

Coordination and Safety Behaviors in Commercial Aircraft Maintenance

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Commercial aviation maintenance related incidents reported to the Aviation Safety Report System were investigated focusing on coordination problems. Among 1000 analyzed reports from a two-year period, 98 internal coordination issues within the maintenance team, and 24 external coordination issues between maintenance and other departments were discovered. Frequently established problematic included: *not delivering information*, *sending wrong information* and *lack of responsibility*. Most conflicts were solved by competing (or accommodating) behavior, such that one party prevailed over the other party's opinion. Coordination problems have the potential to render many necessary safety procedures ineffective. This study identifies coordination problems that are potential sources impairing safety procedures in aircraft maintenance such as misapplication of minimum equipment list items, missing inspections, logbook entry failures, and wrong parts installation.

INTRODUCTION

Work in commercial aviation organizations is generally constituted by a distributed system, where people with different competencies may need to work together as a team (Rasmussen, Goodstein & Pejtersen, 1994). In aviation maintenance, technicians (AMTs) perform specific tasks for which they train extensively. While their individual expert abilities are important, accomplishing safety also depends upon their interpersonal skills and development of effective, cooperative working relationships with other employees in different jobs. This involves team coordination, a dynamic interaction during a task process (Rasmussen et al., 1994) to "orchestrate the sequence and timing of interdependent actions" (Marks, Mathieu, & Zaccaro, 2001, p. 363).

Effective team coordination is essential for productivity, safety, and job satisfaction. It is especially important in safety critical industries such as aviation (Flin, O'Connor, & Crichton, 2007). Teamwork improves both safety and efficiency by detecting and correcting individual errors and by using all available resources in organized manners (UK Civil Aviation Authority, 2006). Gittell (2000) argued that frequent and timely problem solving communication, helping, sharing goals and knowledge, and showing mutual respect among workers improves on-time departure and shorter turnaround times in flight operations.

Communication is a closely related construct within coordination. Although some studies classified them as parallel processes for teams (Flin, et al., 2007; Hoegl, & Gemunden, 2001; Marks et al., 2001; Rousseau, Aubé, & Savoie, 2006), we applied the idea that communication is a critical medium of coordination (Hall, 2002). Specifically, communication is an interactive process of generating and interpreting messages (Rice & Stohl, 2006). In special cases, work domains are designed in advance and controlled in a coordinated way; however, most working systems are loosely coupled, requiring extensive communication among workers (Rasmussen, et al., 1994; Suchman, 1987).

Although procedures in aircraft maintenance are standardized by regulations and company procedures, miscommunication or conflicts inevitably occur, thus deteriorating the quality and efficiency of maintenance work. Hobbs and Kanki (2003) noted in their study of incident reports in the NASA Aviation Safety Report System (ASRS), which collects anonymous voluntary incident reports, that lack of coordination was the third largest contributing factor in aircraft maintenance human error. Lack of teamwork, communication, and assertiveness are also part of Gordon Dupont's Dirty Dozen (1997), a renowned list of errors and factors that can lead to maintenance incidents and errors.

How can we establish effective teamwork? The Federal Aviation Administration (2000) recommended that effective teamwork requires ten characteristics: clear purpose, relaxed interaction, participation, listening, comfortableness with disagreement, openness, clear expectations, shared leadership and responsibility, good relations with others, and team maintenance. We can also learn the importance of coordination from incidents and accidents. For example, unspoken assumptions, fear of asking too many questions, hesitation to thoroughly check the work of colleagues, shift handovers, working with unfamiliar people, and an overall lack of adequate communication are well-known potential factors that lead to maintenance coordination problems (Reason & Hobbs, 2003).

From both a theoretical and practical point of view, continued study is necessary to learn what kind of coordination problems occur in aviation maintenance events that ultimately influence safety. Existing ASRS narratives serve as a valuable resource to study common coordination problems in commercial aircraft maintenance. In the present study we conducted a content analysis, focusing on human error in aircraft maintenance in order to identify weaknesses of the current aircraft maintenance system.

METHOD

We performed a content analysis using maintenance related incident reports pertaining to Federal Aviation Regulation Part 121 scheduled airline operations downloaded from NASA’s ASRS. Initially, 3534 reports were downloaded from the ASRS website and were later narrowed down to 1,000 reports for the 2-year period spanning August 2004 to July 2006. A subject matter expert in aircraft maintenance (forty years experience in airline maintenance, corporate, general aviation, and university teaching/research) and aviation human factor researchers examined the narrative section of each report to code undesirable outcomes and their contributing factors. A combination of qualitative analysis (Denzin & Lincoln, 2000), and categories from the Human Factors Analysis and Classification System (HFACS) (Wiegmann & Shappell, 2003) were applied and modified for the purposes of this study. After individually coding the reports, the researchers achieved an acceptable level of reliability (0.4-0.6 in Cohen’s kappa and 0.8-0.9 in proportion of agreement). When encountering a coding disagreement, a separate human factors researcher coded and settled the conflict. During the coding process, 320 reports were disqualified as they were deemed not to contain human factors issues. Thus 680 reports were examined for this analysis.

Next, the primary raters classified coordination issues in detail, achieving acceptable inter-rater reliability (Cohen’s kappa, 0.75). Coordination issues were divided into two groups: (1) inter-department coordination (among the maintenance team) and (2) intra-department coordination problems (between maintenance and other departments). After reviewing the literature, we designed

our classification system with nine categories consisting of: *not delivering information, sending wrong information, listening attitude, wrong interpretation, lack of responsibility, lack of assertiveness, ambiguous role, emotion, and conflict/disagreement* (see Table 1).

The first four items relate to communication failure. Reason (1997) classified three types of communication errors: message failures, reception failures, and system failures. Message failures are situations where necessary information is not sent, even with an existing channel. *Not delivering information* and *sending wrong information* are among this type of failure, which are due to a mistake by the sender. There may also be a perception failure on the part of the recipient; equivalent to communication distortion (Hall, 2002). *Listening* and *wrong interpretation* are errors of message receivers. Active listening is important for communication free from misinterpretation (Adler & Elmhorst, 1999). System failures include situations where the necessary channels for communication do not exist, function (Reason, 1997). As the name indicates, this type of failure is due to systematic design failure in organizations, rather than merely a temporal human error. *Ambiguous role*, which was pointed out as a type of coordination problem by Flin, et al. (2007), covers these system failures. Once it becomes unclear who is in charge of a specific task, the established communication system may cease to function.

For effective coordination, each team member needs to share responsibility (FAA, 2000). However, AMTs sometimes have problems related to lack of responsibility, by relying on others and by paying less attention to critical issues. *Emotional* factors may affect smooth coordination (UK Civil Aviation Authority, 2006). Good relationships with others and avoiding unnecessary conflict are also

Table 1. Definitions of Coordination problems, type of conflicts/disagreement, and conflict solution style

Coordination problems	
Not delivering information	Necessary information was not shared.
Sending wrong information	Information sender delivered a wrong message.
Listening	Someone's concern was not taken seriously by others/ was not paid attention to.
Wrong interpretation	Information receiver made wrong assumption or misinterpreted a message.
Lack of responsibility	Not enough attention paid due to relying on others / lack of responsibility.
Lack of assertiveness	Person involved in the task was not assertive enough about his/her concern.
Ambiguous role	Person in charge was not clear/not accessible/communication channel was not established.
Emotion	Emotional state (anxiety etc.) disturbed good coordination.
Conflict/disagree	Conflict or disagreement existed.
Type of conflicts/disagreement	
Task conflicts	Conflicts about work such as interpretation of instructions or decisions.
Relationship conflicts	Conflicts based on interpersonal relationships and others’ personalities.
Process conflicts	Conflicts about responsibility, delegation, and how task accomplishment should proceed in work.
Conflict solution style	
Collaborating	Clarifying differences, cooperating and searching for a mutually beneficial outcome.
Competing	Convincing others that their conclusion is correct, seeking one's own interest, regardless of others.
Accommodating	Allowing the goals of the other parties to take precedent while sacrificing one's own goal.
Avoiding	Abandoning one's goals, denying that a problem exists, and avoid confrontation.
Compromising	Accepting a solution that provides incomplete satisfaction to both parties.

important for effective coordination (Flin, et al., 2007). Conflict is defined as “an interactive process manifested in incompatibility, disagreement, dissonance within or between social entities” (Rahin, 2001, P.365). Conflict management is a part of the interpersonal process (Marks, Mathieu & Zaccaro, 2001). When a controversy was identified, the report was coded as containing conflict.

The reports that involved conflict were further investigated, focusing on their conflict type and solution style. Jehn (1997) introduced three types of intra-group conflict to illustrate mechanisms of organizational conflict - task, relationship, and procedural. Task conflicts are conflicts about work such as interpretation of instructions or decisions. Relationship conflicts are problems based on interpersonal associations and others’ personalities. Process conflicts are about responsibility, delegation, and how task accomplishment should proceed in the unit (Jehn, 1997).

There are five types of conflict management or solution strategies: competing, accommodating, collaborating, avoiding, and compromising (Adler & Elmhurst, 1999; Harris, 2002; Robbins, 2005). The competitive style convinces others that their conclusion is correct, seeking one’s own interest, regardless of others. Accommodating accepts others opinions while sacrificing one’s own goal. Collaborating attempts to reach agreement with each other for a mutually beneficial outcome. Avoiding abandons one’s goals and ignores confrontation. Lastly, compromising is somewhere in the middle, accepting solutions that provide incomplete satisfaction to both parties.

RESULTS

Seventeen percent (n=115) of the 680 reports analyzed contained some form of *coordination* error. Coordination errors constituted the fourth predominant contributing factor, following *lack of vigilance*, *time pressure*, and *document and procedure* (Figure 1). Seventy nine percent (n=91) of these errors included coordination issues within maintenance, while 15% (n=17) of included coordination issues between maintenance and other departments, 1% (n=7) included coordination issues both within and outside of maintenance groups.

Inter-department coordination failures. Of 22 inter-department coordination failures we found many cases (N=13, 59%) related to the application of the Minimum Equipment List (MEL) (see Table 2). The MEL is a list of equipment that must be operable for the aircraft to be considered airworthy. Maintenance is not allowed to release aircraft if there is an inoperative component. However, because commercial aircraft have many redundant safety systems, the MEL was established so that aircraft could be released with non-essential inoperative components. Since the MEL application affects the level of safety, careful attention must be paid to the flight and airworthiness

requirements. However, the MEL application can be problematic because special MEL conditions are complicated and decision about these specifications usually has to be made immediately before the scheduled departure under time pressure. Our study found that the application of the MEL could be a source of conflict between AMTs and flight crews.

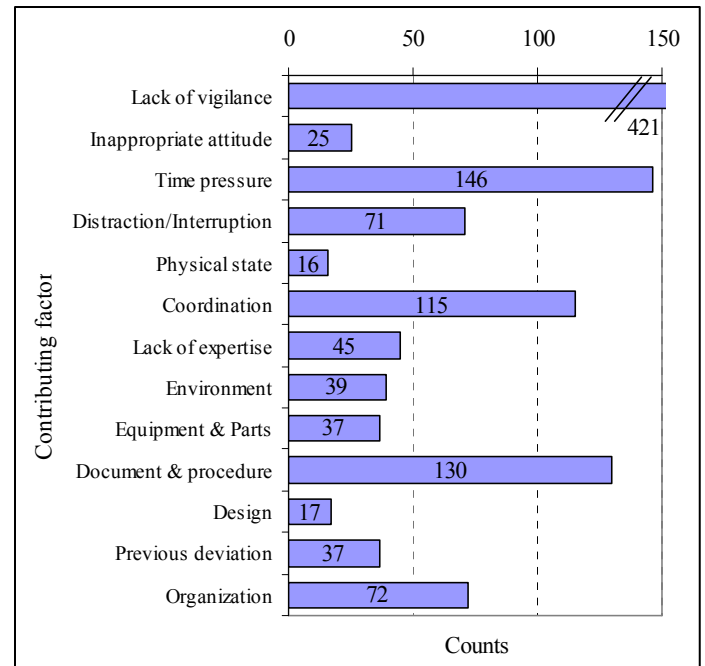


Figure 1. Contributing factors in 680 ASRS reports.

Intra-department coordination failures. Similar to inter-department issues, many MEL related errors were found in coordination errors among maintenance. Factors that appeared frequently in the narratives were *not delivering information*, *sending wrong information*, and *lack of responsibility*. Frequent appearance of *not delivering information* and *sending wrong information* indicated that senders’ errors were predominant in the reports we analyzed. In ASRS report ACN637938, the aircraft was dispatched while an AMT was looking for qualified personnel to re-certify the aircraft. This error was presumably made because the necessary information was not delivered. In ACN650461, an RII inspection (a required inspection item mandated by the Federal Regulation) was missed because an AMT relied on the wrong advice that the inspection was not required, which was provided by a technical service person. In addition to MEL related problems, missing inspections and improper logbook entries were frequently observed. In ACN647933, an AMT assumed that an inspector had completed a task because he/she left the place without saying anything. Due to this lack of communication, a regulatory RII inspection was missed. In ACN669080, an AMT failed to issue a non-routine job card resulting in another AMT, in the next shift, failing to activate the replaced system.

Table 2. Types of coordination failures identified in 680 ASRS maintenance related reports (8/2004 – 7/2006).

	Coordination failures									
	Not delivering information		Sending wrong information		Listening		Wrong interpretation		Lack of responsibility	
Missed inspection	0	4	0	3	1	1	0	2	0	2
Wrong MEL procedure	1	6	1	0	1	0	0	1	0	1
Missed/wrong logbook/document entry	1	2	0	3	1	0	0	0	0	2
Wrong parts installation	0	7	0	4	0	0	0	1	0	6
Inapplicable MEL	2	3	0	3	2	0	1	1	0	1
Wrong damage analysis/troubleshoot	0	2	2	1	1	0	0	1	0	1
Aircraft/component damage	0	2	0	1	0	1	1	0	0	0
Other procedure failures	2	6	1	1	1	2	0	0	1	3
Total	6	32	4	16	7	4	2	6	1	16

	Coordination failures									
	Lack of assertiveness		Ambiguous role		Emotion		Conflict/disagreement		Total	
Missed inspection	0	2	0	1	0	0	1	1	2	16
Wrong MEL procedure	0	0	1	0	0	0	1	1	5	9
Missed/wrong logbook/document entry	0	1	0	1	0	0	2	0	4	9
Wrong parts installation	0	2	0	1	0	0	0	0	0	21
Inapplicable MEL	0	1	0	0	0	0	4	0	9	9
Wrong damage analysis/troubleshoot	0	0	0	0	0	0	1	0	4	5
Aircraft/component damage	0	0	0	0	0	0	0	0	1	4
Other procedure failures	0	2	0	1	0	1	1	1	6	17
Total	0	8	1	4	0	1	10	3	31	90

Note: Left column: inter-department (between maintenance and others), *Right column (italics): Intra-department (among maintenance)*

Inspections mandated by manufacturers, regulators, and companies comprise a critical stage in maintaining the quality of safety in aviation. Inspectors double-check that critical tasks are accomplished properly. Logbooks also function as an aid to coordinating safety. Since aircraft are composed of numerous parts with multiple AMTs conducting maintenance tasks, precise coordination of records is necessary to achieve safety. Otherwise, periodical inspections or part replacements may be missed.

Part installation was another frequent undesirable outcome found in the narratives. These failures arose mainly as the result of AMTs not verifying part numbers, relying instead on others' work.

There were several intriguing reports that did not fit into any of the nine categories. In ACN 657671, an AMT reported that some necessary information was missed somewhere in a conversation. In order to avoid these types of risks in spoken communication, written communication is also used, for greater reliability. However, written communication does not always work well, particularly when AMTs are under time constraints, as a number of logbook/document errors illustrated.

Conflict. Thirteen instances of conflict were found in the reports we studied. Ten of these cases illustrated conflict between maintenance and flight crews, while the rest were contained within the maintenance department. Interestingly, these maintenance/flight crew cases were all reported by the flight crews. Although ASRS is a confidential system, people might hesitate to report conflicts with colleagues, who work closely together. The majority of discord

involved task conflict, with only few process conflicts.

In terms of conflict management, most cases were categorized as competing or accommodating. That is, either party prevailed over the other party's opinion. As an example, flight crews were found to accommodate the view of AMTs, while still having concerns about the issue. At other times, flight crews would compete with AMTs, by not accepting a questionable aircraft. Although there are few samples, opinions of supervisors (i.e., lead mechanics or foremen) prevailed over frontline AMTs. If both parties had cooperated each other, the errors could have been prevented. Solving conflict by the competing style could weaken the level of safety when competing parties have a low degree of competence (Rahin, 2001).

DISCUSSION

Aircraft maintenance has established various organizational procedures to achieve high reliability and efficiency, such as MEL, inspections, logbook recordings, and part number managements. However, even with these procedures, incidents occur due to human errors. Why cannot these safety procedures prevent human errors? The results of this study on coordination failures and conflicts showed that coordination problems weakened these crucial safety procedures, causing undesirable outcomes (see Figure 2). Misapplication of the MEL was the predominant coordination issue between flight crews, maintenance control, and AMTs. Insufficient coordination between inspectors, supervisors, and AMTs were related to missing inspections. Both logbook entry failures and wrong

installations (failures to verify parts numbers), often accompanied coordination problems. A sense of responsibility could be a key factor for preventing these failures. Many AMTs made errors because they did not consider their responsibilities enough while working in teams. Unless airlines improve coordination, these incidents may result in a major incident.

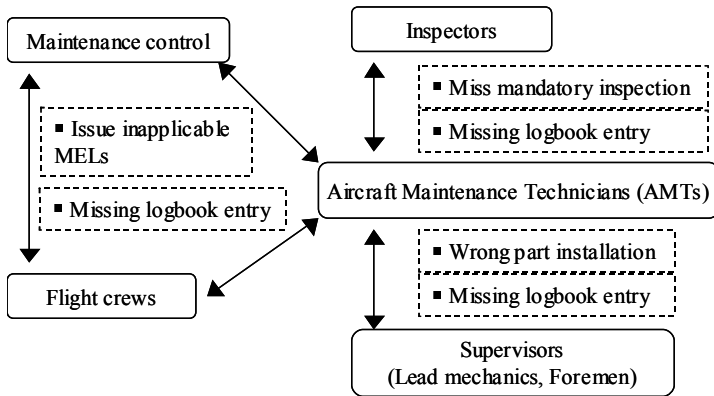


Figure 2. Coordination and unsafe behavior in aircraft maintenance.

Not delivering information, sending wrong information, and lack of responsibility were three frequent factors found in this study. Lack of responsibility is related to complacency and lack of assertiveness. Patankar and Taylor (2004) argued that interpersonal communication minimizes complacency. Munro, Kanki, and Jordan (2004) studied information not shared between flight crew and AMTs. When AMTs and pilots were asked if they think a pilot’s logbook entry is helpful, about 50% of pilots answered “very helpful,” whereas about 20% AMTs answered “very helpful.” Although it is not necessary to share all information because these two parties have different expertise, better communication has the potential to reduce incidents according to our study. As more organizations have begun training programs for non-technical skills such as communication, management, and leadership, findings from this study can be beneficial to enrich the contents of these training programs.

CONCLUSION

This study revealed that coordination problems are potential sources of impairment for safety procedures in aircraft maintenance. Three problematic behaviors were frequently found with coordination problems: *Not delivering information, sending wrong information, and lack of responsibility.* These findings show that coordination systems should be reexamined if an airline has problems such as missing inspections, inapplicable MEL applications, and failure of logbook entries. By offering training about specific problematic communication behaviors found in this study, AMTs would be able to learn common scenarios related to coordination problems.

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