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SHIFT TURNOVER RELATED ERRORS IN ASRS REPORTS

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Aviation Safety Reporting System (ASRS) Maintenance incident reports involving shift turnover communication problems were examined to gain insight into current turnover procedures and possible improvements to them. The Maintenance Error Decision Aid (MEDA) coding system was used to code 1,182 ASRS maintenance incident reports. The incidents involving shift turnover related communication problems (n = 46) were compared with incidents involving non-turnover related communication problems (n=37) and with other maintenance incidents (n = 1099). Turnover related incidents involved a significantly higher proportion of equipment that was classified by ASRS as "critical" than either of the other two samples, and had a significantly higher proportion of severe consequences. Suggestions for improvements to turnover work practices are made based on a detailed analysis of the narratives and a review of best practices in shift handovers.

Introduction

Aviation maintenance provides a supreme test of the turnover process. Sometimes twelve to fifteen shifts work on trouble shooting a problem and then fixing it. All the while, detailed records have to be kept on each part and each change to the aircraft. When turnover errors are made, the consequences can be severe, as demonstrated by the 1991 Continental Express accident. The NTSB attributed this accident, in part, to the lack of one shift communicating to the next that the screws on the upper leading edge of the horizontal stabilizers had been removed and not replaced. Recent FAA and NASA sponsored research has focused on the turnover process in aviation maintenance, but no one, to our knowledge, has examined turnover related incidents in the Aviation Safety Reporting System (ASRS) maintenance database for insights into current turnover procedures and possible improvements to them.

Method

ASRS reports and MEDA coding. ASRS maintenance incident reports were obtained from July, 1998, through March, 2002, yielding a sample of 1182 reports. These reports were coded using the Maintenance Error Decision Aid (MEDA) coding system, which is commonly used by airlines for classifying and analyzing maintenance-related incidents. With MEDA, one can classify the operational event, the maintenance error that led to the event, and also contributing factors—such as whether the incident was related to problems involving information, equipment, airplane design, mechanic qualifications and skills, etc. The factor of interest to us, "Communication Issues," is further broken down into communication issues between departments, people, shifts, crew & lead, lead & management, and other. MEDA coding is determined by what is actually stated in an incident description, rather than what can be logically inferred. Hence, for example, an ASRS narrative which is coded in MEDA as involving a communication problem between shifts, has statements referring to these problems within the narrative. The number of actual turnover related communication problems in the dataset is therefore likely to be underestimated. Also, many ASRS maintenance report narratives are too brief to allow for the coding of any contributing factors, likely resulting in a further underestimation of these problems in this database. (Note that because ASRS is a voluntary reporting system, we are not assuming that numbers or proportions of reports correspond to actual prevalence in the National Airspace System.)

Sample. Of the 1182 ASRS incident incidents coded in MEDA, 91, or about 8%, had communication issues as one of their contributing factors. Of these communication issues, 51% (46/91), were turnover related, i.e., between shifts, 34% (31/91) were not turnover related, 7% (6/92) were between crew and lead and not turnover related, 8% (7/91) were between departments (e.g. between flight and maintenance), and one was classified as "other" (between a technician and an FAA supervisor).

Methods of analysis. We will first describe the 46 turnover related incidents using the MEDA coding and relevant fields on the first part of the ASRS maintenance forms. So as to understand what is unique about turnover communication problems, we will compare these incidents with those with non turnover related communication problems. (In this category, we include the 6 incidents dealing with communication problems between "crew and lead" which increases the sample size from 31 to 37.) We will also compare the turnover related incidents with the rest of the maintenance (MX) incidents (n = 1,099). Finally, we will present the results of a detailed analysis of the narratives. This analysis will be informed by a review of the literature on best practices in shift turnover.

Results

MEDA Coding and ASRS Database

Qualifications and experience of reporters. Those who filed a turnover related report were highly qualified and experienced. Ninety four percent (43/46) were licensed Airframe and Powerplant mechanics, and they had an average of 14 years experience. They did not differ in this regard from those in the other two samples. However, more of those who filed these reports had "Inspection Authority" than either those who filed a non-turnover communication related report (22% vs 3%, Pearsons Chi Square = 6.5, df 1, p =.01) or those who filed a report in the large MX dataset (22% vs. 12%, Pearsons Chi Square = 4.0, df 1, p <.05).

Training. "Is training a factor?" To this question on the ASRS Maintenance Form, only 11% (5/46) of those filing turnover related reports checked the "yes" box. This proportion did not differ between the samples.

Types of errors involved. Although this MEDA coded information is not yet available for the large MX database, it is for the two samples with communication related incidents. It can be seen from Figure 1 that most turnover communication related errors involved installation, followed by improper fault isolation and documentation. The error specifics were also coded in MEDA. Of the installation errors, the largest proportion was incomplete installation (26%,6/23), followed by wrong equipment (17%, 4/23) and system or equipment not activated or deactivated (17%, 4/23). Figure 1 shows that communication errors not related to turnovers had a lower proportion of installation errors, improper repair, and improper fault isolation, but a higher proportion of documentation. Both samples had a relatively high proportion (13%, 6/46 and 19%, 7/37) of improper testing (a subcategory of fault isolation).

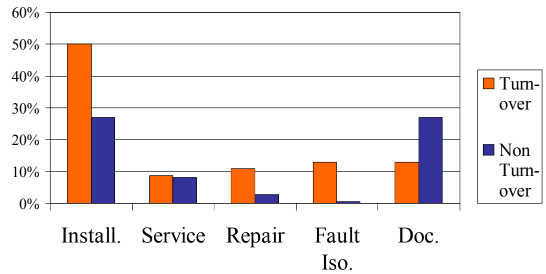

Figure 1. Types of Errors in Incidents Involving Turnover and Non Turnover Related Communication Issues

Type of equipment involved. Equipment that is crucial to the functioning of the aircraft is categorized as "critical" by the ASRS analyst; equipment less crucial is described as "less severe." In the turnover related incidents, nearly all, 96%, of the equipment was termed "critical" whereas this was the case in only 74% of the non-turnover communication related incidents (Pearsons Chi Square = 7.5, df 1, p <.01). Similar results are obtained when comparing turnover related incidents with those in the larger MX database (96% vs. 77%, Pearsons Chi Square = 8.5, df 1, p <.01). Hence turnover related incidents more frequently involve critical aircraft systems. This may be because critical systems are more complex and more likely to involve long-lasting tasks handled by multiple shifts.

Consequences. If in fact, the turnover related incidents are more likely to involve critical systems, one would expect the consequences of these incidents to be more severe. This seems to be the case.

In order to compare consequences between turnover related incidents and non turnover communication related incidents, we have grouped the MEDA consequences into two categories: less and more serious. In the less serious category, we have grouped flight delay, rework, and non-compliance. In the more serious category we have grouped flight cancellation, gate return, in-flight shut down, air turn-back, aircraft damage, injury, and diversion. The consequences of the turnover related incidents fell twice as often into the more serious category (44%) as the non-turnover communication related incidents (22%) (Pearsons Chi Square = 4.1, df 1, p <.05). This fits with the finding from the narratives that 44% of the detectors of the turnover related incidents were pilots; the rest were maintenance personnel.

Our large ASRS MX database includes only a few relevant consequences that we can use for comparison, as can be seen in Table 1. Nonetheless, even some of these were significantly higher for the turnover related incidents than for the large maintenance database.

Table 1. *Consequences of Incidents Across Three Samples*

Consequence	Turnover Com. Related (n = 46)	Non Turnover Com. (n = 37)	Other MX (n=1099)
Diverted	13%**	8%	4%**
Landed as a Precaution	2%	0%	2%
Landed in Emergency	4%	0%	2%
Declared an Emergency	9%*	0%	3%*
Rejected Take-off	7%**	0%	1%**

**Pearsons Chi Square $p \leq .01$ in comparison with Turnover Related Incidents.

Hence, the evidence we have suggests that consequences of turnover related incidents are more serious than other maintenance incidents, possibly because the equipment dealt with over many shifts is more critical to system functioning. It may also be that the faulty transferring of information from one shift to another results in bigger mistakes than non-turnover related errors.

Factors seen by reporters as contributing to MX incidents. Table 2 lists these factors, comparing responses of reporters from the three samples.

Table 2. *Proportion of MX Incident Reporters in Three Samples Checking Off "Contributing Factors" to Incident*

Contributing Factors	Turnover Com. Related (n = 46)	Non Turnover Com. (n = 37)	Large MX Database (n=1099)
Lighting	4%	3%	6%
Weather	0	0	2%
Work Cards	46%**	16%**	14%**
Manuals	19%	20%	22%
Briefing	15%**	8%	2%**

**Pearsons Chi Square $p \leq .01$ in comparison with Turnover Communication Related incidents

First it can be seen that work cards were checked off as a contributing factor in a much higher proportion of incidents involving turnover communication problems than in the other two samples. This fact, and the fact that work cards were seen as contributing to almost half of the incidents, indicates a central role of work cards in the shift turnover process. It suggests that increasing the completeness and accuracy of work cards would result in a marked reduction in shift turnover communication problems.

It is not surprising that briefings would be seen as contributing to a higher proportion of turnover related communication incidents than to incidents in the other two samples. What is surprising is that this proportion is so low—15%. This may indicate that there are fewer problems with verbal briefings. Or it may indicate that verbal briefings are not seen as so central to turnover communications, and that when there is a problem, the reporters are more apt to recognize the need for written documentation. Although verbal briefings alone would certainly not suffice for turnover communications in airline maintenance (given the need for multiple shifts to work on the problem, for inspection, and for data tracking), literature on information transfer suggests that verbal, face-to-face briefings are extremely valuable in supporting written transfer of information, as will be discussed later.

Items seen by reporters as being involved in the incidents. Table 3 lists these items, comparing the responses of reporters in the three samples.

Table 3. *Proportion of MX Incident Reporters in Three Samples Checking Off "Items Which were Involved in the Incident."*

Items Involved	Turnover Com. Related (n = 46)	Non Turnover Com. (n = 37)	Large MX Database (n=1099)
Inspection	61%**	41%	41%**
Testing	28%	24%	21%
Repair	39%	27%	30%
Logbook Entry	39%	38%	27%
Fault Isolation	13%	14%	8%
Installation	46%	32%	34%
Scheduled Maintenance	33%**	19%	18%**
MEL	48%	49%	41%

**Pearsons Chi Square $p \leq .01$ in comparison with Turnover Communication Related incidents.

The fact that inspection is seen as involved in 61% of the turnover related incidents—significantly higher than the 41% in the large Mx database, fits in with the earlier finding that a higher proportion of these reporters have Inspection Authority (22% vs. 11% in the large Mx sample). It is likely that the more critical systems involved in the shift turnover related incidents require more inspections than the less critical systems. Hence, when something goes awry, the problem is not only a problem for the technician who made the error, but also for the inspector who signed off on it.

That "scheduled maintenance" is seen as involved in a higher proportion of turnover problem incidents than the other two samples is understandable, since scheduled maintenance involves shift turnovers (as opposed to line maintenance).

Narrative Analysis

The ASRS descriptive narratives were analyzed and a list was made of work practices which would have helped to prevent the incidents. These are listed, along with the percentage of incidents they applied to, in Table 4. (Each report may have more than one factor applying to it). Many of these practices are self-explanatory; others will be discussed.

Table 4. *Work Practices That Would Have Helped Prevent 46 MX Incidents with Turnover Related Communication Problems.*

Work Practices that Would Have Helped Prevent the Incident	% of cases
Check previous work; stop error propagation	50%
Have better written documentation	41%
Maintenance manual	7%
Work (job) card	9%
Log book	11%
Turn-over documentation	11%
Have direct, verbal briefings	9%
Communicate “next steps”	4%
Video tape	2%
Have turnover	2%
Read turnover log	4%
Include redundancies	
Inspections	4%
Required ops. tests	7%
Computer catch errors	4%
Sign-off *after* all work is done	7%
Tie up loose ends at end of shift	4%
Alleviate stress, schedule pressure	24%

Error propagation. Perhaps the most surprising finding from the narrative analysis is that 50% (23/46) of these incidents were caused by errors being made in the previous shift(s) which were simply carried through the following shift. For example, the previous shift would order an incorrect part, and the next shift would put it in. Fully half of the incidents could have been prevented had the following shift checked on the previous shift's work before proceeding. Shift turnovers present an opportunity for a new pair of eyes to assess the accuracy of the previous shift's work. Although it would take extra time at the beginning of the shift to do this, it it might be a good return on investment, if it could be done.

Have better written documentation. As can be seen in Table 4, in the narratives the reporters referred specifically to deficient documentation in the form of work cards, maintenance manuals, logbooks, and turnover documentation. However, it will be recalled that earlier in the ASRS Maintenance Form, 46% of them had checked off work cards as contributing to the incident, and 39% had checked off the logbook as an item involved. Hence they may not have felt it necessary to refer to these items again in the narrative.

The proportion of reporters that had checked off *either* work cards or logbooks as being involved in turnover related incidents is extremely high—67% (31/46; the comparative figure is 39% in the large MX database, Pearson Chi Square = 15.3, df 1, $p < .0001$). This high proportion indicates that it might not be possible at times to check the accuracy of the previous shift's work. It may be that not only are errors committed on the previous shift, but that there is no documentation to enable the next shift to catch these errors. A two-pronged approach of improving documentation (especially work cards) and increasing the checking of the previous shifts' work, would likely improve turnover communication problems dramatically.

Direct turnovers. It can be seen in Table 4 that 9% (5/46) of the reporters specifically stated that a "direct" turnover would have been better. Frequently in aviation maintenance, the shift lead turns over information to the next shift lead. The technicians who actually do the work get turnover instructions from their lead and then give their turnover report to their lead at the end of their shift.

Direct verbal exchange between incoming and outgoing technician, would not only elaborate and add redundancy to written information, but would have the great advantage of allowing the incoming shift worker to ask questions of the outgoing shift worker. Two-way communication with feedback is an essential component of best shift turnover guidelines.[1 2 3 4] This is because frequently turnover errors are due to differences in the mental models of the outgoing worker and the incoming worker.[5 6] Two-way communication enables the incoming worker to ask questions and rephrase the material to be handed over, so as to expose these differences. Feedback increases communication accuracy.[7] Two studies of shift turnovers have shown how communication errors of outgoing workers have been corrected by questions of incoming workers.[8 9] Face-to-face turnovers enable gestures, eye contact, tones of voice, degrees of confidence, and other redundant and rich aspects of personal communication to be utilized in conveying possible different mental models.[10 11]

Face-to-face turnovers combined with written support are used in many high-risk domains such as nuclear power, air traffic control, off-shore oil, and mission control for both shuttle and space station.[12] In aviation maintenance, face-to-face turnover briefings between outgoing and incoming technicians, with written support, have been shown to reduce errors compared to having the verbal communication filtered through a supervisor.[13]

"*Next steps*." Four per cent (2/46) of the reporters described situations where communicating "next steps" would have helped to prevent the incident. Although this is a very low proportion, these two incidents illuminate a turnover procedure common in some maintenance facilities. One incident will be described as an example both of this procedure and of a typical aviation maintenance turnover. The reporter was working on an Airbus engine and did not complete the final step since it was the end of his shift. This final step was to reconnect the "rod end to the segment ring."

"All removed parts were tagged and labeled and laid out on a work table next to the engine. I stated on the front of the sign-off document what we had *accomplished* [italics mine]. I also gave a status report to our team leader which is then passed on to the day shift team leader. The day shift then briefs the mechanic who will be taking over the job as to what needs to be done to complete the job. A day shift mechanic took over from where we left off. He completed the installation, removed the rig pin, but failed to reconnect the actuator rod end back to the segment ring. The day shift aircraft inspector then inspected the completed installation. This inspector also failed to make sure that the mechanic had attached the rod end back to the segment ring. A line mechanic then test ran the engine, which resulted in an overtemping of the engine. . ." #459650

This resulted in engine damage, but at least the error was discovered before the aircraft was flown. What is noteworthy in this narrative, in addition to the turnover description, is that the reporter described the work he had "accomplished," and did not state what the next step would be. Of course, he might have just left it out of the narrative. But spelling out the next step on written turnover documentation is actively discouraged in many aviation maintenance facilities.[14] This may be due to the general reluctance of those in this domain to commit themselves to paper for fear of later investigations.[15]

This practice flies in the face of what we know about the type of information most successfully transferred from shift to shift. Shift information transfer is most successful when it captures problems, hypotheses, and intent, rather than simply lists what occurred. Recent research indicates that perception and memory are organized by hierarchical goal representations and that these representations in turn drive narrative comprehension, memory and planning.[16 17] Two nursing studies demonstrate that simply listing historical events (either verbally or in written material) is not as effective in conveying accurate mental models of the situation as describing problems, hypotheses, and intent.[18 19] In one study of shift turnover, errors were attributed to listing completed work rather than giving a predictive diagnosis of the situation.[20]

Video tape. A maintenance technician described in detail how, since he hadn't removed a particular aircraft component, it was difficult to know that it consisted of three parts instead of just the two that came as a replacement from the factory. Current video and audio technology could be helpful in documenting the steps and parts involved in the dismantling of a rarely-serviced aircraft component. Video and audio capabilities are now a part of some notebook-size Tablet PCs. Technologies such as these have great potential to reduce turnover errors in aviation maintenance by providing graphics and step-by-step instructions.

Summary

Of all communication related incidents in a large ASRS maintenance database, those related to shift turnover were most frequent. A higher proportion of turnover related incidents involved critical equipment, and had more serious consequences than other incidents. Reporters of turnover related incidents cited "work cards" and "briefings" as contributing factors, and "inspection" and "scheduled maintenance" as events involved in the incident in higher proportions than in other incidents.

We analyzed the narratives in detail and reviewed the literature on best shift turnover procedures. Based on this, we listed work practices which would have helped prevent the incidents. Most important is a two-pronged approach of encouraging workers to check the previous shift's work and of improving shift-related documentation which would enable them to do so. The literature on best practices in shift turnover recommends face-to-face turnovers by the technicians doing the work instead of verbal briefings filtered through a shift lead, as is currently the case in many maintenance facilities. Research also supports the listing of next steps in turnover documentation and briefings. In addition to modified procedures and improved documentation, adoption of new technologies holds great promise for reducing turnover errors in airline maintenance.

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