Team Situation Awareness in Aviation Maintenance

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To assess team situation awareness in an aviation maintenance setting, a methodology was developed for examining situation awareness requirements that incorporates both individual and team situation awareness perspectives. In the present study, inquires were conducted in the field maintenance setting at a major airline. Contextual inquires were combined with a goal directed task analysis to specify the situation awareness requirements involved in each of the interactions (between and within teams) required to perform maintenance tasks. Situation awareness requirements in a team context are discussed along with recommendations for training programs directed at improving situation awareness with and between teams.

INTRODUCTION

Insufficient attention has been paid to problems involved in aircraft maintenance. While the number of incidents due to mechanical failures that can be traced to maintenance problems are relatively few when compared to other causal factors (e.g., in-flight human error), they do exist and can be systematically addressed. Marx and Graeber (1994), for instance, report that 12% of accidents are due to maintenance and inspection faults, and around one-third of all malfunctions can be attributed to maintenance deficiencies. In addition to its impact on safety of flight, the efficiency of maintenance activities can also be linked to flight delays, ground damage and other factors that directly impact airline costs and business viability.

In examining problems that occur within the maintenance arena, several types of difficulties can be identified:

1) The first involves shortcomings in the detection of critical cues regarding the state of the aircraft or sub-system. Several accidents have been traced to metal fatigue or loose and missing bolts that should have been visible to maintenance crews. There have been incidents where aircraft were returned to service with missing parts or incomplete repairs. Frequent errors include loose objects left in aircraft, fuel and oil caps missing or loose, panels and other parts not secured and pins not removed (Marx & Graeber, 1994). While several factors may contribute to this type of error, in each of these cases the state of the system was not detected prior to returning the aircraft to service.

2) Even when important information is perceived, there often may be difficulties in properly interpreting the meaning or significance of that information. For instance, Ruffner (1990) found that in more than 60% of cases, the incorrect avionics system is replaced in an aircraft. While the symptoms may be observed correctly, a significant task remains to properly diagnose the true cause of the failure. While not much data exists regarding the impact of misdiagnoses of this type, there is a significant increase in the probability of an incident occurring when the aircraft undertakes the next flight with the faulty system still aboard.

3) These problems are compounded by the fact that many different individuals may be involved in working on the same aircraft. In this situation, it is very easy for information and tasks to fall through the cracks. The presence of multiple individuals heightens the need for a clear understanding of responsibilities and communications between individuals to support the requirements of individuals in performing those tasks. In addition to the need for intra-team coordination, a significant task for maintenance crews is the coordination of tasks and information across teams to those on different shifts or in different geographical locations. The Eastern Airlines incident at Miami Airport (National Transportation Safety Board, 1984) has been directly linked to a problem with coordination of information across shifts (along with other contributing factors). In addition, considerable energy is often directed at coordination across sites to accommodate not only maintenance tasks within the flight schedule but also parts availability constraints. These factors add a level of complexity to the problem and increases the probability of tasks not being completed or completed properly, important information not being communicated and problems going undetected as responsibility for tasks becomes diluted.

Situation Awareness

All of these difficulties point to a problem of situation awareness. That is, maintenance crews need additional support/training in ascertaining the current state of the aircraft system (supplementing current technical training programs). Situation awareness has been found to be important in a wide variety of systems operations, including piloting, air traffic control and maintenance operations. Formally defined, "*situation awareness is the detection of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future"* (Endsley, 1988). In the context of aircraft maintenance, this means being aware of the state of the aircraft system (and the sub-system one is working on). Termed Level 1 SA, this would include perception of the state of the factors listed in item number one above. Level 2 SA would involve the technicians' understanding or comprehension of the significance of observed system states. Specifically this would include their diagnosis of the causal factors associated with observed symptoms.

While SA has generally been discussed in terms of the operation of a dynamic system, such as an aircraft, the concept is also applicable to the maintenance domain. The complexity of aircraft systems and the distributed nature of equipment and system components posses a significant challenge to the technicians' ability to determine the state of the system (Level 1 SA) during diagnosis and repair activities. Putting together observed cues to form a proper understanding of the underlying nature of malfunctions (Level 2 SA) is a significant problem in diagnostic activities. Level 3 SA, the ability to project the state of the system in the near future, is considered the highest level of SA in dynamic systems. In the maintenance domain, technicians may need to be able to project what will happen to an aircraft's performance with (or without) certain actions being taken or with given equipment modifications/repairs/adjustments occurring. This task may be even more difficult for maintenance technicians, as they often receive little or no feedback on the effects of their actions, and thus may have difficulty developing an adequate mental model for making accurate predictions. The ability to project system status forward (to determine possible future occurrences) also may have a significant relation to the ability to project system status backward, to determine what events may have led to an observed system state. This ability is particularly critical to effective diagnostic behavior.

Team SA

In aircraft maintenance, as in many other domains, the requirement for situation awareness becomes compounded by the presence of multiple team members, and multiple teams. Individuals need not only to understand the status of the system they are working on, but also what other individuals or teams are (and are not) doing as well. Both factors contribute to their ultimate decision making processes and performances. Team situation awareness can be defined as "*the degree to which every team member possesses the situation awareness required for his or her responsibilities*" (Endsley, 1989). In this context, the weak link in the chain occurs when the person who needs a given piece of information (per his or her job requirements) does not have it. The level of SA across the team, therefore, becomes an issue of some concern. The objective of the current study was to identify situation awareness requirements for aircraft maintenance teams, analyze how SA needs are currently being met in a typical maintenance environment and establish concepts and requirements for training Team SA in this domain.

METHODOLOGY

A Team SA Context Analysis methodology was developed for this project. This method consists of two parts: An SA Requirements Analysis and an SA Resource Analysis, as shown in (Figure 11-1, appendix).

SA Requirements Analysis

The first step in addressing situation awareness was to determine the specific situation awareness requirements of individuals in the aircraft maintenance arena. This was addressed through a goal-directed task analysis which assessed: 1) the goals and sub-goals associated with maintenance crews, 2) the decision requirements associated with these goals, and 3) the situation awareness requirements necessary for addressing the decisions at all three SA levels - detection, comprehension, and projection. This type of analysis has been successfully conducted for several classes of aircraft (Endsley, 1989; Endsley, 1993), air traffic control (Endsley & Rodgers, 1994) and airway facilities maintenance (Endsley, 1994).

Analyses were conducted through expert elicitation with experienced maintenance personnel, observation of aircraft maintenance activities, and review of all available maintenance documentation. The analysis concentrated on the B-Check maintenance activities conducted by a major airline company at a major airport. To date, interviews have been conducted with three maintenance supervisors, four lead technicians and four A&P technicians at the site.

SA Resource Analysis

The second part of the Team SA Context Analysis concentrated on identifying the SA Resources used in the current environment to achieve the SA Requirements. Two major categories of resources were considered:

- Other technical operations personnel as a source of information and
- The technologies used as sources of information.

To provide an assessment of the personnel SA resources in the aviation maintenance setting, an analysis of communications between organizations and individuals was conducted using a contextual inquiry approach. The contextual inquiry approach (Robertson & O'Neill, 1994; Endsley, in press) focused on understanding and describing the communication patterns within and between teams as related to their performance goals. The contextual inquiries were conducted simultaneously with the interviews for determining the SA requirements. The contextual inquires involved semi-structured interviews in which each individual was asked to describe his/her major job functions and goals and the organizations, departments or individuals that served as resources in meeting those goals. A context mapping was then determined showing the communication patterns among and between team members. Each individual was asked to make an estimate of the overall frequency of communication with each identified unit or department and the importance of the communication for achieving his/her goals. Finally each person was asked to identify system, technology or personnel barriers to effective communication and performance in the work setting.

In addition to identifying the SA requirements of teams working on each maintenance task, the technologies for obtaining each requirement within the current system are documented. Based on this analysis, an assessment can be made of the degree to which the current system supports Team SA and the skills and abilities that are required for achieving good SA within this environment.

RESULTS

Examples of the results of the application of the Team SA Context Analysis methodology in the maintenance domain are presented here. Job goals in the aircraft maintenance domain appear to be oriented toward the dual goals of ensuring aircraft safety and delivering aircraft for service on time. A breakout of A&P technician goals is shown in (Figure 11-2, appendix). The major decisions that need to be made for achieving each goal were determined during the analysis and the associated SA requirements were delineated. An example of the output of the SA requirements analysis for one sub-goal is shown in (Figure 11-3, appendix).

The contextual inquiry depicts the personnel SA resources, in terms of the individuals or units within the maintenance technical operations, that are needed to meet the maintenance team's SA requirements. (Figure 11-4, appendix) shows the units and individuals that the A&P technician interfaces with. Lines show communication patterns among and between units. In addition the importance and frequency of each interaction is depicted in (Figure 11-5, appendix).

Problems and barriers for situation awareness at the team level were also identified in the analysis. These include: parts availability and status information; tooling and out-sourcing; tracking of parts and getting parts to the aircraft; instability of the organization; personality conflicts; lack of teamwork and information sharing; shiftwork and fatigue; organizational downsizing; computer system used for tracking parts and materials; workcards and changing procedures; poor housekeeping and maintenance of tools.

DISCUSSION

Overall, the applicability of the concept and importance of situation awareness in maintenance teams has been supported by the preliminary data. Teams of technicians are supported by many other personnel and organizational units to achieve their goals, each of which has a major impact on the attainment of maintenance goals. In the maintenance environment it is necessary to examine how information flows between and among team members in order to identify system and personnel factors that will impact on the degree to which team members are able to develop and maintain an accurate picture of an aircraft's status. This knowledge appears to be crucial to the technicians' ability to perform tasks (as each task is interdependent on other tasks being performed by other team members), their ability to make correct assessments (e.g. whether a detected problem should be fixed now or deferred to later (placarded)), and their ability to correctly project into the future to make good decisions (e.g. time required to perform task, availability of parts, etc.). Five specific recommendations have been identified for training concepts to improve situation awareness. These include:

- Shared mental models
- Verbalization of decisions
- Better shift meetings and teamwork
- Feedback
- Individual SA training.

Each of these concepts will be discussed along with ongoing implementation and evaluation efforts.

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APPENDIX

Figure 11-1: Team SA Context Analysis Methodology

Figure 11-2: A&P Technician Goals

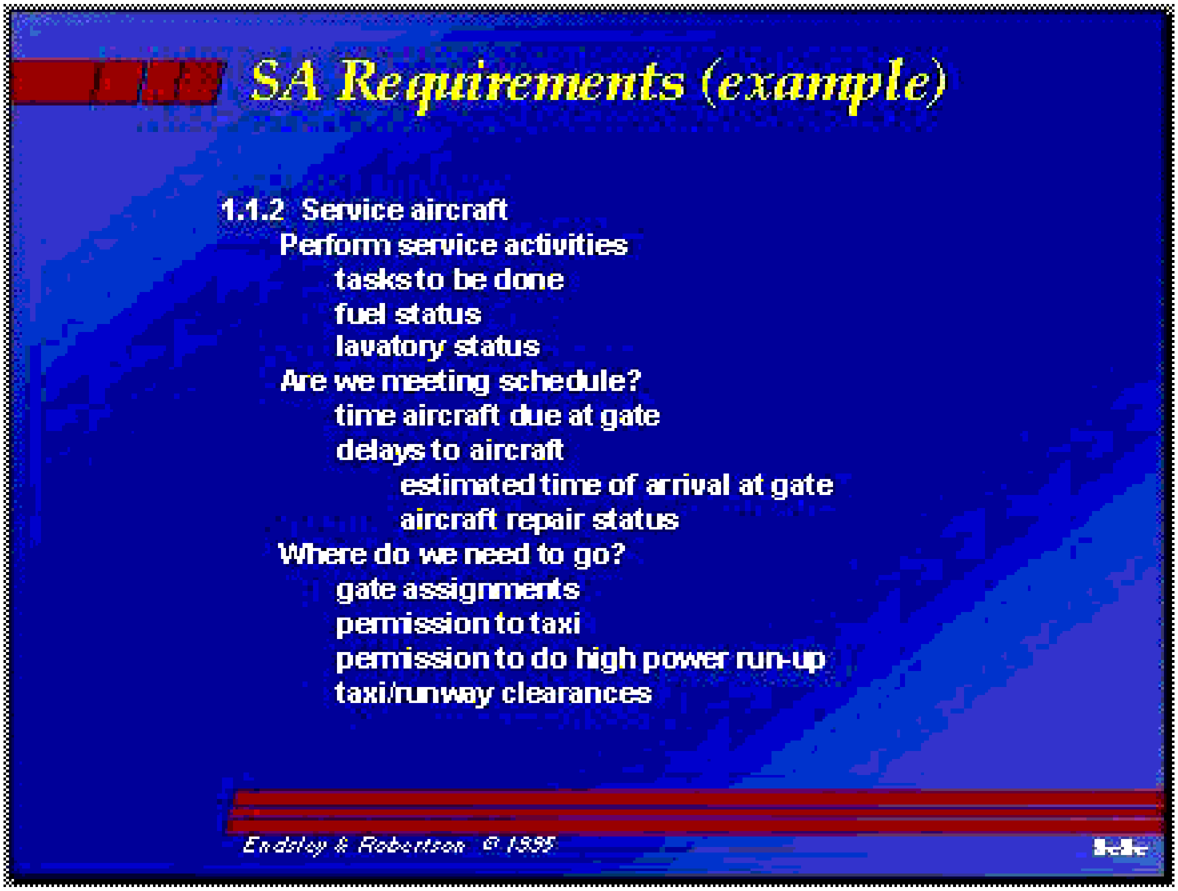

Figure 11-3: SA Requirements - example

1.1.1 Make repairs

Part availability

- correct part supplied?
  - manufacturer's part number
  - aircraft type, model, tail number
  - maintenance and equipment list (M&E) number
  - effectivity number
- how long to get part here?
  - in-stock status
    - manufacturer's part number

- aircraft type, model, tail number
- maintenance and equipment list (M&E) number
- effectivity number

- part & tooling availability
  - where
  - when it will be here
  - delivered or pick-up
  - arrival flight number
  - arrival gate number

Placard problem

- can problem be placarded?
  - type of problem
  - Minimum Equipment List (MEL) status
    - Deferred information placard (DIP)
    - Open item list (OIL)
  - redundant systems available
  - control number
  - log page number
  - flight number

- employee number

Figure 11-4: SA Resources - A&P Technicians Communication Patterns

Figure 11-5: SA Resources - Importance and Frequency