TASK ANALYSIS OF GENERAL AVIATION INSPECTION ACTIVITIES: METHODOLOGY AND FINDINGS

Anand K. Gramopadhye[1], Rahul R. Desai[1], Shannon Bowling[1] and Mohammad Khasawneh[2]
[1]Advanced Technology Systems Laboratory
Department of Industrial Engineering, Clemson University, Clemson, South Carolina 29364

[2]Department of Systems Science and Industrial Engineering
State University of New York at Binghamton, Binghamton, New York 13902

Abstract: General Aviation (GA) constitutes a significant, but often ignored, portion of the aviation system. It is crucial that GA be reliable if we are to ensure the safety of the overall air transportation system. The inspection/maintenance system, which is responsible for identifying and fixing defects, is a key component of this system. For this reason, it is critical to have a sound inspection and maintenance system. In response to this need, this paper reports task analyses of aircraft inspection operations at geographically dispersed GA facilities operated under the Federal Aviation Regulation (FAR) Part 91, 135, and 145. Recommendations forthcoming from this analysis will be used to devise intervention strategies to improve inspection performance. As a first, this paper outlines the methodology used and the preliminary results obtained.

INTRODUCTION

For the Federal Aviation Administration (FAA) to provide the public with a safe, reliable air transportation system, it is important to have a sound aircraft inspection and maintenance system (FAA, 1991). This inspection/maintenance system is a complex one with many interrelated human and machine components, with the human as the linchpin. Recognizing this, the FAA under the auspices of National Plan for Aviation Human Factors has pursued human factors research (FAA, 1991; FAA, 1993). In the maintenance arena this research has focused on the aircraft inspector and the aircraft maintenance technician (AMT) (Drury, Prabhu and Gramopadhye, 1990; Shepherd, 1992; Shepherd, Layton and Gramopadhye, 1995). Since it is difficult to eliminate errors completely, continuing emphasis must be placed on developing interventions to make the inspection/maintenance procedures more reliable and/or more error-tolerant.

Aircraft in the GA environment have their maintenance scheduled initially by a team that includes the FAA, aircraft manufacturers, and start-up operators, although these schedules may be taken and modified to suit individual requirements and meet legal approval. (In many cases the customer may follow a manufacturer's inspection program, which calls for 100 hrs. and a yearly inspection.) Within these schedules, there are checks at various intervals, often designated as flight line checks; overnight checks; and A, B, C and, the heaviest, D checks. The objective of these checks is to conduct both routine and non-routine maintenance of the aircraft. This 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, for example from reports logged by pilot and crew or from line inspection, or items deferred from previous maintenance; and performing scheduled repairs.

One of the areas reported in need of improvement is the human inspection of aircrafts, as this process has been widely reported as a cause of several errors/accidents in the aircraft maintenance industry (see FAA, 1991; FAA, 1993; Hobbs and Williamson, 1995 and the recent Continental Express crash). This problem has been attributed to a lack of well-defined inspection procedures for use by the aircraft maintenance industry. In response, the industry has developed ad-hoc measures and general guidelines to assist various personnel involved in the inspection process. This has resulted in various organizations developing their own internal procedures, which vary in their level of instruction/detail. Because of this situation, inspection procedures are not standardized across the industry. Moreover, they are often not based on sound principles of human factors design.

The two goals that need to be achieved by a maintenance/inspection program are safety and profitability. While safety is of paramount concern, profitability can be realized only when safety is achieved economically. For human inspectors, this means that in addition to performing the inspection task, they have to be sensitive to both efficiency, the speed measure, and effectiveness, the accuracy measure, if they are to optimize their performance. The interrelationship between these performance measures and task factors, among others, is seen in Figure 1.

These 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. As can be seen, it is crucial that inspectors work not only effectively, that is, detect all potential defects, but also efficiently. The problem is further compounded in the GA inspection environment with its large differences in the size and type of maintenance facilities, organizational and physical environment, and inspector experience and technical skills.

In response to this need, a task analysis of inspection activities was conducted at representative GA facilities, with the research looking at the entire inspection process to identify human factors interventions, which will minimize inspection errors. The specific objectives of this research were to analyze the inspection process at representative aircraft maintenance sites, develop a taxonomy of errors and identify human factors interventions to prevent them.

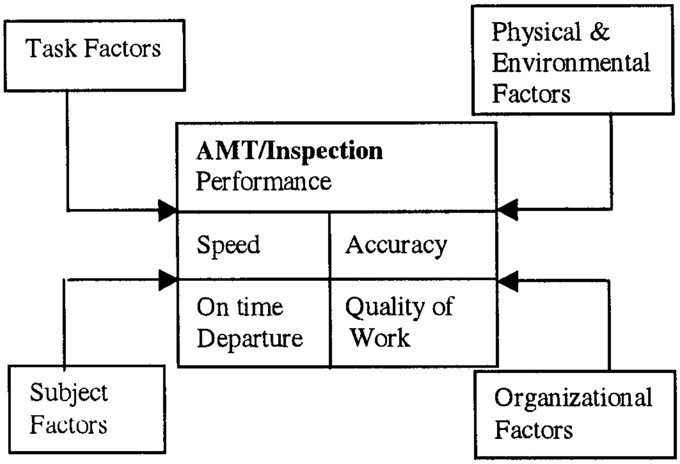

Figure 1. Factors Impacting Aircraft Inspection Performance

METHODOLOGY

As a first step, the study analyzed the inspection process at representative GA aircraft maintenance sites, including the norms, information transfer procedures, guidelines and FAA-mandated procedures. Next, a detailed error taxonomy was developed to help classify the typical inspection errors. These errors were then analyzed and interventions identified to develop a standardized inspection process to minimize them. During this phase of the study, the researchers focused on the mechanic/inspectors, their respective supervisors, and the various entities they interact with. Following this step, recommendations were developed to support improved inspection performance.

Task Analysis of Inspection Operations at GA Facilities

A detailed task analysis of the operations was conducted using data collected through shadowing, observation, and interviewing techniques. The team partners at 14 different maintenance sites located within the continental US provided the research team with access to their facilities, personnel, and documentation and allowed the research team to analyze their existing inspection protocol at different times of the shift. The research team worked with the managers, line supervisor/shift foremen, and more than 100 inspectors and aircraft maintenance technicians. The research team visited sites with both light and heavy inspection and maintenance work governed by FAR Part 91, 135, and 145.

Following this step, the researchers conducted follow-up interviews with the various personnel involved to ensure that all aspects of the inspection process were covered. These interviews discussed issues concerning the tasks they were undertaking or had just performed and general issues concerning their work environment, both physical and organizational.

Task Analysis

The study was initiated with a meeting between the members of the research team and the airline personnel to outline its objectives and scope. The objective was to identify human-machine system mismatches that could lead to errors through shadowing, observing, and interviewing techniques. The goal of the task analysis, which was to understand how the existing system works, was achieved using a formal task analytic approach (Gramopadhye and Thaker, 1998). The first step in this approach is to develop a description of the task, outlining in detail the steps necessary to accomplish the final goal. While various formats can be used to describe a task, this study used a hierarchical one in conjunction with a column format. Figure 2 show a sample hierarchical task analysis (HTA) used for the inspection process. Each step was later described in detail in a column format similar to that used by FAA (1991). This column format identified the specific human subsystem--attention, sensing, perception, decision, memory, control, feedback, communication, and output--required for the completion of each step (Table 1). Using this format enabled the analysts to identify clearly the specific cognitive and manual processes critical in the performance of the tasks, identifying the opportunities for error. As an example, for Sub-Task 1.3, Memory was identified as a critical sub-process; observable errors occurring over various shifts at different sites were tabulated for all technicians for this specific sub-component (see data in Table 2.). Follow-up interviews, questionnaires and observational techniques were used to identify and isolate error-causing mechanisms. This data was later mapped using Rouse and Rouse's (1983) error taxonomy to identify the error genotypes. Having this information, expert human factors knowledge was applied to the sub-task to identify specific interventions (e.g., provide job-aids) to minimize the negative effects due to specific error shaping factors (see Table 3) and to improve performance on the sub-task.

Following the analysis of inspection, a comprehensive error classification scheme was developed to classify the potential errors by expanding each step of the task analysis into sub-steps and then listing all the failure modes for each, using the Failure Modes and Effects Analysis (FMEA) approach (Hobbs and Williamson, 1995). Then, a classification scheme for errors was developed based on Rouse and Rouse's (1983) Human Error Classification Scheme.

Human Error in Inspection – Development of a Taxonomy

The error taxonomy development was a two-step process. Initially, the Failure Effects Modes Analysis (FEMA) Approach was applied to develop the taxonomy of errors. These represent the error phenotypes, the specific, observable errors providing the basis for error control. Error prevention and the development of design principles /interventions for error avoidance rely on genotype identification, associated behavioral mechanism and system interaction. The phenotypes were characterized by the relevant aspects of the system components (e.g., human, task, environment, etc.) with which they interact. The resulting list of phenotypes, error correctability and type, and the relevant error shaping factors, enable designers to recognize these errors and design control mechanism to mitigate their effects. For this purpose, Rouse and Rouse's (1983) behavioral framework was used to classify errors during an inspection process and to identify the genotypes associated with each phenotype. This methodology yielded the mechanism of error formation within the task content. This error framework, which classifies human errors based on causes as well as contributing factors and events, has been employed to record and analyze human errors in several contexts such as detection and diagnostics, trouble-shooting and aircraft mission flights.

DISCUSSIONS AND CONCLUSIONS

Following observations and discussions with various inspectors and a detailed task analysis of the inspection processes, recommendations were identified for improvements to the human and to the environment (physical and organizational). Improvements to the human ranged from inspection training/retraining/certification, job-aiding, to visual standards for inspection. Improvements to the environment ranged from workplace design (lighting, workcard design, equipment design, standardization of tools) to improved procedures for shift change. However, training for inspection showed up most of the times as the intervention strategy of choice. Having performed the task analysis, it will form as the basis for developing an inspection training program to support inspectors in the GA environment and will be used to establish the content, methods, and the appropriate delivery system for training.

ACKNOWLEDGEMENTS

This research was funded by a grant from the Federal Aviation Administration- Aviation Research Grants Program (Program Manager: Dr. William Krebs; Grant Number 02-G-021) to Dr. Anand K. Gramopadhye, Clemson University.

REFERENCES

1. Drury, C. G., Prabhu, P. and Gramopadhye, A. K. (1990). Task analysis of aircraft inspection activities: methods and findings. Proceedings of the Human Factors Society 34th Annual Meeting, pp. 1181-1184.
2. FAA (1991). Human Factors in Aviation Maintenance - Phase One Progress Report, DOT/FAA/AM-91/16, Washington, DC: Office of Aviation Medicine.
3. FAA (1993). Human Factors in Aviation Maintenance - Phase Three, Volume 1 Progress Report, DOT/ FAA / AM-93/15.
4. Gramopadhye, A.K. and Thaker, J.P. (1998). Task Analysis. Chapter 17 In the Occupational Handbook of Ergonomics. (Editors: Karakowaski W. and Manas, W.S. CRC Press: New York.)
5. Hobbs, A. and Williamson, A (1995). Human Factors in Airline Maintenance: A Preliminary Study. Proceedings of the eighth International Symposium On Aviation Psychology. 461-465.
6. Rouse, W. B., and Rouse, S. H., (1983). Analysis and Classification of Human Errors. In IEEE Transactions on Systems, Man and Cybernetics, Vol. SMC-13, No. 4.
7. Shepherd, W.T. (1992). Human Factors Challenges in Aviation Maintenance Proceedings of the Human Factors Society 36th Annual Meeting, Washington, DC: Federal Aviation Administration.
8. Shepherd, W.T.; Layton, C.F., and Gramopadhye, A. K. (1995). Human Factors In Aviation Maintenance: Current FAA Research. Proceedings of the Eighth International Symposium On Aviation Psychology. 466-468.

Table 1: Sample Task Analysis of the Inspection Process

	Task Analysis								
TASK DESCRIPTION	A	S	P	D	M	C	F	O	OBSERVATIONS
1.0 Inspector A completes assigned work on shift A.									
1.1Inspector A completes inspection (portions or complete area)									
1.2 Inspector A enters information status on work completed using work card (WC) and non routine cards (NRC)	*	*	*	*	*			*	
1.3 Inspector A enters information using appropriate system for work in progress (WIP)	*	*	*	*	*				Inspector completes information on items not completed, items started but not signed off.
1.4 Inspector A returns to work center on completion of work	*							*	
1.5 Inspector A returns cards to work center.	*							*	

A: Attention S: Senses P: Perception D: Decision Making M: Memory C: Control F: Feedback O: Others

Table 2: Sample Error Taxonomy (1)

TASK	ERRORS	OUTCOME
1.Inspector A completes assigned work on shift A 1.1 Inspector A completes inspection (portions or complete area) **		
1.2 Inspector A enters information on status of work completed	E1.2.1 Inspector A enters incorrect information E1.2.2 Inspector A enters incomplete information E1.2.3 Inspector A does not enter any information	Inspector A enters correct and complete information of work completed.
1.3 Inspector A enters information using system for work in progress (WIP)	E1.3.1 Inspector A enters incorrect information E1.3.2 Inspector A enters incomplete information E1.3.3 Inspector A does not enter any information	Inspector A enters correct and complete information for work in progress (WIP)
1.4 Inspector A returns to work center on completion of work	E1.4.1 Inspector A does not return to work center on completion of work	Inspector A returns to work center
1.5 Inspector A returns cards to location in the work center	E1.5.1 Inspector A does not return work card E1.5.2 Inspector A places card in incorrect location	Inspector A returns cards to correct location in the work center

Table 3: Error Shaping Factors and Interventions (Example)

Errors from task analysis	Error Shaping Factors						Suggested Improvements
	Human	Task	Work Space	Equipment/ Tools	Documentation	Environment (Organizational And Physical)	
E1.2.1 Inspector A enters incorrect information	Memory slip, overconfidence, incomplete knowledge, recall error, lack of knowledge, familiar shortcut					Lack of training, Loose adherence to system procedures	• Training, Job Aid • Procedure development • Enforcement
E1.2.2 Inspector A enters incomplete information	Memory slip, overconfidence, incomplete knowledge, recall error, lack of knowledge, familiar shortcut					Lack of training, Loose adherence to system procedures	• Training, Job-Aid • Procedure development • Enforcement
E1.2.3 Inspector does not enter any information	Memory slip, overconfidence, incomplete knowledge, recall error, lack of knowledge, familiar shortcut				Lack of procedures	Lack of training, Loose adherence to system procedures	• Training, • Procedure development • Enforcement

Figure 2 Hierarchical Description of the Inspection Process