Standardized Auditing and Surveillance of Aircraft Maintenance Operations

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Abstract

The safety and reliability of air transportation depends on minimizing inspection and maintenance errors that occur in the complex aircraft maintenance system. Significant efforts have been invested to investigate and track maintenance errors. However, these efforts are typically not preventative measures; rather they are reactive in nature: they focus on analyzing maintenance accidents and errors after their occurrence. There exists a lack of standardization in the assessment of maintenance errors across the maintenance industry. This paper addresses the need for development of a proactive system, which promotes standardization in data collection and identifies the contributing, factors that impact aircraft safety.

Keywords
Aviation maintenance, Impact variables, Web-based tool, Proactive system, Surveillance

1. Introduction
Since the mission of the FAA is to provide the public with continuing safe and reliable air transportation, it is important to have a sound aircraft inspection and maintenance system [3]. The system is complicated [3, 6] with interrelated human and machine components. The important aspect is the human. Realizing this, the FAA has pursued human factors research for some time now under the National Plan for Aviation Human Factors [3, 4] to fulfill the mission of the FAA's Flight Standards Service of promoting safety of flight of civil aircraft in air commerce by setting certification standards for air carriers, commercial operators, air agencies, and airmen. By directing, managing and executing certification, inspection and surveillance activities are assured adequacy of flight procedures, operating methods, airman qualifications and proficiency, aircraft maintenance and maintenance aspects of continued airworthiness programs. Given this objective, surveillance of maintenance activity contributes an important function in maintaining and improving aviation safety. Surveillance activity can have a tremendous impact in the implementation of a system that can be used by operators prior to the delivery of an aircraft to the customer to reduce maintenance errors. 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 the airline's Continuous Airworthiness Maintenance Program (CAMP) and General Maintenance Manual (GMM). The primary objective of surveillance is to provide the airline, through the accomplishment of a variety of specific surveillance activities on a planned and random sampling basis, an accurate, real-time, and comprehensive evaluation of how well each substantial maintenance vendor is complying with the airline and FAA approved policies and regulatory requirements.

A study conducted by Boeing and US ATA [1] found that maintenance error was a crucial factor in aircraft accidents from 1982 to 1991, contributing to 15 % of the commercial hull loss accidents where five or more people were killed. Rankin and Allen [9] established the economic costs of these maintenance errors, estimating that 20 to 30 % of in-flight shutdowns are due to maintenance error, 50 % of flight delays are due to engine problems caused by maintenance errors, and 50 % of flight cancellations are due to engine problems caused by maintenance errors. The indication is apparent for a proactive system which will help track maintenance errors, identifying both potential problem areas and the factors causing errors. If such a system is developed it will be possible to manage maintenance errors, resulting in aircraft maintenance which is more safe and robust. To understand the need to develop such a system it is essential to understand the entire aircraft inspection and maintenance system.

2. Background

The complexity of the inspection and maintenance system is complicated by a variety of geographically dispersed entities ranging from large international carriers, repair and maintenance facilities through regional and commuter airlines to the fixed-based operators associated with general aviation. Inspection is regulated by the FAA as is maintenance. However, while adherence to inspection procedures and protocols are closely monitored, evaluating the efficacy of these procedures is much more difficult.

When an aircraft is brought into service, a process called MSG (Maintenance Service Group) is used to determine how each component failure is to be corrected to maintain a high level of safety. Aircraft for commercial use have their maintenance scheduled initially by a team that includes the FAA, aircraft manufacturers and start-up operators. These schedules are then modified by the air carrier so that they suit individual requirements and meet legal approval. Thus, within the carrier's schedule there will be checks at various intervals, often designated as flight line checks, overnight checks, and A, B, C, and D, the heaviest, checks. The objectives of these checks is to conduct both routine and non-routine maintenance of the aircraft, including scheduling the repair of known problems; replacing items after a certain air-time, number of cycles, or calendar time; repairing defects discovered previously, for example, from reports logged by the pilot and crew, line inspection, or items deferred from previous maintenance, and performing scheduled repairs.

Once maintenance and inspection are scheduled for an aircraft, this schedule is translated into a set of job, or work cards containing instructions for inspection and maintenance as the aircraft arrives at each maintenance site. The aircraft is cleaned and the access hatches opened so that inspectors can view the different areas. This activity is followed by a heavy inspection check, primarily visual in nature. Since a significant amount of the maintenance workload depends on the defects found during inspection, it is important that the incoming inspection be completed as soon as possible after the aircraft arrives at the inspection maintenance site. There is always pressure on the inspector to discover critical defects necessitating long follow-up maintenance early in the inspection process. There is a heavy inspection workload at the commencement of each check. It is only after the discovery of defects that the planning group can estimate the expected maintenance workload, order replacement parts and schedule maintenance items. To meet this demand, maintenance facilities frequently resort to overtime, resulting in an increase in the total number of inspection hours, leading to prolonged working hours. Further, inspection such as routine inspections on the flight line is carried out during night shift, between the last flight of one day and the first flight on the next day. Once a defect is rectified, it may generate additional inspection, called 'buyback' inspections, to ensure the work meets the necessary standards.

As evident, the inspector's workload is very high at the arrival of an aircraft. As the service on the aircraft progresses, this workload decreases as the maintenance crew works on the repairs. The inspection load increases at the end of service. Various factors contribute towards the stress of the inspectors and the other personnel [18], stress that is further compounded by the fact that the inspector has to search for multiple defects occurring at varying severity levels and locations [2].

The maintenance task is further complicated because of the wide variety of aircraft defects being reported in older aircrafts. Documented facts indicate that scheduled repairs account for only 30 % of all maintenance in these aircrafts compared to 60-80 % in the younger fleet, a fact attributed to an increase in the number of age-related defects [3]. Thus, a more intensive inspection program is required for older aircraft, and inspection plays a more vital role. It should be realized that the introduction of newer aircraft will not substantially reduce the maintenance workload, as new airframe composites create an additional set of critical variables, affecting maintenance and inspection. The problem of maintenance is further demanding when more experienced inspectors and mechanics are retiring and being replaced by a much younger and less experienced work force. Not only do the new inspectors lack knowledge and skills of the far more experienced inspectors, they are also not trained to work on a wide variety of aircraft.

The cost of inspection is going up. This has resulted in a greater competitive pressure to reduce maintenance and inspection costs. The reasons for increased costs include maintaining minimum staffing levels and adhering to the mandated workload, without of course, risking safety of aircrafts or disrupting flight schedules. From an airline management perspective, two goals need to be achieved by a maintenance and inspection program: safety and profitability. Even though safety is of critical importance, profitability can be realized only when safety is achieved economically. For maintenance it means that in addition to performing the task, technicians have to be sensitive to efficiency, the speed measure, and effectiveness, the accuracy measure, if they are to optimize their performance. The relationship between performance measures and task factors are of critical importance in the maintenance/inspection environment.

The stress produced by this complicated situation, requiring, at times, what appear to be contradictory goals, often results in maintenance errors, a fact that has been confirmed and documented through task analysis of commercial maintenance and inspection activities [2]. This analysis has revealed that aircraft maintenance is a complex activity requiring above average coordination, communication and co-operation between inspectors, maintenance personnel, supervisors and various other sub-systems to be effective and efficient [3, 4]. Thus, it is clear that there exists potential for errors, and it is only through devising strategies that identify where they occur that we can eventually determine problem areas and develop interventions minimizing their impact.

3. Problem Statement

To minimize maintenance errors, the aviation maintenance industry has invested a significant effort in developing methodologies investigating maintenance errors. Literature of human error is rich, having its foundations in early studies analyzing human error made by pilots [5], human error work following the Three Mile Island accident, and recent research in human reliability and the development of error taxonomies [8, 11, 12, 13, 17]. This research has centered on analyzing maintenance accidents and incidents, a recent example being the Maintenance Error Decision Aid (MEDA) [10]. This tool, developed by Boeing along with representatives from British Airways, Continental Airlines, United Airlines, the International Association of Machinists and the US Federal Aviation Administration, helps analysts identify the contributing factors that lead to an accident.

In addition to this, various airlines have also developed their own internal procedures to track maintenance errors. Once such methodology is the failure modes and effect analysis approach [7] that classifies the potential errors by expanding each step of the task analysis into sub-steps and then listing all the failure modes for each. The US Navy Safety Center has done a commendable job in developing the Human Factors Analysis and Classification System-Maintenance Extension Taxonomy and the follow-up web-based maintenance error information management system developed by the Naval Safety Center to analyze naval aviation mishaps [14, 15, 16] and later used to analyze commercial aviation accidents [19]. Although valuable in terms of their insights into performance-shaping factors leading to maintenance errors following their occurrence, these efforts are reactive in nature; i.e., their focus is on analyzing maintenance accidents and errors following their occurrence, and not developing preventative measures. Moreover these efforts are usually ad hoc, varying across industry with little standardization. The lack of standardization in data collection, reduction and analysis is the single biggest constraint in the analysis of maintenance errors within and across the maintenance industry. Without such standardization it is difficult to analyze data and identify potential problem areas at multiple and geographically dispersed maintenance sites.

4. Strategy for Future Research

A proactive approach is required, one which will help identify problem areas and devise strategies to minimize maintenance errors. Since the aircraft maintenance industry needs direction in this area, our future research proposes to develop and implement a web-based application tool (http://www.ces.clemson.edu/~jsg/hcsl/) to perform surveillance activities to ensure that a consistent level of supervision is maintained over the maintenance and inspection operations. The system advocates the need to promote a standardized format for data collection, reduction and analysis to proactively identify contributing factors of improper maintenance. The overall structure of the system is shown in Figure 1. The system will seek input from various sources, including In-Process Surveillance, Verification Surveillance, Final Walk Around, Aircraft Walk Around, Inspection, Storage, among others. These are the sources which provide the maximum input about maintenance and inspection errors and hence are termed as the potential impact variables that affect the performance of the surveillance activity. Data collected from these diverse sources will be reduced and analyzed, enabling researchers to identify future problem areas. The identification of these problem areas will let the industry prioritize factors that transcend across industry to systematically reduce or eliminate potential errors. The system will be developed with a specific aviation partner (FedEx in Memphis, TN) to ensure that it meets the needs of the aviation community and later will be made available as an application that can be downloaded for use by each maintenance facility.

5. Significance and Impact of Proposed Research

The development of a web-based surveillance tool has the potential to reduce maintenance errors impacting aviation safety. The specific advantages of developing such a tool are the following: (1) this proactive approach will reduce maintenance errors by identifying problem areas and error contributing factors; (2) the adoption of this tool by the aircraft maintenance industry will promote standardization in data collection, reduction and analysis of maintenance error data from varied sources; (3) this standardization will result in superior trend analysis of problem areas within and across organizations; (4) the findings can be shared by manufacturers, airlines, repair stations and air cargos to help identify and prioritize factors that transcend across industry; and (5) this research will support the reduction of maintenance accidents and errors by conducting guidelines-based human factors research identifying and implementing intervention strategies.

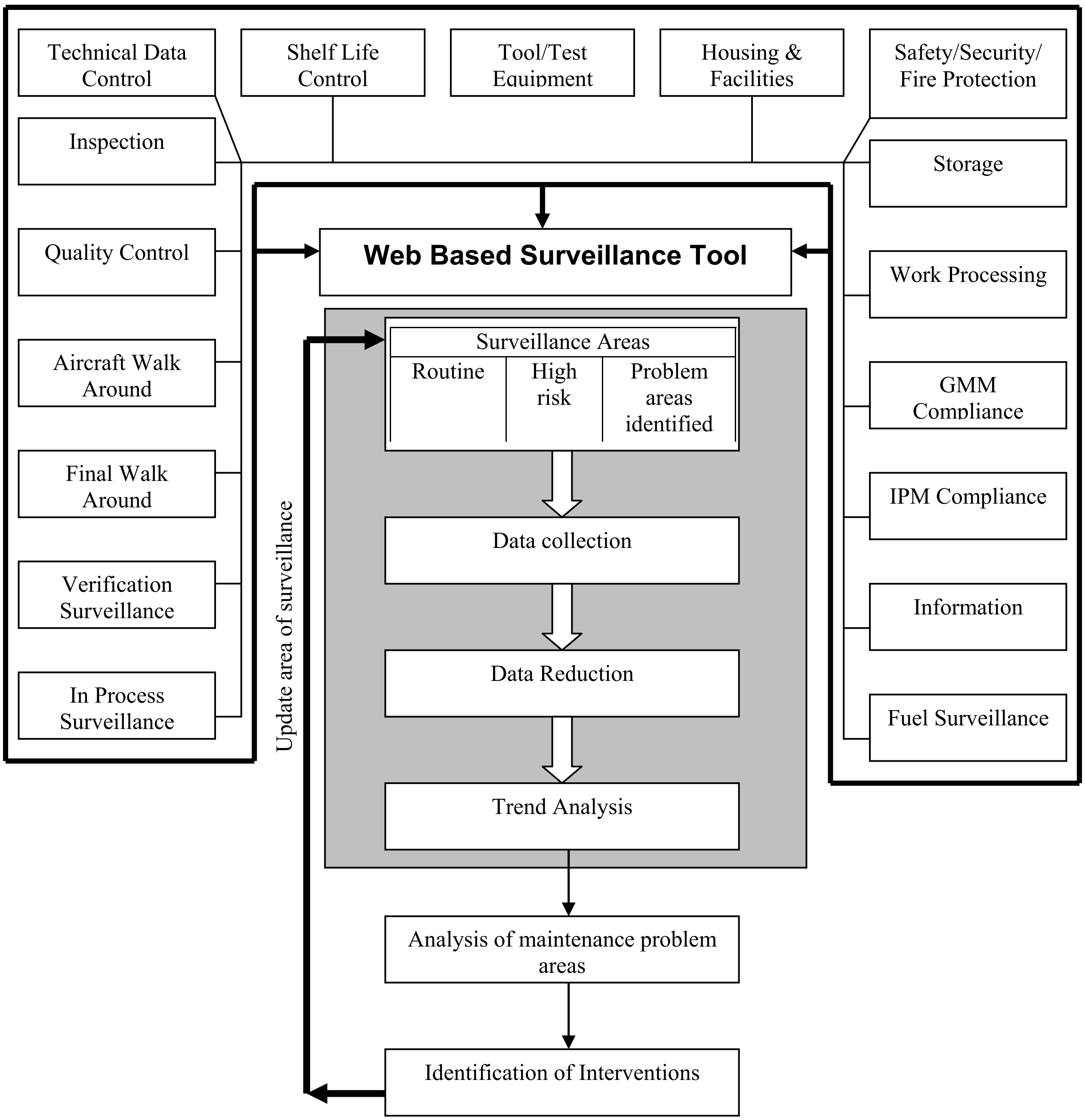

Figure 1. Web based Surveillance Tool with inputs from different sources

6. Conclusion

In summary, the objectives of this research are three fold: (1) identify an exhaustive list of impact variables that affect aviation safety and transcend across various aircraft maintenance organizations; (2) develop data collection/reduction and analysis protocol to analyze errors for the identified set of impact variables; and (3) using the results of the aforementioned activity develop and implement an application in performing surveillance/monitoring to ensure a consistent level of oversight in maintenance.

The results of this research will be disseminated to the aviation community via a number of avenues. These include, but are not restricted to, scholastic publications and training software available for download from FAA's web site. Most importantly, the results of this research will be regularly conveyed to the industry partners.

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