A Descriptive Model of Aircraft Inspection Activities

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Abstract

Task analyses of aircraft inspection/maintenance activities have shown the importance of inspection in ensuring the safety and reliability of aircraft. Drawing from the task analyses and visits to aircraft maintenance site this paper identifies the factors affecting airframe inspection performance.

Keywords
Aircraft, inspection, maintenance, task analysis.

1. Background

In order for the FAA to provide the public with continuing safe, reliable air transportation system it is important to have a sound aircraft inspection and maintenance system [1]. The inspection/maintenance system is a complex one with many interrelated human and machine components. The linchpin of this system, however, is the human. Recognizing this, the FAA (under the auspices of National Plan for Aviation Human Factors) has pursued human factors research [1, 2]. In the maintenance arena this research has focused on the aircraft inspector and the aircraft maintenance technician (AMT) [3, 4, 5]. Since it is difficult to eliminate errors altogether, continuing emphasis must be placed on developing interventions to make the inspection/maintenance procedures more reliable and/or more error tolerant.

2. The Aircraft Inspection System

The aircraft inspection/maintenance system is a complicated one [1, 3]. Moreover, it is affected 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, like maintenance, is regulated by the FAA but, while the adherence to inspection procedures and protocols are closely monitored, monitoring the efficacy of these procedures is much more difficult. Just as effective inspection is seen as a necessary prerequisite to maintenance safety, so inspector reliability is fundamental to effective inspection. Since, 90% of all inspection in aircraft maintenance tends to be visual it is critical that this visual inspection is performed effectively, efficiently and consistently over time. 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 taken by the carrier and modified so that they suit individual carrier requirements and meet legal approval. Thus, within the carriers schedule there will be checks at various intervals, often designated as:

flight line checks, overnight checks, A, B, C and the heaviest (D) check. The objective of these checks is to conduct both routine and non-routine maintenance of the aircraft. The maintenance includes scheduling the repair of known problems; replacing items after a certain air time, number of cycles or calendar time; repairing defects discovered previously (e.g., reports logged by pilot and crew, line inspection, items deferred from previous maintenance) and performing scheduled repairs. If a defect is discovered by the inspection system, it often leads to repair/maintenance. In the context of an aging fleet, inspection takes a more vital role. Scheduled repairs account for only 30% of all maintenance compared to 60-80% in the earlier fleet which can be attributed to an increase in the number of age-related defects [1]. In such an environment the importance of inspection can not be overemphasized.

Once the maintenance and inspection is scheduled on an aircraft, the schedule is translated into a set of job cards or work cards (instructions for inspection and maintenance) as the aircraft arrives at each maintenance site. Initially, the aircraft is cleaned and access hatches opened so that inspectors can view the different areas. This activity is followed by a heavy inspection check. As stated earlier, most of this inspection is visual in nature. Since such a large part of the maintenance workload is dependent on the discovery of defects during inspection, it is imperative that the incoming inspection is completed as soon as possible after the aircraft arrives at the inspection maintenance site. Furthermore, there is pressure on the inspector to discover critical defects that necessitate long follow-up maintenance times, early on in the inspection process. Thus, 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 expected maintenance workload, order replacement parts and schedule maintenance items. Frequently, maintenance facilities resort to overtime, resulting in an increase in the total number of inspection hours. This often leads to prolonged work hours. Also much of the inspection is carried out in the night shift, including routine inspections on the flight line, which are scheduled to occur between the last flight of the day and first flight on the next.

During inspection, each defect is written up as a Non-Routine Repair (NRR) record. This is translated into a set of work cards to rectify the defect. The defect is rectified by the maintenance crew. Once the defect is rectified, it may also generate additional inspection (buy-back) to ensure that the work meets necessary standards. These subsequent inspections are typically referred to as buyback inspections. Thus, it is seen that initially the workload on the inspector is very high with the arrival of an aircraft. As the service on the aircraft progresses, the inspection workload decreases as the maintenance crew works on the repairs. The inspection load again increases towards the end of service. However, the rhythm of the work changes towards the end of service as there are much frequent interruption as AMT's call in inspectors to conduct buybacks of completed work.

Task analysis of aircraft inspection has revealed inspection to be a complex task wherein the inspector has to visually search for multiple defects occurring at varying severity levels and locations (refer to Drury and Gramopadhye for further details) [3]. In performing the inspection task the inspector has to be sensitive to efficiency (speed measure) and effectiveness (accuracy measure). These performance measures are impacted by task factors and others, as seen in Figure 2. The inspector needs to be sensitive to these factors if he or she is to optimize his or her performance. Thus, it is obvious that the inspection is a complex system and as such can be expected to exert stress on the inspectors and other personnel [6].

The inspection task is further complicated by the wide variety of defects that are being reported in older aircraft. Consequently, a more intensive inspection program is required for older aircraft. The introduction of newer aircraft does not strictly reduce the inspection workload, as new airframe composites create an additional set of inspection variables. Nevertheless, the widespread use of older aircraft is expected to continue in the future. Thus, the Office of Aviation Medicine and the FAA Technical Center have recently concentrated their efforts in this area.

The problem of inspection is further compounded since the more experienced inspectors and mechanics are retiring and are being replaced by a much younger and less experienced work force. Not only do the unseasoned AMT's lack the knowledge or skills of the far more experienced inspectors/AMT's they are replacing, they are not trained to work on a wide variety of aircraft. Since inspectors will continue to be a part of the inspection process for the foreseeable future, they must be trained to be effective and efficient. Training has shown to have a powerful effect on inspection performance when applied to both novice and experienced inspectors [3, 7, 8]. However, most of the training for inspectors tends to be on-the-job (OJT) training, especially for visual inspection tasks. However, we know from the literature that this may not be the best method of instruction [1, 9]. Clearly, training is a critical issue because the reliability and safety of the aircraft fleet can be only assured when inspections are conducted properly.

Further, it is seen that the cost of inspection is rising [10]. As a result, there is increasingly greater competitive pressure to reduce maintenance/inspection costs (e.g., by maintaining minimum staffing levels and adhering to the mandated workload), without of course jeopardizing safety or disrupting flight schedules. Thus from an airline management perspective two goals need to be achieved by a maintenance/inspection program: safety and profitability. Thus while safety is of paramount concern, profitability can be achieved only when safety is achieved economically.

The two conflicting goals of safety and profitability are embodied in the inspection function in the form of *accuracy* and *speed*, respectively. Accuracy denotes detecting the defects that must be remedied for the safe operation of the aircraft while keeping false alarms to a minimum. Speed means the task must be performed in a timely manner without the excessive utilization of resources. In order to establish benchmarks for speed and accuracy and quantify the tradeoffs between them, we first need to identify the factors affecting inspection performance.

Following several site visits to aircraft maintenance facilities and task analysis of previous inspection activities, a detailed breakdown of the inspector’s activities was developed [1, 2]. The factors affecting the various activities were identified and are detailed in Table 1.

Table 1a. Inspector's Activities

Activity	***Assign Work/ Inspection tasks***	***Preparatory work***	***Locate area***
Description	Supervisor assigns tasks to the inspector	The objective is to conduct all activities that support inspection.	Inspector locates inspection area on the aircraft
Personnel Involved	Supervisor/ Lead Supervisor, *Inspector*, Planning personnel	*Inspector*, Cleanup crew, Stores	*Inspector*
Performance Shaping Factors	Subject Factors: • Inspector availability, availability of inspectors with specialized skills (e.g., NDI inspection) • Knowledge in assigning tasks, monitoring work and delegation of work • Knowledge to use information to complete tasks • Leadership skills, training Task Factors: • Planning information/workload status • Availability of resources (human, machine, system) • Aircraft schedules: arrivals, departures, types, number, types of checks • Availability of other personnel (e.g., cleanup crew) • Work disruptions: parallel tasks, interference from competing tasks • Safety issues	Subject Factors: • Availability of support personnel (cleanup crew, stores • Training, Team approach Task Factors: • Availability and knowledge on the use of tools and equipment (e.g., NDI calibration, use of cherry picker) • Availability and knowledge on use of information (written and oral) • Safety issues (e.g., X-ray inspection) Environmental Factors: e.g., Temperature, humidity, lighting, noise level, time pressures, shift time	Subject factors : • Knowledge of aircraft and information from other sources (workcards, manuals, ADs) • Ability to organize work Task factors: • Accessibility to area • Availability and knowledge on use of tools, equipment, procedures and other personnel (e.g. cleanup crew) • Parallel or interfering work Environmental factors: e.g., Temperature, humidity, lighting, noise level, time pressures, shift time
Performance Measures	• OTD: On Time Departure • Quality of Work • Percentage utilization of personnel • Incorrect assignment of people → tasks	• Correctness in accomplishing preparatory work so that next task in sequence can proceed without delay • Time to complete preparatory work	• Correct location of area • Time to locate and access area • Incorrect use of equipment/ tools and procedures

Table 1b. Inspector's Activities

Activity	*Inspection*	
	Search	Decision- Making
Description	Search the inspection area for potential defects	The objective is to decide on the severity of a defect once it is located
Personnel Involved	*Inspector*	*Inspector*
Performance Shaping Factors	Subject Factors: • Visual acuity, color vision, peripheral vision • Visual scanning strategy • Experience • Training • Knowledge of aircraft and defects Task Factors: • Task complexity (# of defects, defect types, defect mix, defect probability, defect distributions, search area, defect conspicuity) • Feedforward information and feedback information • Time available for inspection • Standards and job aids Environmental Factors: e.g., Temperature, humidity, lighting, noise level, time pressures, shift time	Subject Factors: • Visual acuity • Experience • Training • Knowledge of aircraft and defects Task Factors: • Task complexity (rules in classifying defect severity based on extent, # of defects, location) • Availability and use of Feedforward and Feedback information • Time available for inspection • Job aids and standards (On-line, documented, none) Environmental Factors: e.g., Temperature, humidity, lighting, noise level, time pressures, shift time
Performance Measures	• Time to locate defects • Time to complete inspection • Percentage defects located • Number of times tools, equipment and procedures correctly applied	• Decision time • Decision accuracy (correctness of decision) • Number of times tools, equipment and procedures correctly applied

Table 1c. Inspector's Activities

Activity	*Record item*	*Fix item*	*Buy Back inspection*
Description	Write up the defect using a non routine card	Perform maintenance	Inspect the maintenance work for quality, adherence to standards and procedures
Personnel Involved	*Inspector*	*Mechanic*	*Inspectors* (same or different)
Performance Shaping Factors	Subject Factors: • Writing skills • Training • Knowledge of rules and procedures, aircraft and defects Task Factors: • Task complexity • Standards and procedures • Availability and use of Feedforward and Feedback information Environmental Factors: e.g., Temperature, humidity, lighting, noise level, time pressures, shift time	--- --- --- --- ---	Same as inspection
Performance Measures	• Accuracy of information contained in non-routine card • Time to complete task	---	Same as inspection

3. Conclusions

Having identified the factors affecting aircraft inspection, the next step involves identifying interventions to improve the effectiveness and efficiency of aircraft inspection operations. These interventions can range from making changes to the human, the inspection process/system or the support equipment/tools. As a first step the Clemson team is evaluating the potential of off-line training for improving inspection performance.

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