

Selection Strategy for Identification of Process Measures for Surveillance in Aviation

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Abstract

Inspection and maintenance errors that occur in aircraft maintenance systems have a formidable impact on the safety and reliability of air transportation. Evaluation of the aircraft maintenance system requires an analysis of the maintenance processes in use. The systematic evaluation of data collected on the aviation maintenance process can provide management with feedback on the performance of the airline and consequently provide proactive support of the decision-making process prior to the dispatch of the aircraft. Recognizing that surveillance, auditing and airworthiness directives form a significant portion of the quality assurance function of an airline, it is critical that data be collected on these processes. Significant efforts have been made to investigate and track inspection and maintenance errors. Although valuable in terms of their contributions to the identification of the performance-shaping factors that lead to maintenance errors, these efforts have tended to be reactive in nature. Surveillance has a more practical bearing on the maintenance of aircraft. Process measures for surveillance was identified by the research team based on human-factor principles, utility of data being captured, and working around mental models of quality assurance personnel. This research establishes the identification strategy the research team adopted to finalize the process measures for surveillance.

Keywords

Surveillance, Aviation maintenance, Selection strategy, WebSAT, Process measures

1. Introduction

The mission of the FAA is to provide safe and reliable air transportation and to ensure airworthiness of the aircraft. The increasing number of maintenance and inspection errors in the aviation industry has motivated the need for human factors research. Maintenance error has been found to be a crucial factor in aircraft accidents [2]. Human factors research in maintenance has deemed the human as the central part of the aviation system [7]. The emphasis on the human and his role in aviation systems results in the development of error tolerant systems. Such systems will be efficient if they closely monitor and evaluate aircraft maintenance and inspection activities. Air transportation is becoming continually complex. The significance of the maintenance function was captured by Weick et al. [22] when they observed that: "Maintenance people come into contact with the largest number of failures, at earlier stages of development, and have an ongoing sense of the vulnerabilities in the technology, sloppiness in the operations, gaps in the procedures, and sequences by which one error triggers another" [22]. Given the ever increasing complexity of an aircraft, a significant proportion of these errors come at the hands of the maintenance personnel themselves due to greater demands on these individuals. Thus, it is very important to take a closer look at the humans involved in aviation maintenance, understand the causal factors for these errors and the possible solutions to counter this situation.

The aviation maintenance industry has also invested a significant effort in developing methodologies for investigating maintenance errors. The literature on human error has its foundations in early studies of errors made by pilots [5], work following the Three Mile Island incident, recent work in human reliability and the development of error taxonomies [20, 14, 19, 17, 18]. This research has centered on analyzing maintenance accidents. Figures emerging from the United Kingdom Civil Aviation Authority (CAA) show a steady rise in the number of maintenance error mandatory occurrence reports over the period 1990 to 2000 [3]. A recent Boeing study of worldwide commercial jet aircraft accidents over that same period shows a significant increase in the rate of

accidents where maintenance and inspection were primary factors [8]. The FAA, in its strategic plan for human factors in aviation maintenance, through to 2003, cited statistics from the Air Transport Association of America (ATA) showing that the number of passenger miles flown by the largest US airlines increased 187% from 1983 through to 1995. Over that same period, the number of aircraft operated by those airlines increased 70% but the number of aviation maintenance technicians increased only 27%. The FAA concluded that the only way the maintenance program could cope with the increased workload was by increased efficiency at the worker level [12].

Attempts have been made to define a core set of constructs for safety climate [6]. Although not entirely successful in establishing core dimensions, this research is useful in suggesting constructs that should be considered for inclusion in research on maintenance errors. Taylor and Thomas [21] used a self-report questionnaire called the Maintenance Resource Management/Technical Operations Questionnaire (MRM/TOQ) to measure what they regarded as two fundamental parameters in aviation maintenance: professionalism and trust. The dimension of professionalism is defined in their questionnaire in terms of reactions to work stressors and personal assertiveness. Trust is defined in terms of relations with co-workers and supervisors. Questions relating to these areas also appear in the questionnaire to be used in the current research. Patankar [16] constructed a questionnaire called the Organizational Safety Culture Questionnaire which included questions from the MRM/TOQ along with items from questionnaires developed outside the maintenance environment. Following the application of exploratory factor analytic routines to a dataset generated from respondents that included 124 maintenance engineers, Patankar identified four factors as having particular relevance to the safety goals of aviation organizations. They are emphasis on compliance with standard operating procedures, collective commitment to safety, individual sense of responsibility toward safety, and a high level of employee-management trust. In addition to the descriptive accident causation models, classification schemes, and culture surveys, there is a need for empirically validated models/tools that capture data on maintenance work and provide a means of assessing this data. However, such models and schemes often tend to be ad hoc, varying across the industry, with little standardization. In order to contend with this issue, the devised empirical models and tools are required to employ standardized data collection procedures, provide a basis for predicting unsafe conditions and design interventions that will lead to reduction in maintenance errors.

This research hopes to indicate the error causes and occurrences using a web based surveillance and auditing tool (WebSAT) tool. The WebSAT team's aviation industry partner is FedEx. This tool will capture and analyze data for surveillance and auditing. Consequently, the first step of this research is to identify process measures. The focus of this paper is to explain the approach used by the team to establish process measures for surveillance. In order to do so, it is important to understand current surveillance process.

2. Method

Surveillance is the day-to-day oversight and evaluation of the work contracted to an airframe substantial maintenance vendor to determine the level of compliance with airline's Maintenance Program and Maintenance Manual with respect to the airline's and FAA requirements. For example, FedEx has a surveillance representative, stationed at the vendor location who schedules surveillance of an incoming aircraft. The specific task to be performed on an aircraft at a vendor location is available on a work card. The representative performs surveillance on different work cards according to a surveillance schedule. The results are documented and used to analyze the risk factors associated with the concerned vendor and aircraft. The FedEx surveillance department is currently using categories to collect the data obtained from a surveillance visit at the maintenance facility. The team used these categories as a starting point in their process to identify the process measures. Some of the categories currently being used by FedEx are in-process surveillance, final walk around, and verification surveillance. These categories were created based on various surveillance tasks and the C.A.S.E. (Coordinating Agency for Supplier Evaluation) guidelines that have to be adhered to by the substantial maintenance vendor and the airline.

The team was tasked with identifying process measures which cover all the data to be gathered during surveillance. The team was also aware of the existence of inconsistency in the definition of the existing categories amongst the surveillance representatives. The selection strategy adopted by the team included noting the fact that the surveillance representatives use just a notepad and pen to document what is abnormal or improper in the maintenance facility. The team was also aware that the representative's own experience could be a road block, preventing him from correctly assigning an error to a category. The details of this strategy have been presented below.

2.1. Human Factor Principles

Humans have three distinct memory storage capabilities (not including permanent deletion). The first is sensory memory, referring to the information we receive through the senses. This memory lasts for a few seconds. Short Term Memory (STM) takes over when the information in our sensory memory is transferred to our consciousness or our awareness [4, 11]. This is the information that is currently active such as reading this page, talking to a friend, or writing a paper. STM can definitely last longer than sensory memory (up to 30 seconds or so), but it still has a very limited capacity. According to research, we can remember approximately 5 to 9 (7 +/- 2) bits of information in our short term memory at any given time [13]. Working Memory is the process that takes place when we continually focus on material for longer than STM alone will allow [1]. The Long Term Memory (LTM), unlike the other two types, is relatively permanent and practically unlimited in terms of its storage capacity. The team was aware of the fact that the surveillance representatives relied on their memory to categorize what they saw in the maintenance facility. This meant that there must be lesser categories and they should be easy to remember.

2.2. Utility of Captured Data

The utility and value of the data being gathered is of paramount importance. The process measures being used for data analysis in surveillance were high in number, had a redundant nature, and there was no common consensus between the various surveillance personnel within the department at FedEx. There were two distinct categories of process measures: Technical and Non-Technical. Process measures which include surveillance involving scheduled maintenance activities performed on an aircraft during a maintenance event are referred to as technical process measures. These process measures include technical activities that are hands-on and performed directly on the aircraft. Technical activity also includes maintenance that is performed in a back shop setting on a removed aircraft part. Example would be a panel removed and routed to a composite back shop for repair, then reinstalled on the aircraft. The surveillance activities involving verification of standardized procedures, referenced manuals, equipment, and facility maintenance requirements are referred to as non-technical process measures. It was important for the team to understand the purpose of the data being gathered and its importance to the aircraft airworthiness. For example, non-technical measure such as shelf life is very important and any mistakes on these measures should be noted and documented as much as hands documentation is done on surveillance of the aircraft itself.

2.3. Mental Working Model of the Surveillance Personnel

In the research team's conversation with the QA surveillance group at FedEx, the team gained insights into the mental working model of the surveillance representatives, the personnel who do the daily surveillance activities on the aircraft, and their managers. One of the managers has been a surveillance representative in the past and hence could empathize with the surveillance representatives. The team recognized that it was pertinent to recognize these models and use them to identify process measures.

3. Choosing a Process Measure

There are no targeted rules to decide which methods are the most appropriate for identifying specific research needs. Each method has its particular strengths and weaknesses and each is useful if applied appropriately. The team applied the three mentioned methods in selecting the final list of process measures. There are various factors which should be considered when selecting process measures.

3.1. Overlap and Redundancy

The first factor to affect the choice of the research team is overlap and redundancy. The team wanted to make sure that the data that fall under one process measure does not fall under other process measures. This can be avoided by identifying measures which do not overlap and through training. There was a situation where the quality assurance representatives felt that General Maintenance Manual (GMM), and Inspection Procedures Manual (IPM) was restricting them. They felt that since GMM is more airline specific and more exhaustive, IPM should be avoided. They mentioned occasions where they go on for an entire stretch of surveillance of an aircraft without documenting anything under IPM. The representatives mentioned that since IPM is vendor specific it becomes extremely overwhelming to cater to various vendor needs and restrictions. However, the management thought differently, and said that the inclusion of IPM would keep the vendor on a strict check.

3.2. Data Gathering Environment

The environment in which the activity happens dictates a lot of final results. The surveillance department is very work intensive, and the aviation industry is extremely regulated. The surveillance representatives are looking for

defects. Since they are in the maintenance facility, they have to stay focused with the work card on hand and inspect the operations performed. This also means that the representatives must avoid being distracted by other minor errors without missing the major one. The managers also expressed a need to document the positive notes on the surveillance site. It was felt that this would be important historical data to help keep a greater control and monitoring on the future maintenance events.

3.3. Process Measure Usage

The kind of work being scrutinized is also an additional factor to consider while deciding on the final set of process measures. The research team spent hours walking around with vendor maintenance personnel, vendor inspectors and, surveillance representatives at these maintenance sites. The team actually took a lot of subtle input from watching people work in their own work domain. This gave the team a better understanding in the limitations of certain process measures when it comes down to finalizing a particular category. The team recognized the fact that it is important to not loose focus with the initial purpose of the surveillance event while identifying a process measure. For instance, if a surveillance representative was doing in-process surveillance on the new paint coat given to a panel on the wing of an aircraft, and he realizes that the paint spray bottle has an expired date on it, the finding would be documented under in-process surveillance, and not under shelf-life, the way many quality assurance representatives do. This sounds right, because the traceability of a problem, and the cause of it, is both accounted for immediately.

3.4. Validation of Process Measures

Once the research team finalized the process measures definition document, and finalized a list of the process measures to be used for surveillance, it was important for the research team to validate their research efforts. The team conducted a two-phase on-line survey to validate results. An on-line survey was initially sent to the surveillance personnel at FedEx. There were two managers, and four quality assurance representatives who took part in the first survey. Prior to the surveillance personnel taking the survey, the research team sent out an e-mail to the participants. This e-mail had detailed instructions about how to take the survey, and the team also expressed its motive for the survey. The team also sent the participants the definitions document to read before taking the survey. The survey was designed to last a maximum of 60 minutes (including the time taken to read the surveillance definition document) and included 21 questions. The questions were of two kinds. There were Yes or No response questions, and open-ended questions. Irrespective of the nature of the questions, each question had a field for the comments of the personnel taking the survey. The reason for this was that the team wanted detailed feedback from the subjects taking the survey because of the regulated nature of the aviation industry. The team felt that if there were aspects which the participants were not in agreement with the research team, the team wanted a detailed explanation from the participants. All the participants of the survey were given the same set of questions. The participants taking the survey were not identified. With no identifiers, the WebSAT team would not know if the responses were from a manager or some other personnel lower on the hierarchy. The team gave two weeks to get inputs from the participants of the survey. Once the data was generated and analyzed, the research team iterated its definition document to incorporate changes expressed by the participants, who also happened to be the primary customer of the product. A conference call was conducted with the managers at FedEx to finalize the first iteration. In the next stage, the research team sent out the same survey to other supporting and partnering airline organizations. These airlines were Alaska Airlines, Delta Airlines, IATA, and America West. The results of this survey are still awaited.

4. Result

The first phase of the survey, gave positive results. The six proposed process measures were accepted by the surveillance representatives. The participants ranked the technical category process measures as the most important. Based on the preliminary results from the second survey, the research team proposes six process measures. In-Process, Verification, and Walkthrough surveillance suggest the technical aspect to surveillance. There are three non-technical surveillance categories. The first amongst these is Documentation surveillance which documents findings coming from surveillance performed on the vendor's documented system to validate issues such as quality control, technical data control, inspection, and work-processing programs. The next non-technical category is Facility surveillance, which documents findings from surveillance which is performed to validate shelf life control, housing and facilities, storage and safety/security/fire protection programs. The final category is Procedures Manual Violation. This surveillance ensures that the vendor is complying with the requirements set forth in the customer maintenance manual, and compliance requirements presented in the vendor Inspection Procedures Manual (IPM) or

Repair Station Manual (RSM). The team also designed a separate Fuel Surveillance Module which evaluates the fuel vendor's operational system, fueling equipment, records and the quality of the fuel. The survey data shows that there is a similarity in the application of surveillance in the other airlines. It appears, unlike FedEx, other airlines tend to perform more detailed audits as compared to hands-on surveillance. In other words, surveillance itself is *not* further categorized into other process measures. Further, it appears that non technical surveillance is not performed in as detailed a manner as conducted by FedEx. Considering technical process measures individually, the survey participants ranked the In process Surveillance process measure as the most important -as expected by the team.

5. Discussion

Overall, the methods adopted and the survey results show that more validation must be conducted on the process measures. The WebSAT research team plans to approach this by visiting other airlines onsite to understand the differences in the surveillance process. The survey is a first step taken by the team to evaluate the identified process measures. The team survey data indicates that the surveillance personnel would find lesser process measures easier to handle and categorize maintenance events. There are often anomalies in deciding what process measure a particular work card would fall into. Though the definitions of the existing process measures were not ambiguous to the managers they were often confusing to the representatives. Previously, there were five process measures which were of either a controversial nature or were inadequately defined and redundant on certain occasions. These categories were Inspection, Quality Control, Work Processing, General Maintenance Manual (GMM), and Inspection Procedures Manual (IPM). The valuable input here was the fact that these were all included in the Non-Technical process measures category. Further, the research team tried to eliminate the ambiguity by reducing the number of process measures and incorporating sub categories in some of these process measures. This allows the representative to choose from the given options, and not to memorize them.

Considering human limitations on processing information, the team adopted a total of 6 process measures for surveillance which fall in the range of 7 plus or minus 2 (13). Further, there are two other modules which capture data from surveillance work function. However, these are not process measures that are required to be memorized by the QA representative. The research team identified a new process measure called "Facility Surveillance" and incorporated the currently used measures like "Housing & Facilities", "Shelf Life Control" and others that have been borrowed from C.A.S.E. standards as sub-categories in this primary measure. It was also identified that there were lot of ambiguities in choosing a process measure for a given discrepancy arising from procedures manuals violation used by the vendors and the company and that of C.A.S.E. standards. Further, the surveillance personnel of the company have to be aware of the details in the procedures manuals of vendors at different locations and the company's manual. In order to assist the personnel in this regard, the research team has combined these two measures in to one measure called "procedures manual violation" so that the data can be consistently captured into one process measure. There are advantages of having both these process measures because it provides the managers with an insight into the vendors' regulated procedures and the discrepancies that exist between vendors' and company's procedures. Hence, 'Vendors Inspection Procedures Manual' and 'Company General Maintenance Manual' are provided as sub categories in the Vendor Inspection Procedures Manual. The survey results showed that the participants perceived no ambiguities in the identified process measures.

"Additional Findings" module further has two sections in it namely 'Information' and 'Aircraft Walk Around.' Information includes the surveillance activities and data that the on-site surveillance representative needs to document for informational purposes and does not necessarily hold the vendor against these occurrences. For example, this data could provide details on a discrepancy identified in the company's own manuals which would eventually help the company to refine it for future use. The other section, 'Aircraft Walk Around' captures data on any technical anomalies found on an aircraft which are beyond the scope of the scheduled maintenance event. Every attempt has to be made by the surveillance representatives to make sure that the finding is not part of the scheduled maintenance event and hence cannot be measured by the process measure -verification surveillance.

Acknowledgements

This research is supported by a contract to Dr. Anand K. Gramopadhye and Dr. Joel S. Greenstein, Department of Industrial Engineering, Clemson University from the Federal Aviation Administration (Program Manager: Dr. William Krebs, AAR-100). Our special thanks to Jean Watson and William Krebs from FAA for extending their support in conducting this research. We would also like to thank Rocky Ruggieri, Ken Hutcherson, Larry McKinnerney and the Quality Assurance department team from FedEx for their cooperation in providing data and

their contribution in data gathering and interpretation sessions. The opinions, findings, conclusions and recommendations presented in this paper are those of the authors and do not necessarily reflect the views of the Federal Aviation Administration.

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