illustration 10. EC: “y’know it goes according to RVSM there” 
((EC shifts his gaze toward the air space map))

27 ((EC shifts his gaze toward the air space map; (0.8))

28 EC:  *Onks se oikeen värinen pinta,* 
Is it the right colored level,

Illustration 11. Is it the right colored level 
((EC bends toward the air space map))

29 ((EC bends toward the air space map; (0.5)))

30 PLC:  *Ei*  
No

31 (0.5) ((PLC shifts his gaze toward the air space map))

32 EC:  *Ei okkaan katopa ny (.) se on väärän värinen*  
No it isn’t watch that (.) it’s the wrong colored

33 EC:  *pinta,*
The PLC points out a possible problem at lines 1 - 3 by indicating an aircraft climbing exceptionally steeply to the EC, who directs his attention to the aircraft’s maneuver by shifting his gaze toward the radar screen after the PLC has said `climbing´ (Illustration 9.). The symbolic representations of the aircraft on the radar screen compose the semiotic field that the PLC has made mutually relevant through his talk and posture. The EC’s response (line 4) displays his orientation to the common object of action and shows his agreement with the PLC through an upgrade. The EC then hurries to state his plan for the aircraft by launching it immediately after his assessment (lines 4 - 6). The subsequent EC’s turn initial “but er”, “mutta tota” projects a complication concerning the next step in the plan (line 7). The PLC immediately shows his alignment with the projected trouble with his last item overlap “ye”, “ni” at line 8.

At lines 10 - 11, the EC states his agreement with the requested flight level (430), which is exceptionally high. The PLC receipts the EC’s plan by shifting his gaze toward the strip board, and then initiates a repair after a short delay (lines 12 - 14). The EC responds with an understanding check `is it four hundred´ at line 15 and shifts his gaze toward the flight strip board. At line 16, the PLC retracts his repair and accepts the EC’s plan by saying `no it’s four thirty´ and simultaneously taps his pen against the flight strip, thereby pointing out his source of information. Through the repair sequence, the controllers have established agreement on their plan as regards the aircraft and established a shared understanding of the basis of their agreement. The flight strips that are printouts of the flight plan data have become a vital aid in organizing the teamwork at this point being mutually available and interpretable visible evidence. The artefacts also have a public character that contributes to the establishment of mutual agreement upon which the collaborative action rests (see also Harper et al. 1991; Hopkin 1995).

In the repair sequence, the PLC has eventually retracted his repair at line 14 with a new correction at line 16, thereby confirming the EC’s original suggestion. In terms of
epistemic organization, the PLC’s initial repair seemed to originate from professional know-how. Although the PLC had immediately turned towards the flight strips, the level 400 did not derive from the flight plan data, in which it had been marked as 430. It seems to have been his gut-feeling about the appropriate flight level. After checking the flight strip (line 17), the PLC first admits his faulty judgment, but then continues to express his surprise through his assessments “o’right” and “jesus”. The code-switching from Finnish to English seems to highlight these assessments. Without articulating it propositionally, the PLC seems to have maintained throughout his stance that something was going wrong, and after the PLC’s second assessment “jesus”, the EC turns toward a new information source, the closed circuit television. This new semiotic field helps the EC orient toward seeking information about the route that is relevant for deciding the appropriate cruising level of the aircraft. The EC’s speech particle “-han” (roughly “y’know”) at line 21 displays his orientation to mutual of knowledge of coordinators concerning the relevance of the RVSM vertical separation procedure for the cruising level. According to the RVSM, the even flight levels are reserved for westbound traffic and the uneven for eastbound (Figure 2.).

![Figure 2. RVSM Airspace within the area of applicability of the ICAO Regional Supplementary Procedures for Europe and Neighbouring Areas.](http://www.ecacnav.com/RVSM)

To check how the route fits into the RVSM vertical separation scheme, the EC shifts again toward another semiotic field, the airspace map (Illustration 10.). After juxtaposing several semiotic fields, the EC starts to draw conclusions, making his effort public through his question about whether the requested cruising level is in accordance with the colour coding of RVSM procedures (line 28). Before the PLC has responded, the

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This code-switching is built remarkable. “O’right” is a marked Americanism. In Finnish, there is a word “Jeesus” but it is not used as a swear-word, like “jesus” pronounced in English. The deliberate shift to foreign words seems to be a powerful metacommunicative gesture.
EC bends his upper body further towards the airspace map to see the information required for his judgment better (Illustration 11.). The PLC, without turning toward the airspace map, responds with a blunt “no”, thereby displaying that he already knows that the cruising level requested was not appropriate (line 30). Subsequently, the EC and the PLC confirm their mutual understanding of the inappropriateness of the level requested, and then briefly negotiate their plan for the flight level (lines 32 - 40). The problem has finally been resolved.

The problem emerged when a latent error became active in the Area Control. The error itself was based on two or more errors. The aircraft had initially requested a flight level that was against the orders of the Central Flow Management Unit (CFMU) of Eurocontrol. The reasons for requesting this flight level fall beyond this article. Second, the departure airport pilot briefing had accepted the incorrect cruising level before take-off, again for reasons unknown. Finally, the Departure Control had handed an aircraft over to the Area Control without any explicit coordination, i.e., without being negotiated. The aircraft had been cleared to the wrong flight level in terms of RVSM procedure. As the wrong level had been passed on to the flight plan, the controllers were at first about to accept the cleared cruising level when the aircraft itself was climbing toward the cleared level of the flight plan. If the Area Control had accepted the incorrect flight level, then another line of defense would have broken down, and a safety hole in the organization of flight would have passed to the new layer.

The organization of the repair which corrected the emerging error was complex. The repair consisted of three dimensions through which the initial repair was first corrected before a new attempt at error correction. This three-dimensional organization of repair makes the epistemic organization of the air traffic control work visible. The controllers recognized the situation, detected deviation, defined the problem and corrected the error through multimodal and multidimensional organization of work, in which several semiotic fields each offer a limited perspective that requires action to be complemented by other fields. In this fashion, human activity binds information gathered from several separate data sources. The repair practices make perspicuous the way in which talk, actions, procedural and technical resources are interwoven. The analysis of the repair shows how the controllers managed to establish and maintain the intersubjective sense of the traffic flow, and eliminate the latent error that had become a part of the situation they encountered. The repair operation allowed the controllers to become aware of the aircraft that had requested the wrong flight level so that they then could reschedule the flight plan to fix this potential safety threat.

5 Discussion

Reason’s model of accident causation broadened the area of accident investigations beyond psychological and technical errors to the latent conditions leading up to an accident, thus opening up their multifaceted nature. However, the nature of errors has remained underspecified, since the model does not target errors in their activity context (c.f. Dekker, 2002; 2006). Consequently, Reason’s model has been criticized for

13 The basic rule is that handovers must be coordinated. However, to minimize the work involved in handling routine handovers, many are usually carried out without any explicit coordination, i.e., without being negotiated.
shifting the focus away from the front-line action (Young et al., 2005). Reason (1997: 234) himself has warned that "the pendulum may have swung too far in our present attempts to track down possible errors and accident contributions that are widely separated in both time and place from the events themselves". At worst, front-line activities may have fallen out of focus because of the insistent search for the latent conditions of failures.

Subsequently, human factors analysis was designed to describe the holes in the cheese, as a response to gaps in Reason’s model (Shappell and Wiegmann, 2000). The taxonomy of unsafe operations was developed to bridge between the model and human processes (Shappell and Wiegmann, 2001; Wiegmann and Shappell, 2001), dividing unsafe acts into skill-based, perceptual, decision errors and violations (purposeful breaches of procedure). Human factors analysis also follows the psychological tradition in its focus on individual actions. Failures in communication and co-ordination are cited as preconditions for unsafe actions. In human factors analysis, communication and collaboration are underlying causal factors, not events as such.

While Reason’s model and the human factors analysis develop accident investigation, neither of them addresses the order at the level of work practices, nor the reflexive tie between talk and action in work interaction. The detailed studies on the coordination of talk and action may discern the ways in which failures and errors not only happen but may be achieved as a part of the ongoing activity (Nevile and Walker, 2005). They may both contribute to our understanding of what the holes in the cheese are, how they appear and become relevant in the course of action and, not least, identify a new layer of action, a set of systematic practices through which parties in collaborative action repair emerging troubles to prevent incidents and accidents before their occurrence. Studies of the coordination of talk and action allow inspection of the dimensions of order that exist between incipient failures and active failures. The repair practices that have been identified within ordinary, mundane talk-in-interaction (see Schegloff, 1979; 1992) compose a structural defense against emerging accidents that works within situated action.

Reason’s model, for its part, can be applied to augment the studies on the coordination of talk and action. The model is a heuristic tool that assists analysts to reverse engineer the safety critical aspects of interaction in complex socio-semiotical systems. It helps the analyst to address latent context of the problems that have become actively relevant for the ongoing action-in-interaction, thereby allowing the analysis of local interaction to be connected with wider aspects of the mobility system. Indeed, our analysis shows that in aviation there are a considerable number of latent failures that become in the surface in the frontline aviation teamwork forming a defense against latent failures to become active incidents. The recurring problems in the sequential coordination of activities, linguistic problems and organizational failures become relevant for the coordination of talk and action in aviation and are repaired in action before they have caused incidents or accidents. In all, the model allows a clearer picture of the relationship between communication (and its problems), technical errors and failures in the aviation procedures by highlighting the nature of problems so that we can see more distinctly the role of communication and other kinds of errors in practice.
The sequential co-ordination failures involve a lack of shared understanding of the phase of flight. Activities may be initiated at the wrong time, before or after, their sequentially appropriate slot. Timing failures also include cases of failed initiations of co-operative action when the recipient was focused on the ongoing task. Further analysis of timely places for interrupting ongoing tasks is needed. Linguistic failures include lexical/terminological looseness that eludes the sense of the action requested. Sloppiness may concern the referent or the sense of the request. Procedural rigidity of prescribed response options in standard operational protocol may also make giving an appropriate response impossible in situ. Organizational failures include unnecessary complexities, such as variation in standard terminologies between aircraft types. Faulty decisions at earlier stages of the ongoing actions, such as an incorrectly prescribed flight level, come out as organizational failures at the front-line level. Acceptance of faulty decisions also displays lack of co-ordination and cross-checking.

The repair practices were used in amending troubles in co-operative practices in aviation interaction. These practices have their origin in mundane interaction and their forms originate from the practices of ordinary talk-in-interaction. However, the repairs in the aviation interactions are tied to the organization of the settings. The repairs make the organization of work observable by displaying the ways in which activities are tied to the sequential progression of phases of action. The repairs of trouble show what the normal order is and what resources and practices can be invoked to defend it. A conspicuous feature of repairs in aviation is that they often are more complex than repairs in mundane communication (c.f. Schegloff, 1979; 1992). The repairs in aviation interactions are often composed of multiple rounds, involving reformulations (extract 1), multiple initiations (extract 2), other-repairs that are carried through self-repairs (extract 3) and repairs of repairs (extract 4). These complexities appear at the level of material practices in the cockpit and the ATC suite in the use of several, intertwined data sources. They show how professional practices become relevant for the organization of work so that the errors at one level of action are corrected with the help of other data sources. Since complex technological environments include multiple simultaneous communication flows whose value partially depends on their mutual linkage, individual actions may be embedded in their real-time co-ordination with the actions of others. The repair practices show how safety is achieved in action.

Local, situated knowledge is needed to decipher and identify the errors in the multi-dimensional, computer-assisted organization of aviation practices. From a methodological point of view, a number of requirements become relevant. Multimodality is an elementary feature of the organization of action in technical environments. The analysis has to take into account verbal, embodied, organizational and technical resources. Research requires competence in the analysis of talk-and-action-in-interaction and sufficient, passive understanding of the area in question. Aviation interactions are verbal, embodied and technically mediated. Bodily coordination complements verbal coordination of action. Gestures, gaze directions, glances and postures are particularly relevant at critical moments when a focus of attention is needed immediately. Thus, visual information is obligatory for clear understanding of action in aviation. Moreover,

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14 An actor may fail to do an action that s/he is responsible for. These absent actions are resolved by reminders of the actor’s responsibility. Despite their relation to the topic in hand, the absent actions fall beyond the scope of this article, and are analyzed elsewhere (see Auvinen 2009 forthcoming).
material artifacts are numerous and quintessential for the achievement of action. For instance, in air traffic control, instruments include radar, radio- and interphone, pc, air space map, flight monitoring data systems, paper flight strips,\textsuperscript{15} and paper and pencil. Collaboration via objects, instruments and multiple media makes the multimodality of actions not just salient but an irreplaceable part of the aviation interaction. The chief methodological point is thus to resist the distinction between social and technical aspects of action. The aim is to investigate social action as a situated accomplishment that emerges from its practical management within language, social configuration and material resources.

\textbf{6 Conclusion}

Repairs are a salient but neglected level of order within human factors in aviation, a layer of organization that exists between incipient and active failures in addition to technical and procedural back ups, such as check lists. To catch this beast, we have to have tools sensitive to the local production of social organization. Ethnomethodologically inspired studies on action allow us to focus on the practices and procedures of situated actions and events, enabling us to analyze and decipher the meaning of technology in action. These studies on the coordination of talk and action may complement Reason’s model in a significant way, helping us to re-specify the nature of work processes, including the emergence of failures and troubles. The analysis of breakdowns of order provides useful hints for evaluating the sufficiency and usefulness of existing safety procedures. The knowledge gained through the analysis of troubles and their repairs may be used to expand our understanding of how the work is done through the appropriate use of artefacts, and what may happen if complications emerge. In all, technologically advanced forms of social interaction and communication present a new challenge to social and human studies, posing a new task for research and development but also requiring new methodological solutions such as combination of Reason’s model with studies on social interaction.

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\textbf{References}


\textsuperscript{15} Paper flight strips were still used in 2003 when this data was collected. Digital instruments replaced them in 2005.


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**Table, Figure and illustration legends**

Table 1. Air carrier volumes and flight safety (airlines) in the US 1930-2005. (Leary 1995 for the 1930 and 1939 figures, and US Department of Transportation 2001.)

Figure 1. The Swiss cheese model of accident causation (Reason, 1990).

Figure 2. RVSM Airspace within the area of applicability of the ICAO Regional Supplementary Procedures for Europe and Neighbouring Areas. [http://www.ecacnav.com/RVSM](http://www.ecacnav.com/RVSM)

Illustration 1. CDR: “N:o.=I mean the ↑emergency<,” ((COP has a normal checklist in his right hand))

Illustration 2. ((COP gives the QRH to CDR))

Illustration 3. COP: “W:::=what briefing thing.,=” ((COP glances at CDR))

Illustration 4. CDR: “This,” ((CDR points to the `worm box´))

Illustration 5. COP: “It’s done,” ((COP points to the `worm box´))
Illustration 6. ((CDR starts to shift his gaze and hand to the FMS))

Illustration 7. CDR: “Or wait a minute” ((CDR raises his index finger))

Illustration 8. CDR: “keep it still for a while” ((CDR points toward COP))

Illustration 9. PLC: Look how is climbing quite @ swiftly@ ((EC shifts his gaze toward the radar screen.))

Illustration 10. EC: Y’know it goes according to RVSM there ((EC shifts his gaze toward the air space map))

Illustration 11. EC: Is it the right colored level ((EC bends toward the air space map))