# An Exploration of Deviations in Aircraft Maintenance Procedures

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## Abstract

An informal study on deviations in aircraft maintenance procedures was conducted during a human factors training course in March of 2009. The purpose of the study was to pilot test the Maintenance Events Checklist (MEC) with a relatively small sample of aircraft maintenance technicians. The MEC is intended to capture participants' responses to statements related to maintenance deviations. Participants consisted of aircraft maintenance technicians who worked in non-airline operations (i.e., corporate and business aviation, helicopter operators, and FBOs). Results showed that nearly 50% of the participants' indicated they had "very rarely" deviated from the MEC content items. However, 22% indicated they had deviated "occasionally" and 5% indicated they had deviated "often." Causes and implications are discussed, which focus on organizational pressure, individual complacency, and deficiencies in aircraft maintenance documentation itself.

An Exploration of Deviations in Aircraft Maintenance Procedures

Deviations from approved procedures have been implicated in a number of maintenance-related aircraft accidents. These deviations may stem from factors such as time pressure, stress, fatigue, lack of resources, or ambiguous or confusing documentation. These factors typically do not occur in isolation but are linked together and may increase the likelihood of skipped steps, signoffs without verification, or continuing a job without the correct tools or equipment. This was recently the case where American Airlines Flight 1400 experienced an in-flight engine fire requiring a turnback and emergency landing in St. Louis (STL). The investigation revealed that a component in the manual start mechanism of the engine was damaged when a mechanic used an unapproved tool to initiate the start of the #1 (left) engine while the aircraft was parked at the gate at STL. The deformed mechanism led to a sequence of events that resulted in the engine fire, to which the flight crew was alerted shortly after take-off (National Transportation Safety Board, 2009).

Hobbs (2002) developed the Maintenance Events Checklist (MEC) that is intended to capture aircraft maintenance technicians' (AMTs) responses to statements related to deviations. While not a scientific instrument, the MEC is an effective tool to aid researchers in identifying problematic areas in aviation maintenance activities. Once these areas are identified, further research can be conducted to address specifically those deviations which appear to be most problematic.

Previous studies have identified a number of recurring problems in aircraft maintenance tasks. Some of the more recent studies have utilized the ASRS database to provide a rich, and relatively new, source of information relating to aviation maintenance errors. One such study used ASRS reports to identify associations between existing ASRS codes and the area of the aircraft involved in the incident (using ATA coding) (Hobbs & Kanki, 2008). The authors point out that these associations have not been adequately examined in the past but could be a valuable source of data for human factors training, the design of procedures, and the identification of improvements in aircraft design (p. 5). A recent study in the United Kingdom also segregated maintenance errors by ATA code. In that study the researchers found that the top three most frequent maintenance errors by aircraft area were (1) Equipment and Furnishings (ATA 25: 18.27%), (2) Landing Gear (ATA 32: 10.6%), and (3) Flight Controls (ATA 27: 8.59%) (Civil Aviation Authority, 2009).

Other studies have investigated specific types of maintenance errors that occur at the AMT level. A study in the United Kingdom found that the majority of errors were incorrect installation of components, the installation of wrong parts, electrical wiring discrepancies, and tools left in the aircraft (Civil Aviation Authority, 1992). Another study found that incomplete installations, incorrect assembly or location, vehicles or equipment contacting the aircraft, material left in the aircraft, wrong part, and part not installed were the most common incidents reported by AMTs in Australia (Hobbs & Williamson, 2002). According to Hobbs and Williamson (2003) these types of errors can be broadly categorized into three groups: memory failures, rule violations, or knowledge-based errors. Memory failures address prospective, rather than retrospective memory. In other words, an AMT forgets to do something in the future such as removing a tool from an interior aircraft work area.

Rule violations may include deviating from documented procedures or developing a completely different way to conduct a task. A study conducted in Europe by McDonald, Corrigan, Daly, and Cromie (2000) found that 34% of the aircraft mechanics in their study acknowledged that their most recent task was performed in a way that contravened formal procedures. The previously mentioned Australian study by Hobbs and Williamson (2002) found that 30% of AMTs acknowledged that in the previous 12 months they had decided not to perform a functional check or an engine run. Over 30% reported that they had signed off a task before it was completed, and over 90% reported having done a task without the correct tools or equipment.

Rule violations may be propagated at the individual or organizational levels. Patankar (2002) conducted a comprehensive study that investigated rule violations by aircraft mechanics. On the individual level he found that the most problematic areas, ordered by percentage, were (1) lack of awareness, (2) complacency, (3) time constraints, (4) lack of knowledge or experience, and (5) workplace distractions. An individual factor was defined as, “A maintenance error that seemed to be within the individual mechanic’s span of control.” From the organizational perspective the results showed that the most problematic areas, ordered by percentage, were (1) procedures or information quality, (2) aircraft design/configuration of system or quality of parts, (3) maintenance management or leadership, (4) workplace norms/peer pressure, and (5) lack of training (p. 15).

Knowledge-based errors are a result of failed problem-solving or a lack of system knowledge (Rasmussen, 1983). An AMT might be unfamiliar with a particular system and uses past experiences or trial and error to dictate the steps to be taken for a particular task. An example of this might be an AMT assuming that a red rocker switch is an avionics master when in fact the switch is an engine starter. This assumption is made based on previous experience where the red rocker switch on a particular model aircraft was used as an avionics master. While working on a different type of aircraft the AMT engages the red rocker switch and inadvertently begins to rotate the propeller. If someone is in the proximity of the engine, serious harm or even death may occur.

While much of the extant literature focuses on error types as a result of organizational or individual deficiencies, only recently have researchers begun to investigate potential deficiencies in aircraft maintenance documentation. Researchers postulate that many of the aforementioned shortcuts and bootleg procedures may be the result of poor quality documentation. For instance, procedural errors, which are defined as any information-related error involving documents (Maintenance Error Decision Aid, 1994), have been implicated in 44% to 73% of maintenance errors (Veinott & Kanki, 1995; Nord & Kanki, 1999; Patankar, Lattanzio, Kanki, & Munro, 2003). Nord and Kanki (1999) found that errors were fairly evenly distributed across documents. The three most problematic areas identified were inspection and verification issues (34%), incompleteness of the documents (27%), and incorrectness of the documents (22%). Similarly, in a study of 458 ASARs reports submitted by AMTs, Lattanzio, Patankar, and Kanki (2008) found that the most frequently cited maintenance document deficiencies were missing information (48%), incorrect information (19%), difficult to interpret (19%), and conflicting information (19%).

Rogers, Hamblin, and Chaparro (2008) conducted a seminal study on the types of errors found in aircraft maintenance manuals published by four manufacturers. Their study was based on Publication Change Requests (PCRs) by AMTs. Results showed that the majority of PCRs related to procedures found in Flight Controls, Landing Gear, and Powerplant systems. These PCRs appear to mirror the most frequent problem areas identified in the previously mentioned ATA code segregation study (Civil Aviation Authority, 2009). The highest percentage of PCRs involved Procedural Errors (42.5%) followed by Language (29.9%), Technical (16.5%), Graphic

(8.1%), and Effectivity (n/a). Common procedural errors were categorized as Step(s), Ordering, Alternate method, Check/Test/Inspection, Caution/Warning. Language errors included typographical errors (Typos), grammatical errors (Grammar), a need for clarification of the information (Clarity), and inaccurate information within a step (Incorrect) (pp. 301-302).

Most of the previous studies have focused primarily on line maintenance operations and thus there has been somewhat of a paucity in studies related to AMTs who work in other settings such as corporate and charter flight departments, fixed base operators (FBOs), and helicopter operators. This study is intended to provide insight into these areas of aviation maintenance that tend to be overlooked in current research. It is not the intent to infer the results are descriptive of the larger population of AMTs in non-airline operations. Instead, this informal study was conducted as a pilot test and possibly a starting point for future research in this area.

## Method

### *Participants*

The sample consisted of 27 AMTs ($N$=27) who were attending a human factors training course in Minneapolis, MN in March of 2009. Participants were assured anonymity and all in attendance participated voluntarily in the study. Participants’ job position was the only demographic data captured. Positions were categorized as Supervisor/Inspector (67%), Line Mechanic (30%), and Director of Maintenance (3%). The majority of AMTs were employed in business/corporate aviation, FBOs, and helicopter operations.

*Instrument*

The MEC was distributed to all participants in the human factors training course. The MEC is a short, informal checklist that is used to capture AMTs responses to statements related to maintenance deviations. The checklist consists of seven statements with four response choices labeled; Never (1), Very Rarely (2), Occasionally (3), and Often (4). The complete MEC is shown in Table1.

At work in the last year, how often would a *typical* maintenance worker have:

1. Done a job without the correct tool or equipment
2. Decided not to do a required functional check because of a lack of time
3. Done a job a better way than that in the manual or approved maintenance documents
4. Corrected an error by another maintainer, but not documented what they had done to avoid getting the person into trouble.
5. Done an unfamiliar job without being certain they were doing it correctly
6. Been misled by confusing documentation
7. Signed a job on behalf of another person without checking it

Table 1. Maintenance Events Checklist (Hobbs, 2002)

*Procedure*

The MEC is typically distributed as a single survey and worded exactly as depicted in Table 1. However, in the current study, the MEC distribution was modified in that it was split into two duplicate checklists with the following exceptions; the first checklist asks the participant to estimate how often these items have been done by *themselves*, in the last year. The second checklist asks the participant to estimate how often these items might have been done by *other* workers in their organization, in the last year.

# Results

A total of 28 sets of MECs were collected. However, one MEC had to be discarded due to incompleteness (more than half of the statements had no response). Data were analyzed with SPSS v. 15.0 (2006) software. Descriptive statistics were used for basic data analysis which included mean response scores, standard deviations, and percentages. Inferential statistics were not used due to sampling limitations which are described in the Discussion section.

The results were broken down into four graphic presentations. The first and second presentations show participants' responses about themselves and others (Table 2 and Table 3 respectively). The mean scores represent the average of the responses for all participants for each statement. The standard deviation (SD) shows how much variability there is from the mean. The smaller the SD, the less variability there is in the participants' overall answers. The third and fourth presentations show a breakdown by percentage of the participants' responses about themselves and others (Table 4 and Table 5 respectively).

Table 2

*Participants' Responses About Themselves*

| Item No. | Description | *M* | *SD* |
|---|---|---|---|
| 1 | Done a job without the correct tool or equipment. | 2.22 | 0.5773 |
| 2 | Decided not to do a required functional check because of a lack of time. | 1.59 | 0.6360 |
| 3 | Done a job a better way than that in the manual or approved maintenance documents. | 2.37 | 0.8835 |
| 4 | Corrected an error by another maintainer, but not documented what they had done to avoid getting the person into trouble. | 2.14 | 0.8182 |
| 5 | Done an unfamiliar job without being certain they were doing it correctly. | 1.96 | 0.7586 |
| 6 | Been misled by confusing documentation. | 2.51 | 0.7000 |
| 7 | Signed a job on behalf of another person without checking it. | 1.85 | 0.9488 |

Mean Score Key: Never (1), Very Rarely (2), Occasionally (3), Often (4).

Table 3

*Participants' Responses About Others*

| Item No. | Description | *M* | *SD* |
|---|---|---|---|
| 1 | Done a job without the correct tool or equipment. | 2.59 | 0.5723 |
| 2 | Decided not to do a required functional check because of a lack of time. | 1.88 | 0.5773 |
| 3 | Done a job a better way than that in the manual or approved maintenance documents. | 2.33 | 0.7337 |
| 4 | Corrected an error by another maintainer, but not documented what they had done to avoid getting the person into trouble. | 2.40 | 0.7472 |
| 5 | Done an unfamiliar job without being certain they were doing it correctly. | 1.96 | 0.6493 |
| 6 | Been misled by confusing documentation. | 2.55 | 0.6405 |
| 7 | Signed a job on behalf of another person without checking it. | 2.03 | 0.9397 |

Mean Score Key: Never (1), Very Rarely (2), Occasionally (3), Often (4)

Table 4

*Participants' Responses About Themselves*

| | Response (%) | | | |
|---|---|---|---|---|
| | Never | Very Rarely | Occasionally | Often |
| Done a job without the correct tool or equipment. | 7 | 63 | 30 | 0 |
| Decided not to do a required functional check because of a lack of time. | 48 | 44 | 7 | 0 |
| Done a job a better way than that in the manual or approved maintenance documents. | 15 | 44 | 30 | 11 |
| Corrected an error by another maintainer, but not documented what they had done to avoid getting the person into trouble. | 18 | 56 | 18 | 7 |
| Done an unfamiliar job without being certain they were doing it correctly. | 26 | 56 | 15 | 4 |
| Been misled by confusing documentation. | 4 | 48 | 41 | 7 |
| Signed a job on behalf of another person without checking it. | 44 | 33 | 15 | 7 |
| *M*= | 23 | 49 | 22 | 5 |

*Percentages have been rounded and may not equal 100%

Table 5
*Participants' Responses About Others*

| | Response (%) | | | |
|---|---|---|---|---|
| | Never | Very Rarely | Occasionally | Often |
| Done a job without the correct tool or equipment. | 4 | 33 | 63 | 0 |
| Decided not to do a required functional check because of a lack of time. | 22 | 67 | 11 | 0 |
| Done a job a better way than that in the manual or approved maintenance documents. | 15 | 37 | 48 | 0 |
| Corrected an error by another maintainer, but not documented what they had done to avoid getting the person into trouble. | 7 | 52 | 33 | 7 |
| Done an unfamiliar job without being certain they were doing it correctly. | 22 | 59 | 19 | 0 |
| Been misled by confusing documentation. | 4 | 41 | 52 | 4 |
| Signed a job on behalf of another person without checking it. | 33 | 37 | 22 | 7 |
| *M*= | 15 | 47 | 35 | 3 |

*Percentages have been rounded and may not equal 100%

## Discussion

Although no formal hypotheses were posited or tested in this study, there is enough descriptive data to look at overall trends. Participants rating themselves tended to rate lower (deviate less) than when rating others. In fact, when looking at the mean percentages in Table 4 and Table 5, there is evidence that in almost all response sets participants believed that others have deviated from procedures more often than themselves. This could be due to AMTs perceptions that "other mechanics would do that but I never would." The effects of the fundamental attribution error and locus of control, for instance, may influence these different perspectives between the two versions of the MEC. This social-psychological influence was expected and could be explored further in a future study. However, the rest of this section will focus specifically on participants' responses about themselves.

When percentages were averaged, nearly 50% of the participants' indicated they would "very rarely" deviate from the MEC content items. However, 22% indicated they would deviate "occasionally" and 5% indicated they would deviate "often." Twenty three percent of the participants indicated they would "never" deviate from procedures. Although this was a quantitative, descriptive study, and lacked qualitative input from participants, one may infer why these deviations might be occurring in the maintenance hangar. For example, 7% of the participants indicated that they had "occasionally" decided not to do a required functional check because of a lack of time. Time pressure can be a significant factor in aircraft maintenance operations but the root cause of this pressure tends to be propagated by a widespread organizational culture that condones inappropriate or unrealistic deadlines. Conversely, the omission of this important step may occur at the individual AMT level as a manifestation of complacency. The well-intentioned AMT may have done the job hundreds of times before and never had a problem. As such the AMT may decide to skip a functional check assuming everything has been done correctly. Coupled with a perceived time savings, it may become very tempting for the AMT to skip this required step. Thirty percent of the participants indicated that they have "occasionally" done a job without the correct tool or equipment. This could be due to a lack of resources occurring at both the organizational and individual levels. Poor quality documentation may account for 41% of the participants "occasionally" being misled by confusing documentation or the 30% that indicated that they have "occasionally" done a job a better way than that in the manual or approved maintenance documents. Eleven percent indicated that they "often" do a job in this manner. This could be due to the quality of the documentation itself and may correlate with the study by Rogers, Hamblin, and Chaparro (2008) discussed earlier.

## Limitations

Although this study was conducted in an efficient and impromptu manner which facilitated a quick collection of data, there were a number of limitations that may have affected the results. First, the convenience sample was quite small ($N$=27) and was from one geographic location (Minnesota) in the United States. Thus the results may not be representative of the broader AMT population. Second, the study was conducted informally at a human factors course and lacked the rigor of the scientific method. Third, the human factors course itself may have acted as a confounding variable in that the MEC was distributed toward the end of the course. Due to these limitations one should interpret the results of this study with caution. This research was intended to be a pilot study; however, the results could be used as a foundation for additional, and more formal, studies relating to aircraft maintenance deviations.

## Conclusion

The results of this study provide a look into deviations in aircraft maintenance procedures with a focus on non-airline operations. A person from outside the aviation domain might look at these results and be astonished that AMTs would deviate from required procedures at all. Yet, for those who work in the aviation maintenance domain, these results may not come as a surprise. Regardless, one must be careful not to assume that deviations are simply symptomatic of “bad apple mechanics.” There are a number of reasons why these deviations occur which may include organizational pressure, norms, complacency, and poor quality documentation. Each item on the MEC carries with it its own special nuances with corresponding complexities for reparation. Simple exhortations such as “make sure you always do a functional check” will not be effective. Organizations need to emphasize to their AMTs, in an ongoing manner, the importance of following approved procedures. Similarly, AMTs need to be aware of the consequences of deviating from procedures. Human factors training courses should emphasize that the majority of maintenance-related aircraft accidents and incidents have been the result of deviations from approved procedures.

Finally, researchers should continue to investigate aircraft maintenance documentation itself. Evidence has been found to indicate that there are a number of problems with manufacturers’ written procedures. Until documentation issues such as missing information, incorrect information, difficulty in interpretation, and conflicting information are resolved, it will be difficult to sell the idea of following approved procedures to AMTs on a far-reaching basis.

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