The Effect of Shift Turnover Strategy and Time Pressure on Aviation Maintenance Technician Performance

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THE EFFECT OF SHIFT TURNOVER STRATEGY AND TIME PRESSURE ON AVIATION MAINTENANCE TECHNICIAN PERFORMANCE

by

William R. Warren
B.S., Embry-Riddle Aeronautical University, 2008

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THE EFFECT OF SHIFT TURNOVER STRATEGY AND TIME PRESSURE ON AVIATION MAINTENANCE TECHNICIAN PERFORMANCE

By: William R. Warren

This thesis was prepared under the direction of the candidate’s thesis committee chair, Dr. Elizabeth Blickensderfer, Ph.D., Department of Human Factors & Systems, and has been approved by members of the thesis committee. It was submitted to the Department of Human Factors & Systems and has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Human Factors & Systems.

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Abstract

Aviation maintenance technicians (AMTs) provide the technical and applied knowledge required to maintain airworthiness in aircraft. In commercial aviation, maintenance tasks are performed across multiple shifts. When AMTs share a maintenance task between shifts, the shift turnover strategy used may determine if information is effectively transferred between AMTs. Ineffective shift turnover strategies are a contributing factor in many aviation accidents and incidents. Additionally, time constraints on certain maintenance tasks may cause AMTs to commit error when performing a task. The present study examined the effect of shift turnover strategy (face-to-face or written) and time pressure on error capture, accuracy, and completion time of a maintenance task that was shared between two shifts. Forty AMT students completed an unfinished maintenance task while subjected to conditions of shift turnover strategy and time pressure. Three dependent variables, the number of skill-based errors, the number of trigger event errors, and task completion time measured AMT performance. Results indicate that the face-to-face shift turnover strategy was significantly more effective in preventing trigger event errors than the written strategy. Additionally, AMTs under time pressure completed the task significantly faster than AMTs not under time pressure. Therefore, the current study partially supports the argument to require face-to-face shift turnover strategies in aviation maintenance. Thus, the use of the face-to-face strategy may increase AMTs understanding of the task, as suggested in the literature.
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**Introduction**

Aviation maintenance is one of many critical systems in air transportation. This system relies on a number of assets to effectively maintain aircraft. Perhaps the most important asset to this system is the Aviation Maintenance Technician (AMT). AMTs provide the technical and applied knowledge required to maintain airworthiness in aircraft. However, their ability to do so requires constant and effective communication with each other, especially between shifts. A critical point in aviation maintenance where effective communication is required is during a shift change. Consequently, the method of communication between different shifts is often influenced by the organizational culture of the company.

Concurrently, increased demand for flight-ready aircraft is reducing the time an AMT is allocated to complete repairs. In some situations, time constraints may cause the AMT to commit error when performing a task. The accident case of Alaska Airlines Flight 261 exemplifies these situations.

On the afternoon of January 31, 2000, while in route to San Francisco International Airport, Alaska Airlines Flight 261 crashed into the Pacific Ocean about three miles off the coast of California. All persons onboard suffered fatal injuries. The primary cause of the accident was a mechanical failure of the jackscrew trim system, which controlled pitch for the aircraft via a horizontal stabilizer (see Figure 1). The retaining nut of the jackscrew sheared off in-flight, causing the aircraft to pitch violently in a nose-down attitude, subsequently leading to loss of aircraft control.

An investigation by the National Transportation Safety Board (NTSB) found that an extension of the scheduled maintenance interval of this particular jackscrew allowed Alaska Airlines to continue to operate the aircraft well beyond the recommended maintenance interval. Additionally, the NTSB recognized the organizational culture at Alaska Airlines as “inadequate”.
More specifically, the use of “pencil-whipping” was prevalent in many of the company’s aircraft inspections (National Transportation Safety Board, 2003). In fact, an Alaska Airlines aircraft maintenance inspector found that the jackscrew was out of specifications and deemed the aircraft unairworthy, until replacement of the jackscrew. He documented this statement on the aircraft maintenance work order form and left for the day. The next shift supervisor did not agree with the decision and because of time pressure to return the aircraft to service, crossed out the previous inspector’s instructions and signed-off the aircraft as airworthy. The failure of communication between the two shifts involved is perhaps the most disturbing causal factor of this accident.

![Diagram of aircraft stabilizer system]

Figure 1. The jackscrew is a 2-foot-long, 1-1/2-inch-diameter threaded shaft that moves up and down, raising and lowering the leading edge of the stabilizer, the wing structure on the tail that controls the plane's angle of flight.

The previous tragedy identifies two distinct problems in aviation maintenance operations, “shift turnover communication” and “time pressure”. As seen in this particular accident, a lack of face-to-face communication between work shifts may have resulted in the release of an unairworthy aircraft. The problem of communication during shift turnovers lies within the organizational practices of each aviation maintenance company. If Alaska Airlines had utilized
properly structured, face-to-face, shift turnover briefings, the outgoing inspector may have verbally stressed the dire importance of replacing the jackscrew to the incoming shift, which may have prevented this accident. Moreover, the rapid pace of commercial aviation induces time pressures, as the industry itself relies upon constant availability of airworthy aircraft. With the addition of time pressure, the incoming shift, in a rush to abide with schedule demands, made a critical error by not discussing the reported issue with the outgoing shift before releasing the aircraft.

The present study aimed to determine the effect of shift turnover strategy (face-to-face communication or written communication) and time pressure on error capture, accuracy, and completion time of a maintenance task that was shared between two shifts. The following literature review presents discussion on shift turnover related accidents in high-risk organizations, the aviation maintenance industry, shift turnover practices in the aviation maintenance, and if shared mental model theory may improve cohesion between shift workers.

**Shift turnover accident examples**

Similar to aviation maintenance, many other high-risk industries rely upon 24-hour operations. To accomplish tasks across multiple shifts, workers must communicate important information regarding the tasks during a shift change. When proper communication does not occur, dire consequences follow, as documented by the following cases.

**The Sellafield Beach incident.** In November 1983, workers at British Nuclear Fuels Limited’s Sellafield Works accidentally discharged highly radioactive liquid waste into the sea. An investigation found that, due to a failure of communication between shifts, a tank, which was assumed to contain a liquid suitable for discharge to the sea, in fact, contained highly radioactive material that created an environmental hazard. This incident occurred during a plant shutdown for routine annual maintenance. As workers transferred a written description of the tank contents
from one shift log to the next across several consecutive shifts, the written description of the tank contents changed from “ejections from HASW” to “ex HASW washout.” As a result, what had originally been interpreted as highly radioactive material was later interpreted as being low-level runoff suitable for discharge into the sea. In this incident, the contents of the tank were described in terms of their origin rather than their nature. Liquid waste, in this instance, is either categorized as highly active, medium active, or low level runoff. Failure to accurately describe the tank's contents, coupled with transcription errors made as written logbook contents were copied from page to page, led to a misunderstanding (Miles, 1998).

**The Piper Alpha disaster.** In 1988, 167 workers were fatally injured when an offshore oil platform in the North Sea exploded and subsequently burned. Failure of critical information transfer was a significant cause to this disaster. Specifically, the outgoing shift did not notify the incoming shift of the inoperative condition of a commonly used valve. Lack of this knowledge led to the incoming shift turning the valve, which initiated the disaster (Parke and Kanki, 2008). Investigators concluded that no written procedures for shift handover existed. Additionally, there was no pre-determined analysis or categorization of important items to include in the handover (Miles, 1998).

**Continental Express flight 2547.** In 1991, Continental Express Flight 2574 crashed in a cornfield in Texas, killing all 14 onboard. The NTSB determined that an outgoing maintenance shift failed to communicate to an incoming shift the importance of replacing the missing fasteners for the de-ice boot on the horizontal stabilizer. Subsequently, the upper leading edge of the aircrafts horizontal stabilizer ripped off during flight, causing the pilots to lose control (National Transportation Safety Board, 1992).

The previous accidents exemplify the consequences of improper communication between shifts. To understand why errors in shift turnover communication in an aviation maintenance
environment are prevalent, it is vital to understand the individuals involved, how they are trained and, the aviation maintenance industry.

**The aviation maintenance system**

The aviation maintenance system is complex and requires the collective effort of many professionals to transport thousands of people everyday safely. The AMT is the key player in this system.

**Aviation maintenance technicians.** Aviation Maintenance Technicians perform the necessary repairs and inspections to maintain airworthiness on all certificated aircraft. Title 14, Part 65 of the Code of Federal Regulations outlines AMT activities. Specifically, Part 65.81 provides a brief explanation of aircraft mechanics' rights and responsibilities. It states that, "A certificated mechanic may perform or supervise the maintenance, preventive maintenance or alteration of an aircraft or appliance, or a part thereof, for which he is rated (but excluding major repairs to, and major alterations of, propellers, and any repair to, or alteration of, instruments), and may perform additional duties in accordance with sub-sections 65.85, 65.87, and 65.95‖ (Federal Aviation Administration, 2010a). The latter sub-sections briefly describe the requirements for an AMT to perform 100-hour inspections on an airframe or powerplant. Though these governing rights and responsibilities ensure that only certain people may perform the duties of an AMT, they only provide general guidelines and do not fully explain the rigorous detail that AMTs apply to ensure airworthiness.

**Professionalism in aviation maintenance.** Unlike other maintenance professions (e.g., automobile mechanic), AMTs are trained to be meticulous in every aspect. Using the automobile mechanic as a comparison, differences in professionalism become evident. First, an AMTs work will affect thousands of people in future flights. This means that every task they perform must be done so with the highest level of accuracy. AMTs maintain this high-level of accuracy by
following written procedures, as well as having their work double-checked by an inspector. Conversely, automobile mechanics are not required to follow written procedures, nor have their work inspected by a second person. An automobile mechanic's work may only affect a few people, and in most cases, a malfunctioning vehicle can simply pull over. Second, AMTs must possess a greater level of professionalism than automobile mechanics, combining such characteristics as competence, control and commitment to safety (Taylor & Thomas, 2003). A simple comparison of a car mechanic's toolbox and an AMT's toolbox demonstrates the level of commitment to safety. The automobile Mechanics toolbox is unorganized, with tools strung about, whereas an AMT's tools lie neatly placed in order. Commonly referred to as a "shadowed box", each drawer of an AMT's toolbox has shaped holes that fit the exact tool that lies there. This ensures that no tools are accidently left onboard an aircraft. The AMT simply checks his toolbox for missing tools, before the aircraft is released for flight. Thirdly, for an AMT to perform maintenance on a certificated aircraft, he must possess a certificate issued by the Federal Aviation Administration (FAA), whereas car mechanics require no certification to work on automobiles.  

Training for aviation maintenance. Aviation maintenance is a highly specialized field of work, which requires numerous hours of schooling compared to other maintenance programs. An AMT must accrue approximately 1900 contact hours of training to be eligible for testing, whereas an auto mechanic must only posses two years of unstructured hands-on experience to be eligible for ASE testing (Federal Aviation Administration, 2010c; National Institute for Automotive Service Excellence, 2009). Aviation maintenance schools must retain certification from the FAA and must teach a specific list of topics. These topics are split into three categories or ratings: Powerplant, Airframe, and General. Both the Powerplant and the Airframe categories

\footnote{Thankfully, most reputable auto. mechanics possess certification from institutions such as the National Institute for Automotive Service Excellence (NIASE, 2009).}
cover the technical knowledge required to service these aviation systems. The General category, on the other hand, consists of basic math and English proficiency, common repair procedures, regulations and requirements, and most importantly, written documentation. The written documentation portion of the General rating ensures AMTs are able to read procedural items such as maintenance manuals, airworthiness directives, work cards, as well as, effectively document repairs or alterations performed on an aircraft in a record or database (Federal Aviation Administration, 2009). The General rating does not include any training on interpersonal communication (Taylor & Christensen, 1998). Other communication training may occur, but only at the discretion of individual AMT instructors.

**Written documentation/”work cards”**. Written documentation plays a significant role in the successful operation of aviation maintenance. AMTs rely on written documents to provide instructions on maintenance tasks as well as to ensure compliance with regulations. There are numerous types of documents used in aviation maintenance. The FAA provides regulatory documents, such as FARs and airworthiness directives, while aircraft manufacturers provide maintenance manuals, work cards, and service bulletins. AMTs use work cards to show the progress of a task. The use of work cards attempts to eliminate any chance for error by providing step-by-step instructions for maintenance tasks. By checking-off each step of a task, an AMT can document his progression through a task.

**Aviation maintenance industry**. Aviation maintenance operates on a time-based schedule to keep airworthy aircraft available for thousands of daily flights. A delay in flight schedules can cost thousands of dollars and possibly the choice of customers to purchase future flights with that airline. This constant need to keep aircraft in a ready-to-fly state translates down to a necessity for an effective organizational structure and, ultimately, to effective job performance of AMTs.
Aviation maintenance is performed in many different environments, but the most familiar (in commercial aviation) include Line Maintenance Operations (LMOs) and hanger maintenance. AMTs that work in LMOs are often in view of the flying public and are part of the ramp crew (i.e., the crew that services the aircraft at the gate). These AMTs work to solve issues (i.e., light maintenance) during the time the aircraft is cycling between passengers. LMO mechanics are some of the most experienced technicians and therefore must be able to diagnose and repair problems rapidly. It is rare that a maintenance task is not completed before a shift change occurs in LMOs, as their tasks usually take less than one hour to complete. However, LMO mechanics have their share of time constraints, as the aircraft they service are typically in between flights. A maintenance task deemed beyond the capabilities of the LMO mechanics is moved to a maintenance hangar.

The majority of aircraft maintenance in commercial aviation is performed in maintenance hangars, which are usually located just off the tarmac. Maintenance performed in a hanger environment is deemed medium to heavy maintenance. Medium maintenance tasks vary in time depending on the problem item. For example, tire changes require a few hours, while, multipoint inspections require several hours. Heavy maintenance tasks range in complexity and require several hours or in some cases up to several days to complete. The AMT’s that work in medium to heavy maintenance are subjected to time pressures, as each maintenance task is allotted a certain time frame and must be completed in order to meet schedule demands. Although aircraft maintenance is carried out in many environments, this paper will focus on hanger maintenance, as many maintenance tasks in this environment are performed across multiple shifts.

**Shift work in aviation maintenance**

Most medium to heavy maintenance is a 24-hour operation and therefore occurs over multiple shifts. The likelihood that more than one shift will work on a single aircraft is high; at
times as many as 12 to 15 shifts work on a single aircraft (Parke & Kanki, 2008). Multiple shifts imply that each shift is comprised of different AMTs. Some tasks require multiple people to complete a task, while other tasks only require a single person. If, for instance, a group of AMTs is performing a multipoint inspection on an aircraft and their shift ends, another group of AMTs takes over the inspections. Regardless of how many AMTs there are on a team, it is generally the sole responsibility of the AMT working on a particular aircraft or component to brief the next shift of the critical information necessary to maintain a smooth transition. This exchange of information is often informal, speedy, and requires not only interpersonal trust, but also the ability to communicate information concisely and completely.

According to the FAA, shift turnovers are one of the critical phases of aviation maintenance and must be performed correctly (Federal Aviation Administration, 2005). Unfortunately, current Federal Aviation Regulations (FARs) do not directly address specific shift turnover practices in aviation maintenance and therefore the procedure in which they occur varies across maintenance organizations (Maddox, 1998). In fact, FAR Part 121.369 only requires an organization's maintenance manual to contain, "Procedures to ensure that required inspections, other maintenance, preventative maintenance, and alterations that are not completed as a result of shift changes or similar work interruptions are properly completed before the aircraft is released to service" (Federal Aviation Administration, 2010b). Essentially, this regulation only requires aviation maintenance organizations to complete any maintenance task they begin, yet does not require, or outline a structured shift turnover briefing. An ideal aviation maintenance shift change includes (a) time for the outgoing person to prepare, (b) a shift handover, where outgoing and incoming persons exchange information that is relevant to the task that must be finished, and (c) "cross-checking" the outgoing persons' briefing, while enabling the incoming person to ask questions about the task (Miles, 1998).
Shift turnovers in aviation maintenance generally occur in two ways. There are written shift turnovers, where the shift-lead acts as a liaison between shifts, passing information from the previous shift to the incoming shift and there are face-to-face shift turnovers, where the outgoing shift communicates directly with the incoming shift. These two types of information exchanges are also referred to as synchronous and asynchronous, respectively (Drury & Ma, 2003).

**Written shift turnover.** In a written shift turnover, little or no face-to-face communication occurs between the outgoing and incoming shifts. Instead, a step-by-step progression of the task is documented in writing on a work card. If an AMT’s shift ends before he can complete a task, the general practice is to sign his name next to the last step he completed on the work card. The AMT then hands over the written documentation to the shift lead and leaves for the day. The shift lead then passes the written documentation from the outgoing AMT to the incoming AMT. The incoming AMT then proceeds from the last step signed-off by the outgoing AMT to complete the task. Though this may seem like a sound method of information transfer, there may be errors with the outgoing AMT's work. Therefore, the incoming AMT must decide between two methods of completing the work: either trust the outgoing AMT’s work and quickly finish all remaining tasks, or spend additional time checking over the outgoing AMT’s work before continuing with the task. A check over the outgoing AMT’s work likely results in an increase in task completion time, thereby increasing the effect of time pressure, which may cause the AMT to make errors. It is important to note that if the task is not completed in the allotted amount of time, the aircraft will not be released until the task is complete. However, as time pressure increases, the AMT may speed through the task to make the deadline, possibly making critical errors, such as installing incorrect hardware.

**Face-to-face shift turnover.** In a face-to-face shift turnover, the outgoing AMT discusses the task directly with the incoming AMT. By stopping his work early, the outgoing
AMT is able to gather all pertinent information related to the task for the incoming AMT. This information includes what items have been completed in the task, what items remain, any changes that have occurred to the procedure (i.e., airworthiness directives), as well as any concerns about the task. A shift turnover briefing then occurs, where the outgoing and incoming AMTs can directly discuss the task. Having an opportunity to ask the outgoing AMT questions about the task, as well as crosscheck the outgoing AMTs work, the incoming AMT may have a higher probability in safely completing the task in the allotted amount of time.

**Research on shift turnovers in aviation maintenance.** Currently, the use of written shift turnover reports is the predominant method of shift change in aviation maintenance, especially across multiple shifts (Parke & Kanki, 2008). The prevalence of written shift turnovers in aviation maintenance organizations is likely because no FAA standardized shift turnover process exists. Unfortunately, the indirect strategy may be ineffective. According to Parke and Kanki (2008), vague and brief shift turnovers are a leading cause to the dispatch of unairworthy aircraft. Parke and Kanki (2008) analyzed 46 Aviation Safety Reporting System (ASRS)\(^2\) reports that pertain to shift turnover communication issues. They found that, when compared to non-turnover-communication-related reports, errors in part installation occurred much more frequently (50% vs. 27%) and of these installation instances, 96% carried a label of critical equipment installation versus 74% in non-turnover-communication-related incidents reports. Additionally, they found that incidents that were deemed “serious” such as, in-flight shut down and injury, occurred twice as often in reports involving shift turnover, than those that did not. They found that the highest contributing factor in errors during a shift turnover were workcards, accounting for nearly half (46%). This suggested the critical role that workcards play during a turnover and that increasing the completeness and accuracy of workcards would result

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\(^2\) ASRS reports are submitted on a voluntary basis and therefore do not fully represent the total amount of incidents that occur.
in a reduction of issues in shift turnover communication (Parke & Kanki, 2008). Interestingly though, briefings were reported as a much lower contributing factor to errors (15%). The researchers suggested that fewer errors may occur when verbal briefings are used during shift turnovers, but also may indicate that verbal briefings seldom occur (Parke & Kanki, 2008). All maintenance organizations utilize some form of written communication to document what maintenance activities occur.

For example, discrepancies may exist in the written documentation and an alteration to the procedure of one of the tasks is necessary. When a shift change occurs, the outgoing AMT may not provide a written explanation for the alteration of the procedure. Without face-to-face communication between the incoming and outgoing AMT, the misinterpretation of the alteration can led to the incoming AMT making errors. The incoming AMT may not share the same understanding or mental model of the maintenance task, aircraft configuration, or work cards. Additionally, the incoming AMT may have been away from work for an extended period and may not be aware of procedural changes, in which interpreting any written communication even more challenging. Experience levels may also differ across shifts and an AMT may make assumptions about their knowledge that may not be true of other technicians (International Civil Aviation Organization, 2003) which, again, interpretation of written remarks may prove difficult.

**Unsafe acts.** A lack of shift turnover communication in aviation maintenance may increase the likelihood of unsafe acts. Hobbs and Williamson (2002) developed a 48-item survey that asked AMTs a series of questions regarding the occurrence of unsafe acts in the aviation maintenance domain. The survey items contained specific language and technical detail appropriate to unsafe acts that occur in aviation maintenance. A total of 1,359 of 4,600 AMTs, licensed by the Civil Aviation Safety Authority, completed and returned the survey. AMTs rated each item using a 5-point Likert scale (1 = ‘Never’, 5 = ‘Very often’). The highest reported
unsafe acts include, “Not referred to the maintenance manual or other approved documentation on a familiar job \( (M = 3.18) \)” and “Been misled by confusing documentation \( (M = 2.84) \)”. The latter occurs when the AMT is confused by a previous shift's written communication. This may indicate that often there are no face-to-face briefings between shifts and because the opportunity to ask questions did not exist, an unsafe act occurred (Hobbs and Williamson, 2002).

**AMTs’ opinions on shift turnover briefings.** Organizations that have developed their own standardized shift turnover process show increased levels of trust and professionalism amongst their AMTs. Taylor and Thomas (2003) surveyed 3,150 AMTs across five aviation maintenance companies using the Maintenance Resource Management Technical Operations Questionnaire. The survey was comprised of 34 items that measure attitudes and opinions related to aviation maintenance functions. Participants were asked to express their agreement or disagreement to a series of statements. Results indicated a high level of trust and professionalism amongst team members. Particularly, when asked their opinions of the statements “Debriefing after major task is important” and “Start of shift meetings are important”, AMTs responded with agreement, across all but one company (Taylor and Thomas, 2003).

**Group discussions.** Group discussions can also improve shift turnover communication by allowing members to capture problems and discuss intent, rather than reading written documentation of what occurred in previous shifts. Parke and Mishkin (2005) demonstrated this notion by observing the evolution of shift turnovers in an interplanetary robotic control program. By analyzing errors made by a previous robotic rover control program, they gained insight on how to improve the next mission. The program implemented “best practices,” including a shift turnover meeting, in which operators discussed past issues as well as future pathing or direction of travel of the robot. All operators from both outgoing and incoming shifts, as well as managers, attended the shift turnover meetings. The program involved three shifts that
controlled a robotic rover on Mars. The accuracy and attention to detail required to maneuver a robot on Mars necessitates a need for effective shift turnover communication. Any errors can have dire future consequences, due to the delay of time from controller input to robot maneuver. An improvement in reduction of errors, as well as an increase in efficiency in robot operation was attained by implementing the shift turnover meetings. Additionally, Parke and Mishkin (2005) developed and proposed a generalized checklist that outlines the typical communicative items that occur during a shift change, which was derived from shift turnover literature.

**Coordination.** Coordination during a shift turnover may decrease the likelihood of errors. Suzuki, von Thaden, and Geibel (2008) analyzed 680 ASRS reports, ranging from August 2004 to July 2006, pertaining to FAR Part 121 scheduled airline operations to identify contributing factors in aviation maintenance related incidents. A combination of a qualitative analysis and categories from the Human Factors Analysis and Classification System (Wiegmann & Shappell, 2003) were applied to the narrative reports. Subject matter experts classified communication and coordination issues, and then divided the reports into nine categories. Errors related to “lack of vigilance” occurred the most times (n = 421), while “coordination” errors occurred in 17% (n = 115) of the reports. Not surprisingly, errors related to “time pressure” had the third highest occurrence (n = 146). AMT’s reported not paying attention when they missed a task or not being aware of the task entirely. It was also suggested that because AMTs also reported a high level of multi-tasking, their attention level was reduced in order to cope with multiple tasks under time pressure. Most significantly, time pressures showed a positive association with decision-making errors, whereas routine violations showed a negative relationship to time pressures. Though shift turnover communication errors were not directly investigated, the results of this study cite coordination and communication in aviation maintenance operations as critical in preventing errors. A proper shift turnover may increase
coordination and communication in aviation maintenance teams (Suzuki, von Thaden, and Geibel, 2008).

**Maintenance Resource Management**

Literature on Maintenance Resource Management (MRM) provides further precedence for the need of improved communication in shift turnovers. The FAA describes MRM as a "process for improving communication, effectiveness, and safety in aircraft maintenance operations" (FAA, 2000, p. 6) which addresses "teamwork deficiencies within the aviation maintenance environment" (p. 6). As mentioned previously, written communication is dominant in the aviation maintenance environment. This notion is generally true for all the players involved, including management, inspectors, parts clerks, tool clerks, and even FAA inspectors. The only exception is if the organization has received training that specifically deals with interpersonal and intrapersonal communication, such as the more popular MRM programs that are spreading throughout the industry. MRM programs have shown success in improving communication amongst aviation maintenance personnel.

**Development of MRM.** Derived from the more popular Crew Resource Management (CRM), MRM aims to reduce errors in the aviation maintenance environment through the understanding of human factors. The first reported CRM program geared towards AMTs began in late 1989. The need for MRM became apparent after the Aloha Airlines accident on April 28, 1988, where the overall focus of blame shifted from the individual to the entire operational system. Additionally, it revealed issues such as human performance limitations, teamwork, communication, organizational culture, and training (Patankar & Taylor, 2008). Currently in its fourth generation, MRM has demonstrated a pattern of changing interest in the focus of organizational variables and longitudinal stability of post-training attitude and behavior changes (Taylor & Patankar, 2001).
**First Generation MRM.** As described by Taylor and Patankar (2001), the first generation of MRM training primarily focused on communication skills and awareness between AMTs. Successful training was measured through individual attitude changes, rates of injuries and aircraft ground damage. However, lack of continued organizational support hindered ongoing success of first generation MRM training. Taylor and Patankar report that many first generation programs were either discontinued or forgotten following management or strategic changes.

**Second Generation MRM.** Second generation programs primarily focused on direct communication (i.e., focus groups with AMTs) rather than impersonal classroom training. The program was successful in reducing paperwork and logbook errors. However, Taylor and Patankar note that second generation programs had the tendency to highlight prior issues rather than proactively teaching the avoidance of key factors before they become issues.

**Third Generation MRM.** Third generation MRM programs focused on situational awareness and coping mechanisms, individual issues that affect safety, and encouraged organizational change, while directly targeting management and FAA inspectors (Taylor and Patankar, 2001). These programs also helped to identify twelve major causes of maintenance errors, commonly named the "Dirty Dozen" (see Table 1); as of 2001, this list is included in all reported MRM programs implemented in North America since 1994 (Taylor and Patankar, 2001; FAA, 2005).
Table 1

*The "Dirty Dozen"

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1</td>
<td>Lack of Communication</td>
</tr>
<tr>
<td>2</td>
<td>Complacency</td>
</tr>
<tr>
<td>3</td>
<td>Lack of Knowledge</td>
</tr>
<tr>
<td>4</td>
<td>Distraction</td>
</tr>
<tr>
<td>5</td>
<td>Lack of Teamwork</td>
</tr>
<tr>
<td>6</td>
<td>Fatigue</td>
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<tr>
<td>7</td>
<td>Lack of Resources</td>
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<tr>
<td>8</td>
<td>Pressure</td>
</tr>
<tr>
<td>9</td>
<td>Lack of Assertiveness</td>
</tr>
<tr>
<td>10</td>
<td>Stress</td>
</tr>
<tr>
<td>11</td>
<td>Lack of Awareness</td>
</tr>
<tr>
<td>12</td>
<td>“Destructive” Workplace Norms</td>
</tr>
</tbody>
</table>

Research on third generation training revealed a new concern. Taylor & Christensen (1998) found that initial post-training reports showed AMTs showed enthusiasm and positive feelings towards MRM training. However, after several months, Taylor reports that AMTs showed frustration and anger with MRM training. When asked why, the AMTs reported a lack of managerial and organizational support for implementing training information and an uncertainty if the training had been successful for the organization. Taylor concluded that the MRM training implemented at this specific company did not match the organizations leadership practices or environmental factors of the facility. These findings encouraged MRM to evolve, once again, ensuring that the context of training fit the organizational and environmental factors.

**Fourth Generation MRM.** The fourth (current) generation of MRM training programs has attempted to correct the weaknesses of previous generations by incorporating systems theory, actively identifying errors before they occur, while focusing on the individual behavior approach of the third generation to promote a structured communications process (Taylor and Patankar, 2001). The current generation is interested in measuring AMT attitudes not only on safety-
related issues (such as whether AMTs feel their work impacts passenger safety), but also on organizational context issues such as leadership and environmental factors.

To further stress the importance of MRM training, the FAA issued an Advisory Circular (AC120-72) that provides guidelines in developing MRM programs (FAA, 2000). Advisory Circulars are documents sent to all aviation organizations and are regarded as important recommendations from the FAA. Essentially, this document provides the information and guidelines for an organization to design and implement an MRM training program. The introduction and growth of MRM programs have made a positive contribution to improving safety in aviation maintenance. Although MRM programs are currently “recommended”, they may become a requirement in the future. Additionally, the issue of shift turnover communication is also growing equally in popularity and priority.

**Recent initiatives in improving shift turnover communication**

In 1998, the FAA published “The Operator’s Manual for Human Factors in Aviation Maintenance” with the intention of providing maintenance organizations guidelines for implementing human factors training. Chapter 4 of this manual outlines eight challenges related to shift turnovers as the following:

1. high demand for teamwork and interpersonal communication skills, 
2. need for structured and standardized policies and procedures, 
3. need for a location that is conducive for discussion and planning, 
4. ineffective verbal and written communication, 
5. finishing workers are tired and want to depart facility, 
6. lack of adequate shift overlap to provide time for one-on-one briefings between the team leaving and the team coming on, 
7. absence of a process to ensure departing personnel have documented all tasks accomplished or started, 
8. minimal training on procedures for shift/task turnover (FAA, 2005).
Similar challenges with shift turnovers in aviation maintenance are discussed in chapter 7 of the “Guidance Material on the UK CAA Interpretation of Part-145 Human Factors and Error Management Requirements” (Civil Aviation Authority, 2003). This document cites three basic elements that must occur for a successful shift turnover: "1) the outgoing person’s ability to understand and communicate the important elements of the job or task being passed over to the incoming person. 2) the incoming person’s ability to understand and assimilate the information being provided by the outgoing person. 3) a formalized process for exchanging information between outgoing and incoming persons and a place and time for such exchanges to take place". The NTSB issued a similar document (A-04-15, 16) that recommends implementing human factors training in aviation maintenance (NTSB, 2006). All of these documents cite shift turnover communication as one of many problem areas that require immediate attention.

The suggestions made by the regulatory bodies cumulate the necessity for a shared understanding or a “shared mental model” between two shift workers. Essentially, the steps they suggest for successful information exchange mirrors how researchers describe shared mental model theory (Mathieu, Rapp, Maynard, & Mangos, 2010).

**Shared Mental Model Theory**

A mental model is comprised of organized knowledge structures that enable individuals to interact with their environment (Mathieu et al., 2010). People use mental models to predict and explain environmental changes, to identify and recall the way certain parts of the environment are grouped together, and to construct expectations for future events (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). For instance, when an AMT encounters an aircraft part he has inspected many times in the past, he draws from the knowledge and experience of that part. The theory of "shared mental models" extends the mental model concept to the team. That is, a shared mental model refers to 2 or more teammates having a mutual
understanding of the task, their respective roles and responsibilities, procedures, and timing (Blickensderfer, Reynolds, Salas & Cannon-Bowers, 2010). This mutual understanding allows teammates to work efficiently together, without high levels of communication (Blickensderfer, et al., 2010).

According to Stout, Cannon-Bowers, and Salas (1996), preexisting shared mental models will not be important in situations where team members are allowed to freely communicate with each other when sharing a task, for example, AMTs working together on the same shift. In this situation, the team has the ability to discuss the next moves, without relying on preexisting knowledge to complete a task. On the other hand, in situations where communication is limited, such as one technician on one shift and his teammate on the next shift, shared mental models are crucial to team functioning, as they allow the members to predict the information and resource requirements of their teammates (Mathieu et al., 2000).

Consider an aviation maintenance task, where a shift change occurs mid-task. In the course of working on the part, “Technician 1” has acquired information particular to that repair. He now has an understanding of the particular situation, the implications of the job, and any details specific to that case/job. Thus, he now has a full, detailed mental model of the job. It is essential for this understanding to be passed to the next worker (“Technician 2”), and that Technician 1 and Technician 2 have a shared mental model of what needs to be done and details specific to the job. Exchanging written documentation alone may not provide all information needed for workers on different shifts to acquire a shared mental model of the task. If the inspection of the part is performed across two work shifts, both AMTs may need to communicate, face-to-face, in order to attain a shared mental model.

**Implications of face-to-face communication in shift turnovers.** A number of arguments exist that support a positive outcome with the inclusion of face-to-face
communication in shift turnovers. Face-to-face communication occurs when two or more people communicate verbally about a subject. The value of this form of communication lies within the additional knowledge attained by either party. Open discussions allow each person to fully grasp the idea being discussed. Conversely, written communication may leave gaps, as the reader leaves what is written to interpretation. The reader may contact the writer to ask questions, but in cases of shift changes, the writer may not be available for clarification.

Parke and Kanki (2008) suggest that adding face-to-face communication in shift turnovers helps teams to achieve a shared mental model by conveying gestures, eye contact, tones of voice, degrees of confidence, and other rich aspects of personal communication (Knapp, 1995). More importantly, all aspects of the task can be discussed in detail. Direct face-to-face communication adds redundancy to written documentation used during a shift turnover by enabling the incoming AMT to ask questions, while allowing the outgoing AMT to provide feedback (Parke & Kanki, 2008). Researchers agree that written communication alone is not as powerful in effective information transfer as a combination of written and face-to-face communication during a shift turnover (Coiera & Tombs, 1998; Suzuki, von Thaden, & Geibel, 2008; Majoros, 2008; Parke & Kanki, 2008).

Another issue in shared mental model generation is with differing experience levels between shifts. In this sense, the task is familiar to the outgoing technician, but not the incoming technician. When a person reads information, for instance a workcard, they may interpret and process that information differently than someone else. Their understanding of the task, certain terminology, tools, and procedures is pulled from their long-term memory store and is combined with immediate environmental stimuli to formulate a mental model of the task (International Civil Aviation Organization, 2003; Federal Aviation Administration, 2005). When two shift technicians discuss the task face-to-face, the inexperienced technician can learn from the
experienced technician, where, if the inexperienced technician just read the workcard, he may not understand the task completely.

Face-to-face communication may better allow both shifts to share ideas, recall past experiences, and make accurate predictions of what may occur when performing the task. Body gestures, facial expressions, and tone of voice help to focus attention to details (Parke & Mishkin, 2005). For example, the inspectors involved in the Alaska Airlines accident did not communicate face-to-face. Though the outgoing inspector requested in writing that the jackscrew be replaced, the incoming inspector disregarded the written instructions and released the aircraft. If these two inspectors had participated in a face-to-face shift turnover, the incoming inspector may have made a different decision because of his perception of the danger involved in not replacing the jackscrew, as shown by the facial expressions and tone of voice of the outgoing inspector. Even with the addition of face-to-face communication and improved shared mental models to shift turnovers, the AMT is still subjected to time pressure when completing the task left by the previous shift, and time pressure may have additional implications for task performance.

**Time pressure.** In an effort to reduce costs and maximize profits, commercial aviation companies are streamlining their operational processes. To remain competitive, companies are decreasing turnaround time for aircraft repairs. This decrease in turnaround time leads to an increase of time pressure placed on the technicians performing the repairs. When time pressures increase, the chance of committing errors may also increase. Even with the appropriate documentation (e.g., maintenance manuals, work cards), AMT’s continue to make mistakes on repairs when subjected to time pressure. Suzuki, Von Thaden, & Geibel (2008) found that time pressure (n = 145, 27.5%) was the second major contributing factor found in 680 ASRS incident reports related to maintenance error. The most significant contributing factor was lack of
vigilance (n = 418, 79.3%). AMT’s reported not paying attention when they missed a task or not being aware of the task entirely. It was also suggested that because AMTs also reported a high level of multi-tasking, their attention level was reduced in order to cope with multiple tasks under time pressure. Most significantly, time pressures showed a positive association with decision-making errors, whereas routine violations showed a negative relationship to time pressures. However, it can be speculated that an AMT who has an elevated understanding of the task may be more resistant to time pressure, where if he did not interact with the previous shift, the pressure of completing the task on time may cause slips and unsafe acts.

AMTs must retain and use a certain amount of domain specific rules to effectively make repairs (acquired in training). These rules vary from knowledge of tool usage to specific rivet patterns on a wing repair. AMTs then use these specific rules, combined with the written procedures to repair aircraft. However, when AMTs are subjected to time pressures, these rules become ever more important, as they must be able to recall and implement the rules without hesitation. In a study on emergency decision making while under time pressure, Lin and Su (1998) found that time pressure had a destructive effect on the performance of rule-based reasoning. Additionally, people under time pressure suffered a significant decrease in accuracy when implementing the domain rules compared to those who were not subjected to time pressure (Lin and Su, 1998).

The way people cope with time pressure varies dependent on the situation and task knowledge. Chu and Spires (2001) suggest that people cope with time pressure using three strategies. The first coping mechanism, a process termed acceleration, occurs when people may try to process the same amount of information, but at a faster rate. The second coping mechanism, termed filtration, occurs when people process only a subset of available information, usually the most important information. The third coping mechanism, termed process changes,
occurs when people change or modify their decision processes. These process changes vary from a moderate change (switching from a compensatory process to a non-compensatory process) to an extreme change (avoidance or escaping from the task). Additionally, filtration and acceleration may be combined in some situations, where the person focuses on a portion of the total available information and processes it faster (Chu & Spires, 2001).

The way people make decisions while performing complex tasks may be dependent on the level of time pressure induced and their experience with the task. In a study of decision making in dynamic environments, Gonzalez (2004) found that performance during a complex task degraded in people under severe time pressure than those who had more time for reflective decision making in the same complex task. Those people under severe time pressure had three times more practice sessions than those in the less stringent time pressure group. Gonzalez suggested that performing a task several times, under severe time pressure, results in poorer overall performance in future incidents of the same task. Where, performing a task, under low time pressure, results in better performance when the task is encountered in the future (Gonzalez, 2004).

**Summary of literature review**

Incorrect information transfer between shift workers is a causal factor in accidents and incidents in complex systems. The complexity of the aviation maintenance system requires its technicians to have a high-level of professionalism and training. Concurrently, technicians are placed under time pressures to keep pace with a constant demand system. A critical element in aviation maintenance is information exchange, and this is particularly tricky during shift changes. Inadequate communication between shifts has led to costly errors in aviation maintenance as well as other high-risk industries. Problems identified in the literature point to documentation comprehension, misunderstandings of a previous shifts work, and loss of
attention. Currently, technicians primarily use written documents when transferring information between shifts. Written documents alone, however, may not provide other unique rich qualities one would receive in a face-to-face conversation. The evolution of MRM has helped in recognizing the issue of improper shift turnovers. Its contribution has provided insight on the capabilities of AMTs, as well as identified the major issues in aviation maintenance communication. The success of MRM programs paved the way for more detailed research in specific issue areas, such as shift turnover communication.

The addition of face-to-face to written information provides redundancy to shift turnovers, by allowing both shifts to actively interact and possibly develop a shared mental model of the task being handed over. A face-to-face shift change may help AMTs to ensure critical information is understood and successfully transferred to the next shift.

Statement of Problem

Based upon the above literature review, written shift turnover practices may not be suitable for complete transfer of information between shifts. Therefore, the present study aimed to determine the effect of shift turnover strategy (face-to-face or written) and time pressure on error capture, accuracy, and completion time of a maintenance task that was shared between two shifts.

Statement of hypotheses

This research attempted to distinguish which type of shift turnover is best suited for aviation maintenance in time-sensitive situations. It was expected that the turnover strategy would affect AMT performance, specifically;

H1a: AMTs subjected to a written shift turnover would make more errors on a maintenance task than AMTs who received a face-to-face briefing.
H1b: AMTs who received a written shift turnover would take longer to perform a maintenance task than AMTs who receive a face-to-face shift briefing.

Additionally, it was expected that time pressure would influence maintenance task performance, specifically;

H2: AMTs who were subjected to time pressure would make more errors than AMTs who were given ample time to complete a maintenance task.

Finally, it was expected that the type of shift turnover would moderate the effect of time pressure on performance, such that;

H3: AMTs who received a face-to-face shift turnover would be less impacted by time pressure than AMTs who received a written shift turnover.
Method

Participants

A sample of 40 students ($M = 25.2$ years) enrolled in the Aviation Maintenance Science program at Embry-Riddle Aeronautical University participated in the study. This sample was selected due to the specialties and criticalities required to accurately represent the population of aviation maintenance technicians. Males (87%) represented the majority of the sample and females represented only 13%. The researcher recruited participants by directly addressing AMT classes. All Participants in the study completed the "Regulations, Documentation and Drawing" course before participating. This course (AMS 118) specifically includes privileges and limitations of FAR Parts 43, 65, and 91 pertinent to aircraft maintenance and the associated documents, publications, and records applicable to the AMT. This requirement ensured that participants had enough knowledge in maintenance documentation to provide consistency when reading all related written materials associated with the task. A brief assessment, administered during participant introduction, verified that participants understood the importance of Airworthiness Directives, what purpose workcards serve, as well as the effective use of a digital multi-meter and torque wrench. All participants indicated a proficiency in reading and writing the English language.

Materials

Demographics form. Participants completed a demographics form (see appendix A) that asked their gender, age, English proficiency, if they have completed the AMS 118 course or equivalent, which mechanic ratings they held, as well as their knowledge of torque wrenches, digital multi-meters, and basic hand tools.

Consent form. Participants completed and signed a written consent form to acknowledge their participation in the study (see appendix B). The consent form described the
purpose of the study, the expected duration of participation, benefits and risks to the participant, confidentiality, and the voluntary nature of the study.

**Written documentation packet.** All participants received the same "written documentation packet" which included a work card, an airworthiness directive, and pertinent sections from a maintenance manual (see Appendix C). The work card contained step-by-step instructions to complete the maintenance task. Each step includes a space where the technician must place their initials after it is completed. The airworthiness directive constituted a required inspection of a specific section of the alternator. The FAA issues airworthiness directives when certain safety issues dictate a change in the performance of a part or inspection method. AMTs must comply with airworthiness directives or face severe punishment. The pertinent pages from the maintenance manual contain detailed step-by-step instructions on how to disassemble, inspect, repair, and reassemble the alternator. The researcher designed these documents exclusively for this study.

**Tool pack.** Each participant received a standardized “tool pack” that included the following tools: pencil and paper, standard size socket set with ratchet, inch-pound torque wrench, and digital multi-meter. All participants completed a preliminary evaluation with the inch-pound torque wrench and digital multi meter before entering the study.

**Work area.** Participants completed the maintenance task in an isolated room. The room contained enough space for the participant to efficiently work on the alternator, as well as provided a suitable environment for a shift turnover to occur.

**Experimental task.** The maintenance task consisted of a Delco-Remy Model K5 alternator. The researcher disassembled, cleaned, inspected, and reassembled the alternator prior to use in the experiment. Because there was no available written maintenance manual for this particular alternator, the researcher developed a unique set of maintenance manual pages based
on other models of alternators. For convenience, the researcher removed the springs that retained pressure for each brush from the alternator. At the beginning of each participant trial, the researcher disassembled the alternator to a predetermined state to simulate the work performed by the previous shift. To complete the maintenance task, the participant inspected and reassembled the alternator. The common parts of a typical alternator are presented in figure 2 to aid the reader.

![Common parts of a typical alternator](image)

**Figure 2.** Common parts of a typical alternator.

**Trigger event errors.** The experimental task included three trigger events for participants to capture and correct. The trigger events represented common occurrences in aviation incidents and accidents that involved shift turnovers, as depicted in the literature (see Parke and Kanki, 2008).

**Documentation event.** The maintenance documentation purposely did not include the importance of the alignment marks between the case and body of the alternator. Instead, the step on the workcard only read, “Install case onto body*”. The asterisk pointed to important information that would normally be located on the corresponding step in the maintenance manual. However, the maintenance manual pages provided no mention of the case alignment.
The case and the body pieces make up the frame of the alternator and alignment of these components is necessary for proper alternator operation. The researcher placed a mark on both the case and body, approximately ¼ inches long for alignment purposes. For participants in the face-to-face condition, the previous shift actor mentioned the lack of notation of the alignment marks in the maintenance manual. However, for those participants in the written condition, only good judgment provided the means to capture the alignment marks. A successful error capture occurred when the participant correctly aligned the case and body.

Existing installation event. An incorrectly installed part (diode) by the researcher simulated an installation error performed by the previous shift. A diagram provided a visual reference of the correctly installed diode. A successful error capture occurred when participants correctly identified the incorrectly installed diode and either voiced concerned to the manager or corrected the error and documented it on the workcard.

Procedural event. An airworthiness directive (AD) described a change to the torque value of the four case bolts (from 25 to 28-inch pounds), simulating a change in procedure. A successful error capture occurred when the participant complied with the AD by applying the correct torque to the case bolts and most importantly, documenting compliance of the AD on the workcard.

Design

This study followed a 2 x 2 between subjects, fully factorial design. The first independent variable was time pressure and had two levels. In the first level, time pressure was present, where participants completed a maintenance task within a time limit (20 minutes). In the second level, time pressure was absent, which allowed participants to complete the task without any intervention, unless they exceeded a 35-minute time constraint for study purposes.
The second independent variable was shift turnover strategy and had two levels. In the first level, written documentation was the primary means of information transfer. In the second level, both written and face-to-face communication was exchanged.

**Independent variables**

**Written.** The purpose of the written level of the independent variable was to simulate a shift turnover that only involved written literature left behind from the previous shift technician, which is the standard practice in aviation maintenance organizations. It was comprised of select maintenance manual pages, a workcard, and an airworthiness directive, all of which make up the “written documentation packet” (see Appendix C). The workcard was designed to be used as a step-by-step reference; however, a truly accurate understanding of the experimental task is achieved when the workcard was used in conjunction with the maintenance manual pages and the airworthiness directive. Participants solely relied on the information contained in the “written documentation packet” to complete the experimental task.

**Face-to-face.** The purpose of this level of the independent variable was to simulate a shift turnover that involved a face-to-face briefing with the previous shift technician. It served as a means for adding redundancy to the maintenance literature, while providing an opportunity for the participant to develop a complete understanding of the overall task. Particulars discussed included, what steps of the task the previous shift technician had completed and which step to complete next, any abnormalities in the maintenance literature. Additionally, the briefing provided the participant with an opportunity to ask questions about the task. To provide a consistent briefing, the shift change actor, following a script, described the overall task as well as, what, why, and how they performed each step. The actor also specifically mentioned three trigger events in a manner that encouraged the participant to investigate the errors. The
participants in this condition also received all of the written information that the "written" group received.

**Time pressure.** The purpose of this independent variable was to simulate a situation where completion of the experimental task required a short time frame. In commercial aviation organizations, a constant pressure to retain aircraft in a “flight ready” status is prevalent. This time pressure may adversely affect the AMT, causing slips in maintenance tasks. Participants were subjected either to time pressure (20 minutes) or to no time pressure. In the time pressure conditions, the manager actor, following a script, reminded participants of the due back time periodically as they completed the experimental task (i.e., 15, 10, 5, and 2 minutes remaining). Participants exceeding the 35-minute study time constraint were stopped and evaluated by the researcher in a manner to which the participant would explain any remaining steps to be completed.

**Dependent variables**

Three distinct variables measured participant performance: task completion time, number of skill-based errors, and number of three trigger events errors. The manager actor used a stopwatch to measure total time of task completion. This period started once the participant began working on the task and then stopped when they reported to the manager. The researcher evaluated the number of skill-based errors using a task evaluation sheet (see Appendix D). Skill-based errors occurred when the participant did not read and/or not adhere to the maintenance manual (e.g., assembling alternator parts incorrectly). The researcher measured three distinct trigger events using the task evaluation sheet. An airworthiness directive simulated a trigger event that represented a change in task procedure; a missing reference in the maintenance manual simulated a trigger event that represented a documentation error; and finally, an incorrectly installed part simulated a trigger event that represented a previous technician installation error.
Table 2 provides a brief description of each task, the possible number of errors, the type of error associated, and measurement procedure. Evaluation of errors took place after the participant left the experiment.
Table 2

*List of tasks and type of measurement used for each task.*

<table>
<thead>
<tr>
<th>Task</th>
<th>Number of Possible Errors</th>
<th>Evaluation</th>
</tr>
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<tbody>
<tr>
<td>Check position of diode</td>
<td>1</td>
<td>Did participant recognize previous shift installation error and place diode in correct position? Yes or No?</td>
</tr>
<tr>
<td>Install stator onto body [30 inch/lbs]</td>
<td>3</td>
<td>Did participant check the torque value of three nuts @ 30 inch/lbs? Torque value of nuts within ± 1 inch/lb?</td>
</tr>
<tr>
<td>Assemble case to body</td>
<td>1</td>
<td>Did participant align the case and body correctly, using the alignment marks? Yes or No?</td>
</tr>
<tr>
<td>Secure case to body [35 inch/lbs]</td>
<td>4</td>
<td>Did participant check the torque value of four bolts @ 35 inch/lbs (per AD-37748)? Torque value of bolts within ± 1 inch/lb?</td>
</tr>
<tr>
<td>Attach fan and spacer to shaft</td>
<td>2</td>
<td>Did participant install the spacer and fan correctly? Yes or No?</td>
</tr>
<tr>
<td>Attach pulley, lock washer, and nut to shaft</td>
<td>3</td>
<td>Did participant install the parts in the correct order? Yes or No?</td>
</tr>
<tr>
<td>Total Errors</td>
<td>12</td>
<td>3</td>
</tr>
</tbody>
</table>

**Manipulation check.** Participants completed a reaction survey that presented statements about their perception of the shift turnover effectiveness, their perception of time pressure, and their thought of crosschecking a previous shift technicians work (see Appendix E). Participants rated the statements using a 5-point Likert scale (i.e., 1- strongly agree, 5-strongly disagree).
Procedure

Experimental task setup. Before the beginning of each run of a participant, the experimenter used a checklist to ensure the proper set up of the alternator. The researcher setup the participant briefing area, which included a consent form, a demographics form, a maintenance survey, a task evaluation sheet, and the participant introduction script. The researcher briefed the manager and shift turnover actor on the conditions of the day, and provided the appropriate scripts. The researcher placed the alternator and the tools in the work area in a disassembled state. Specifically, the disassembled alternator replicated the previous shifts completion of steps 1-7 on the workcard. Figure 3 provides a photographic representation of the work area as presented to participants.

Figure 3. Layout of alternator and tools on work area.
**Participant Briefing.** Participants received one of four conditions: written with time pressure, face-to-face, written, or face-to-face with time pressure. Each participant read and signed a consent form. The researcher answered any questions about the consent form before proceeding. Participants then filled out a demographics form. Following the introduction script, the researcher briefed participants about the study dependent on the condition assigned to them (see Participant Introduction, Appendix F). After the briefing concluded, participants met the manager, who assigned them to a condition. The manager then read a script pertaining to the condition. The four conditions follow.

**Written with time pressure.** Participants in this condition received no verbal communication from the outgoing shift. Instead, they received a task assignment and the written documentation packet from the manager. The manager instructed participants to complete the task in 20 minutes. The manager provided no support to participants once he left the work area and returned to the manager’s desk. The condition simulated a busy working environment, as the particular task used in this study required no additional help from others once the participant began the task. The manager started a stopwatch as he left to return to the manager’s desk. The manager walked back to the work area and reminded the participant of the due back time at four separate intervals: 15, 10, 5, and 2 minutes remaining, respectively, with an increase in demanding vocal tone for each reminder (see Managers Script, Appendix F). The manager stopped the stopwatch when participants indicated a completion of the task. The manager documented total time of task completion for each participant. The manager actor received training on projecting himself as a managerial figure.

**Face-to-face with time pressure.** Participants in this condition received instructions from the manager to relieve an outgoing shift (shift turnover actor) from the task. The shift turnover actor provided participants with the written documentation packet, and a thorough
briefing of the task. Additionally, the shift turnover actor provided answers to any questions posed by participants about the task (see Shift Turnover Actors Script, Appendix F). Once the briefing concluded, the actor notified participants of a due back time of 20 minutes. The manager started a stopwatch when the shift turnover actor returned to the manager’s desk. The manager reminded participants of the due back time at four separate intervals: 15, 10, 5, and 2 minutes remaining, respectively, with an increase in demanding vocal tone for each reminder. The manager provided no support to participants.

The shift turnover actor served as a subject matter expert in aviation maintenance and shift briefings. The actor received training on how to communicate aspects related to the task assertively and accurately. The shift turnover actor’s script followed the “checklist for effective shift handovers”, developed by Parke and Mishkin (2005) from shift change literature. The checklist reveals a method of efficient and thorough communication that should occur during a shift turnover. The checklist ensured that participants received an efficient and thorough shift turnover.

Written. Participants in this condition received no verbal communication from the outgoing shift. Instead, the manager gave participants the written documentation packet, and then instructed them to complete the task. The manager provided no support to participants.

Face-to-face. Participants in this condition received instructions from the manager to relieve an outgoing shift (shift turnover actor) from the task. The shift turnover actor provided participants with the written documentation packet, and a thorough briefing of the task. Additionally, the shift turnover actor provided answers to any questions posed by participants about the task. The manager provided no support to participants.

Once finished with the task, the manager guided participants to the researcher’s desk. Each participant filled out a reaction survey. The researcher provided a debriefing (see appendix
G) and dismissed participants from the area. Table 3 represents a structural breakdown of the procedure.

Table 3

Average times of each phase of study for time pressure conditions in minutes.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Written</td>
</tr>
<tr>
<td>Participant introduction</td>
<td>5</td>
</tr>
<tr>
<td>Participant reads and signs out consent form</td>
<td>3</td>
</tr>
<tr>
<td>Participant fills out Demographics form</td>
<td>1</td>
</tr>
<tr>
<td>Participant receives shift turnover</td>
<td>5</td>
</tr>
<tr>
<td>Participant completes maintenance task</td>
<td>25</td>
</tr>
<tr>
<td>Participant fills out survey</td>
<td>3</td>
</tr>
<tr>
<td>Participant receives debriefing and leaves</td>
<td>3</td>
</tr>
<tr>
<td>Researcher inspects alternator for errors</td>
<td>12</td>
</tr>
<tr>
<td>Researcher “resets” alternator for next participant</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total Duration</strong></td>
<td><strong>56</strong></td>
</tr>
</tbody>
</table>

Note: Participants in conditions without time pressure were allocated an additional 15 minutes to complete the maintenance task.

Data collection

*Error check.* The researcher inspected the assembled alternator following the “Task Evaluation Sheet”. This sheet describes what errors the researcher must look for in the inspection. The researcher documented the total number of skill-based errors and trigger event errors.

*Task Completion Time.* The manager actor documented total task duration using a stopwatch. Task time began when either the manager or shift turnover actor assigned the participant the task. Task time ended when the participant indicated they were finished with the task.
**Results**

The purpose of this study was to determine the effect of shift turnover strategy (face-to-face or written) and time pressure on error capture, accuracy, and completion time of a maintenance task that was shared between two shifts. It was hypothesized that AMTs subjected to a written shift turnover strategy would make more errors and would require more time to complete a maintenance task than AMTs who received a face-to-face shift turnover strategy. Additionally, it was hypothesized that AMTs under time pressure would make more errors than AMTs not under time pressure. Finally, it was hypothesized that the type of shift turnover strategy would moderate the effect of time pressure on performance, such that; AMTs who received a face-to-face shift turnover strategy would be less impacted by time pressure than AMTs who received a written shift turnover strategy.

Results from three dependent measures evaluated AMT performance. The first dependent measure examined the number of skill-based errors made on the maintenance task, such as incorrect torque values for bolts or incorrect placement of parts. The second dependent measure examined the AMTs ability to recognize three trigger events, specifically, compliance with an airworthiness directive, alignment marks on the alternator, and an incorrectly installed part by the previous shift\(^3\). The third dependent measure examined the amount of time participants needed to complete the maintenance task. Finally, for verification of manipulation strength, a reaction survey provided perceptions of the shift turnover strategy and time pressure. Table 4 lists inter-item correlations for all dependent measures and reaction survey composite variables.

---

\(^3\) This trigger event provided little variability, as the majority of participants did not recognize the installation error, thereby warranting exclusion from analysis.
Table 4

_Correlations for Dependent Measures and Reaction Survey Composite Variables_

<table>
<thead>
<tr>
<th>Dependent Measure</th>
<th>Trigger Event Errors</th>
<th>Skill Based Errors</th>
<th>Task Completion Time (minutes)</th>
<th>Shift Turnover Perception</th>
<th>Time Pressure Perception</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger Event Errors</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skill Based Errors</td>
<td>.011</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task Completion Time</td>
<td>.068</td>
<td>.166</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shift Turnover</td>
<td>-0.072</td>
<td>-0.055</td>
<td>-0.314*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Perception Time Pressure</td>
<td>0.266</td>
<td>-0.291</td>
<td>-0.267</td>
<td>0.106</td>
<td>1</td>
</tr>
</tbody>
</table>

* Denotes significance at the .05 level (two-tailed)

To accommodate the two independent variables and three dependent measures, a two-way multivariate analysis of variance (MANOVA) was used for this study. A Box’s M test was not significant, $F(18, 4579.73) = 1.23, p = .224$, indicating the assumption of homogeneity of covariance was not violated. The following sub-sections present the results based upon hypotheses.

**Main Effects**

_Shift turnover strategy._ Hypothesis 1 was comprised of two parts, the first of which concerned the effect of shift turnover strategy on error rate in a shared maintenance task (H1a) and the second of which concerned the effect of shift turnover strategy on task completion time (H1b). The multivariate test showed a significant main effect for shift turnover strategy on performance, Hotelling’s Trace, $F(3, 34) = 4.49, p = .009$, partial $\eta^2 = .284$, observed power = .840. According to partial eta$^2$, shift turnover strategy accounted for 28% of variance in the combined dependent variables. Univariate tests provided the specific effect of shift turnover strategy on each dependent measure (see Table 5).
Table 5

*Univariate F-test results for effect of shift turnover strategy on dependent measures.*

<table>
<thead>
<tr>
<th>Dependent Measure</th>
<th>$F$</th>
<th>$p$</th>
<th>Partial $\eta^2$</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger Event Errors</td>
<td>9.28</td>
<td>.004</td>
<td>.205</td>
<td>.843</td>
</tr>
<tr>
<td>Skill-based Errors</td>
<td>2.92</td>
<td>.096</td>
<td>.075</td>
<td>.383</td>
</tr>
<tr>
<td>Task Completion Time</td>
<td>2.27</td>
<td>.141</td>
<td>.059</td>
<td>.311</td>
</tr>
</tbody>
</table>

Specifically, AMTs who received a written turnover strategy made significantly more trigger event errors ($M = 1.4$, $SD = 0.82$) than AMTs who received a face-to-face turnover strategy ($M = 0.70$, $SD = 0.66$), as the univariate test revealed, $F(1, 36) = 9.28; p = .004$, partial $\eta^2 = .205$, observed power = .843. Shift turnover strategy accounted for 20.5% of the variance in trigger event errors. AMTs who received a written turnover strategy made more skill-based errors ($M = 1.10$, $SD = 1.17$) than AMTs who received a face-to-face turnover strategy ($M = 0.55$, $SD = 0.83$), however, this difference was not statistically significant with the univariate test, $F(1, 36) = 2.92; p = .096$, partial $\eta^2 = .075$, observed power = .383. These results partially support hypothesis H1a, in that AMTs who received a written turnover made more trigger event errors than AMTs who received a face-to-face turnover, but no significant difference appeared between the groups on skill-based errors.

With respect to task completion time (H1b), AMTs who received a written turnover required more time to complete the maintenance task ($M = 24.76$ minutes, $SD = 8.49$) than AMTs who received a face-to-face turnover ($M = 21.38$ minutes, $SD = 7.18$). However, the univariate test found these means did not differ significantly, $F(1, 36) = 2.27; p = .141$, partial $\eta^2 = .059$, observed power = .31. These results do not support hypothesis H1b, which stated that
AMTs subjected to a written shift turnover would take longer to perform a maintenance task than AMTs who received a face-to-face turnover.

**Time pressure.** Hypothesis 2 predicted an effect of time pressure on error rate. The multivariate test showed a significant main effect for the presence of time pressure, Hotelling’s Trace, $F(3, 34) = 4.99, p = .006$, partial $\eta^2 = .306$, observed power = .880. Next, univariate tests provided the specific effect of time pressure on each dependent measure (see Table 6).

Table 6

**Univariate F-test results for effect of time pressure on the dependent measures.**

<table>
<thead>
<tr>
<th>Dependent Measure</th>
<th>$F$</th>
<th>$p$</th>
<th>Partial $\eta^2$</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger Event Errors</td>
<td>3.03</td>
<td>.090</td>
<td>.078</td>
<td>.396</td>
</tr>
<tr>
<td>Skill-based Errors</td>
<td>1.18</td>
<td>.284</td>
<td>.032</td>
<td>.185</td>
</tr>
<tr>
<td>Task Completion Time</td>
<td>10.48</td>
<td>.003</td>
<td>.225</td>
<td>.883</td>
</tr>
</tbody>
</table>

Although AMTs who were subjected to time pressure made less skill-based errors ($M = 0.65, SD = 0.93$) than AMTs not under time pressure ($M = 1.00, SD = 1.12$), the univariate test indicated that these means did not differ significantly, $F(1, 36) = 1.18; p = .284$, partial $\eta^2 = .032$, observed power = .185. Similarly, while AMTs subjected to time pressure made more trigger event errors ($M = 1.25, SD = 0.85$) than AMTs not under time pressure ($M = 0.85, SD = .75$), the subsequent univariate test indicated that time pressure did not have a significant effect on trigger event errors, $F(1, 36) = 3.03; p = .090$, partial $\eta^2 = .078$, observed power = .396. In contrast, AMTs under time pressure completed the maintenance task significantly faster ($M = 19.44$ minutes, $SD = 6.23$) than AMTs not under time pressure ($M = 26.70$ minutes, $SD = 7.94$), $F(1, 36) = 10.48; p = .003$, partial $\eta^2 = .225$, observed power = .883. Thus, time pressure accounted for 22.5% of the variance in task completion time. These results do not support the hypothesis.
that AMTs subjected to time pressure would make more errors than AMTs who were given ample time to complete a maintenance task.

**Interaction Effect**

Hypothesis 3 predicted that turnover strategy would moderate the effect of time pressure on performance. The multivariate test showed no significant interaction effect, Wilks’ Lambda, $F(3, 34) = .465, p = .709$, partial $\eta^2 = .039$, observed power = .134. While, AMTs who received a face-to-face turnover performed better across all dependent measures than AMTs who received a written turnover (see table 7), no comparisons yielded a significant difference between groups. Therefore, the hypothesis that AMTs who received a face-to-face turnover would be less impacted by time pressure than AMTs who received a written shift turnover was not statistically supported. Figures 4, 5, and 6 show the skill-based errors, trigger event errors, and task completion time for all study conditions.
Table 7

*Means and Standard Deviations of Interactions by Dependent Measures.*

<table>
<thead>
<tr>
<th>Dependent Measure</th>
<th>Turnover Strategy</th>
<th>Time Pressure Condition</th>
<th>$M$</th>
<th>$SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill-based Errors</td>
<td>Written</td>
<td>Present</td>
<td>1.00</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absent</td>
<td>1.20</td>
<td>1.23</td>
</tr>
<tr>
<td></td>
<td>Face-to-face</td>
<td>Present</td>
<td>0.30</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absent</td>
<td>0.80</td>
<td>1.03</td>
</tr>
<tr>
<td>Trigger Event Errors</td>
<td>Written</td>
<td>Present</td>
<td>1.70</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absent</td>
<td>1.10</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>Face-to-face</td>
<td>Present</td>
<td>0.80</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absent</td>
<td>0.60</td>
<td>0.52</td>
</tr>
<tr>
<td>Task Completion Time</td>
<td>Written</td>
<td>Present</td>
<td>20.58</td>
<td>7.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absent</td>
<td>28.95</td>
<td>7.65</td>
</tr>
<tr>
<td></td>
<td>Face-to-face</td>
<td>Present</td>
<td>18.31</td>
<td>4.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absent</td>
<td>24.46</td>
<td>7.98</td>
</tr>
</tbody>
</table>
Figure 4. Mean Skill-based Errors by Shift Turnover Strategy and Time Pressure.

Figure 5. Mean Trigger Event Errors by Shift Turnover Strategy and Time Pressure.
Figure 6. Mean Task Completion Time by Shift Turnover Strategy and Time Pressure.

Reaction Survey

The reaction survey included ten statements. Four statements measured the perception of effectiveness of the shift turnover, four statements measured the perception of time pressure during the task, and one statement measured the perception of trust of in the previous shift. Participants rated their agreement of the statements using a 5-point scale (1 – strongly disagree, 2 – disagree, 3 – neutral, 4 – agree, 5 – strongly agree). All participants completed the survey immediately after finishing the maintenance task. A Pearson’s product-moment correlation coefficient was computed to assess the relationship between the statements. Table 8 lists all statements and their respective correlations.
## Table 8

**Summary of Inter-item Correlations for Reaction Survey Statements**

<table>
<thead>
<tr>
<th>Statement</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>.590**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>.703**</td>
<td>.399*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>-0.019</td>
<td>-1.189</td>
<td>-0.019</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>.805**</td>
<td>.591**</td>
<td>.593**</td>
<td>-0.040</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.356*</td>
<td>.652**</td>
<td>.213</td>
<td>-0.245</td>
<td>.340*</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.347*</td>
<td>.228</td>
<td>.252</td>
<td>.051</td>
<td>.378*</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.337*</td>
<td>-0.309</td>
<td>-0.317*</td>
<td>.396*</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.095</td>
<td>.142</td>
<td>.098</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.013</td>
<td>-0.061</td>
</tr>
</tbody>
</table>

**.** Denotes significance at the 0.05 level (2-tailed).

1. I had a good understanding of how to inspect and reassemble the alternator correctly.
2. The previous shift technician provided a clear picture of what work had been done to the alternator.
3. All information required to complete the task was in the documentation.
4. I felt pressured to finish the alternator task quickly.
5. I fully understood each and every step of the task.
6. I am confident that the previous shift technician completed every step correctly.
7. I always look-over someone else's work before I sign-off on a task.
8. I had plenty of time to finish the alternator task.
9. I was aware the alternator had a "due back time" and I tried to finish the task quickly.
10. I was in a hurry to finish the alternator task.

With respect to the effectiveness of the shift turnover, statements 1, 2, 5, and 6 fit well together (Cronbach’s alpha = .83), which resulted in the formation of a composite variable that represented whether participants felt the shift turnover they received was effective in transferring information related to completion of the task. With respect to the effectiveness of time pressure, statements 4, 8, and 10 fit well together (Cronbach’s alpha = .73), which resulted in the formation of a composite variable that represented whether participants felt pressured to finish the task quickly. Statements 3, 7, and 9 did not fit well with any other statements and were not...
included in analysis. Tables 9 and 10 summarize the means and standard deviations of shift turnover perception and perception of time pressure, respectively.

Table 9

*Means and Standard Deviations for Perception Shift Turnover Effectiveness*

<table>
<thead>
<tr>
<th>Turnover Strategy</th>
<th>Perception of Shift Turnover Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written</td>
<td>3.14 (0.86)</td>
</tr>
<tr>
<td>Face-to-face</td>
<td>4.03 (0.82)</td>
</tr>
</tbody>
</table>

Table 10

*Means and Standard Deviations for Perception of Time Pressure*

<table>
<thead>
<tr>
<th>Time Pressure condition</th>
<th>Perception of Time Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>3.56 (0.56)</td>
</tr>
<tr>
<td>Absent</td>
<td>2.70 (0.58)</td>
</tr>
</tbody>
</table>

An Independent samples t-test determined any significant difference in responses for both shift turnover and time pressure conditions. When asked about shift turnover perception, those who received a written shift turnover felt the turnover was significantly less effective ($M = 3.14$, $SD = .86$) than those who received a face-to-face shift turnover ($M = 4.03$, $SD = .82$), $t(38) = -3.34$, $p < .05$. When asked if participants felt the need to complete the task quickly, those who were under time pressure felt significantly more pressured to complete the task quickly ($M = 3.56$, $SD = .56$) than those who received no time pressure ($M = 2.7$, $SD = .58$), $t(38) = 4.82$, $p < .05$. 
Discussion

The purpose of this study was to determine if shift turnover strategy and time pressure affect AMT performance on a maintenance task shared between shifts. Many issues affect AMTs, however, situations that combine both time pressure and communication between shift technicians may have led to accidents such as Alaska Airlines Flight 261. Though past research has proposed a possible relationship between shift turnover strategy and errors (Maddox, 1998; Miles, 1998; Parke & Kanki, 2008, etc.), the majority of available data is based on self-reported incidents. Research does indicate that people under time pressure are more likely to make more errors when performing a task then people given ample time (Lin & Su, 1998; Chu & Spires, 2001). Some results from the current study provide empirical support to the argument for the need of face-to-face shift turnovers in aviation maintenance, especially when different shifts share a maintenance task. The following sections provide interpretation of the results.

Effect of Shift Turnover Strategy

To examine an effect of shift turnover strategy, the current study used two shift turnover strategies. The first, a written shift turnover strategy, simulated a situation where the outgoing shift technician generated a shift turnover report (work card) for the incoming shift technician to complete an unfinished maintenance task. The second, a face-to-face shift turnover strategy, simulated a situation where the outgoing shift technician verbally briefed the incoming shift technician about an unfinished maintenance task. In the current study, AMTs given the written shift turnover strategy made significantly more trigger event errors than AMTs given the face-to-face shift turnover strategy. These results were expected, as during the face-to-face turnover, the outgoing shift informed AMTs about the airworthiness directive and case alignment marks (trigger events) during the verbal briefing. In contrast, the written documentation packet provided no information about the alignment marks, but included the airworthiness directive.
AMTs who received a written turnover strategy had to recognize both trigger events by their own investigation. A great effort is made by publishers of maintenance literature to include any critical information (e.g. alignment marks) in documentation. However, inconsistent quality and lack of standardization across publishers of maintenance literature is prevalent (see Chaparro, Groff, Chaparro, & Scarlet, 2002) and therefore this reality was replicated in this study by excluding any statement of the alignment marks. These results indicate that how task specific knowledge is shared via, in this study, a face-to-face turnover, can make a significant difference in the interpretation and use of that knowledge. The face-to-face strategy allowed the incoming technician to pose questions about the task, communicate concerns, gain perspective on the task, and acquire critical information that may have otherwise been assumed knowledge. The results partially support the hypothesis that AMTs given a written turnover strategy would make more errors than AMTs given a face-to-face shift turnover strategy.

Regarding skill-based errors, no significant difference existed between the two groups. The experimental task and the performance measures may be the reason why the predicted effect did not occur. Specifically, the design of the maintenance task included 12 possible points to make skill-based errors. These errors consisted of AMTs not applying the correct torque to bolts and AMTs not installing components of the alternator correctly. Two limitations guided the selection of the 12 possible errors. The first limitation was the length of the time to complete data collection. The researcher designed the task to allow a completion time limit of 35 minutes for each participant. This limitation allowed data collection to occur within a reasonable time frame for a thesis project. Therefore, the researcher designed the task to exclude lengthy procedures found in actual aircraft maintenance, such as safety wiring. In a real-world setting, maintenance tasks are much more complex and may require many hours to complete.
The second limitation was mechanical experience level of participants. In order to recruit a sizable sample of participants for the current study, recruitment was targeted to students who had finished the General portion of AMT training. These students met the requirement of completing a course on maintenance documentation and aviation law. However, they were not required to have the knowledge and skill as a fully licensed aircraft mechanic. Therefore, the researcher designed the maintenance task with just enough difficulty for a novice mechanic to understand.

Ultimately, the simplification of the task resulted in a ceiling effect on scores. AMTs in both turnover strategies made a low number of skill-based errors. The means show a small improvement in performance for AMTs that received the face-to-face strategy compared to AMTs that received the written strategy. Perhaps if a greater length of time was allocated to accommodate a more complex task, a significant difference in skill-based errors may have appeared between shift strategies. Further research is recommended to determine if shift turnover strategy will have a significant effect on skill-based errors.

It was hypothesized that AMTs given the written strategy would take longer to complete the task than AMTs given the face-to-face turnover strategy. Shift turnover strategy had no significant effect on task completion time. AMTs in both turnover strategies took about the same amount of time to complete the task. This result may also be attributed to the simplicity of the task described previously. Additionally, the manner in which the information was presented in the face-to-face turnover was intended to help the AMT gain a better understanding of the task. It is possible that too much information was communicated during the face-to-face turnover. Perhaps AMTs in the face-to-face turnover did not effectively retain the information the outgoing shift presented to them, which ultimately led to a comparative understanding that the
written turnover had of the task. Once they begun the task, they may have forgotten a portion of the information presented in the briefing.

**Effect of time pressure**

This study used two levels of time pressure. The first level, time pressure present, essentially required AMTs to complete the maintenance task within an allocated amount of time, while being subjected to constant reminders of a “due back time” by the manager (actor). This condition simulated a maintenance task with a short deadline be returned to an aircraft awaiting departure. The second level, time pressure absent, allowed AMTs ample amount of time to complete the task and no reminders from the “manager”. It was hypothesized that AMTs under time pressure would make more errors than AMTs given an ample amount of time to complete the task; however, the results do not support the hypothesis.

Since increases in workload, which can be due to time pressure, is well known to impact human performance (Staal, 2004), it is likely the lack of effect in this study was due to the manipulation of time pressure. That is, the manipulation of time pressure was not strong enough to put the participants in a high workload/high stress environment. Interestingly, however, the participants in the high time pressure condition performed the task in significantly less time. Additionally, the reaction survey indicated that participants in the high time pressure condition felt significantly more time pressure than the participants in the low time pressure condition.

Now consider the curvilinear relationship between workload and performance. If a person is subjected to low workload, their performance tends to suffer. A medium amount of workload tends to stimulate a person enough to achieve the best performance. Finally, people subjected to high workload tend to become overwhelmed, and thus their performance degrades. (see Hancock & Szalma, 2008). AMTs in the no time pressure condition received very little stimulation and their performance was slightly worse (although not statistically different) than
those exposed to the high time pressure condition. It may be that the high time pressure condition actually was just a moderate amount of stimulation given by the reminders by the manager. However, the reminders were not strong enough to overload AMTs to a point where performance would begin to degrade. Essentially, AMTs may have been pressured just enough to perform effectively. Perhaps the method of reminders used in this study may not represent other forms of time pressure AMTs experience. Possibly a situation where AMTs were actually working on an actual aircraft that was waiting for departure may provide a stronger representation of time pressure in future research.

Further refinement of the task and measures also may have enabled greater assessment of the effect of time pressure on performance. Perhaps different types of skill-based errors and trigger events should be evaluated.

Effect of time pressure and shift turnover strategy on performance

The results indicated no significant interaction between shift turnover strategy and time pressure. This is attributed to the combination of a simple maintenance task and a weak manipulation of time pressure. However, increasing the difficulty of the maintenance task and strengthening the manipulation of time pressure may result in a significant interaction.

Future research

Environment. The environment in which participants received briefings and completed the maintenance task simulated a small component repair station, where working in a quiet, climate-controlled environment is commonplace. This environment was well suited to provide internal validity for this study. However, as stated previously, the majority of aviation maintenance is performed in a hanger environment. Factors such as lighting, temperature, noise, and distractions make up a typical hanger environment. Therefore, a replication of this study in an active maintenance hangar may provide a more accurate assessment of AMT performance.
**AMT experience level.** The participants in this study were not certificated AMTs, but students in an AMT program that had completed enough training to understand the importance of the written documentation packet, the regulations surrounding aviation maintenance, and most importantly, the rights and responsibilities of an AMT. A third trigger event involved AMTs recognizing a mistake made by the outgoing shift. Specifically, the diode of the alternator was incorrectly installed with the intent of AMTs discovering and correcting the error. Unfortunately, the majority of AMTs missed this error (77%) and subsequently, this trigger event was removed from all analysis. It is possible that the average experience level with alternators was not high enough for AMTs to recognize the incorrectly installed part, even though the maintenance manual indicated all applicable parts to for the task and inspection of the diode was a required step that was already completed by the outgoing shift. This trigger event was removed from analysis.

**Conclusion**

In conclusion, the current study partially supports the argument to require face-to-face shift turnover strategies in aviation maintenance. Conceivably, use of the face-to-face strategy helped increase AMTs understanding of the task. The outgoing shift actor explained how he completed each step of the task and indicated which step was next. Additionally, the outgoing shift actor was available to answer any questions AMTs had about the task. The results of the reaction survey substantiate this notion as AMTs in the face-to-face strategy perceived the shift turnover as helpful and effective. Additionally, a level of inter-shift trust may have increased confidence levels for AMTs in the face-to-face strategy, which has been shown to be trait of AMTs (Taylor & Thomas, 2003).

Written shift turnover reports may be difficult to interpret, poorly written and may not contain critical information, such as procedural changes. The latter is based on assumptions by
the outgoing technician that the incoming technician would already know any procedurals changes. Therefore, the common practice of the outgoing shift generating and distributing written shift turnover reports to the incoming shift, without any verbal briefing may not provide the most effective means of information transfer.

Additional research on this topic is needed to identify which types of errors are mitigated by the use of face-to-face turnover strategies. Researchers should make the following considerations when designing an aviation maintenance shift turnover study: a) the difficulty of the maintenance task should reflect the experience level of AMTs performing the task, b) if possible, published maintenance literature specific to the task should be used, c) a suitable amount of trigger event errors should be assigned to the maintenance task, d) the task should allow the possibility of skill based errors to occur, e) the shift turnover should consider all the best practices supported by the literature (Maddox, 1998; Miles, 1998; Federal Aviation Administration, 2005; Parke & Kanki, 2008).

An ideal study would take place in an active maintenance hangar that practices the written turnover strategy; perhaps with a task that is commonly performed by the AMTs who work there, so that the additional effect of complacency can be measured.
References


Appendix A

Demographics Form

Please answer the following questions honestly and accurately.

What is your gender? Male or Female

What is your age? ______

Are you proficient in reading and writing the English language? Yes or No

Have you completed the “Regulations, Documentation, and Drawing” course (AMS 111) or equivalent? Yes or No

Do you currently hold any FAA mechanic ratings (A, P or A&P)? Yes or No

If “yes”, list all ratings ________________________________

Are you able to determine “continuity” using a digital multi-meter? Yes or No

Are you able to use an inch/lb torque wrench? Yes or No

Are you able to use basic hand tools? Yes or No
Appendix B

Participant Information

Measurement of task completion after shift change

Conducted by William R. Warren
Advisor: Dr. Elizabeth Blickensderfer
Embry Riddle Aeronautical University
600 S. Clyde Morris Blvd.
Daytona Beach, FL 32114

Purpose of Research
This study will measure your ability to complete an unfinished maintenance task. The researcher will provide all related material to complete the task.

Duration of Participation
A total commitment of 2 hours is required for participation.

Benefits to the Individual
Participants who complete the task will receive an entry ticket into a drawing for a $300 gift card for tools. The ticket shall contain your name and choice of contact information (phone number or email). The winner will have the choice of a gift card valued at $300 from one of the following tool retailers: Snap-on™, Matco™, or Craftsman™. A single ticket will be drawn from a box in the presence of the researcher’s committee at the conclusion of the study. The winner will be notified via phone and email.

Risks to the Individual
There are no known risks associated with this study. Safety glasses will be available for use, but are not required.

Confidentiality
Participation in this study is anonymous. You will be assigned a number, and only that number will be used while recording and reporting data. All data will be kept in a locked file cabinet in the Department of Human Factors and Systems at Embry-Riddle.

Voluntary Nature of Participation
I acknowledge that my participation in this research is voluntary and that I may stop participating at any time. I understand that withdrawal from the study negates entry into the tool prize. I have been informed of the general scientific purposes of this study. You may request a copy of this consent form, as well as, a copy of the results of this research by contacting William R. Warren (warre88c@erau.edu) or Dr. Elizabeth Blickensderfer (elizabeth.blickensderfer@erau.edu).
Statement of Consent

Embry Riddle Aeronautical University

I consent to participating in the research project entitled: **Measurement of Task Completion after Shift Change.**

Researcher: William R. Warren

The individual above has explained the purpose of the study, the procedures to be followed, and the expected duration of my participation. I have read the page labeled “Participant Information” and agree to the conditions of the study. Possible benefits of the study have been described, as have alternate procedures, if such procedures are applicable and available.

I certify that I have met the following requirements:

- Completed the “Regulations, Documentation, and Drawing” course (AMS 111) or possess an Airframe or Powerplant Certification or combination (A&P).
- Have knowledge of basic hand tool use (including torque wrench and digital multi-meter)
- Ability to read and write the English language

I acknowledge that I have had the opportunity to obtain additional information regarding the study and that any questions I have raised have been answered to my full satisfaction. Furthermore, I understand that I am free to withdraw consent at any time and to discontinue participation in the study without prejudice to me. I understand that withdrawal from the study negates entry into the tool prize.

Finally, I acknowledge that I have read and fully understand the consent form. I sign it freely and voluntarily.

________________________
Date

________________________
Participant’s Name (please print)

________________________
Participant’s Signature

________________________
Researcher Signature

_____Yes, I would like to be contacted regarding the results of the study.
_____Yes, I would like to be entered into the tool drawing (phone number & email required).
Appendix C
Written Documentation Packet
Maintenance Manuel Pages

Vent Ace Model 100-F

Service Manual Rev. 3

Delco-Remy Model K5 Alternator Repair

Disassembly

1-Remove Pulley. Place a number 8 Allen wrench in center of the shaft and loosen nut with a 15/16 wrench.

2-Remove fan and two spacers. *Note placement of spacers and fan.

3-Remove four case screws using a 5/16 deep well socket, loosen the four case bolts. Retain washers with bolts.

4-Separate case from body. Carefully slide case off center shaft.

5-Remove rotor from body. Grasp center shaft and carefully pull out rotor from body

6- Remove stator from body. Remove the two nuts, and lift the stator from the body.

Diode Inspection

Note: The internal components of this alternator are delicate. Handle with care.

7- Remove Diode. Remove the two bolts and lift the diode out of the body. *Note position of diode in diagram.

Check for continuity between the two terminals of the diode.

— If no continuity, diode is ok.
— Install diode. **Hand tighten the nuts using 1/4 socket.**
**Transducer Inspection**

8-Test for no continuity between Body and terminals 1, 2, and 3. Connect an ohmmeter between terminal 1 and body. There should be no continuity. Repeat test for terminal 2 and 3, using body as ground. If continuity is present, replace transducer.
*See diagram

**Reassembly**

9- Install stator onto body. Connect wires to the three posts. Stator should fit snugly into body. Note: **Hand tighten the nuts using 11/32 socket.**

10- Install rotor into body. Grasp center shaft and carefully place rotor into body. Ensure center shaft is fully engaged in main bearing. Looseness of rotor is normal.

11- Assemble case to body. Line up shaft bearing and slide case onto body.

12- Secure case to body. Insert bolts into body. Note: **Hand-tighten the bolts first, then torque the bolts to 25 inch/lbs.**

13- Attach fan and spacers to shaft. Slide on spacers and then fan onto shaft. *See diagram

14- Attach pulley to shaft. Place pulley onto shaft. Install lock washer and nut. *Hand tighten nut only (final tightening torque is applied during installation on engine).
**Delco-Remy Model K5 Alternator Repair**

**Work Card #812F**

**Each step must be initialed when complete.**

<table>
<thead>
<tr>
<th>Disassembly</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Remove Pulley</td>
<td></td>
</tr>
<tr>
<td>2- Remove fan and two spacers*</td>
<td></td>
</tr>
<tr>
<td>3- Remove four case bolts*</td>
<td></td>
</tr>
<tr>
<td>4- Separate case from body</td>
<td></td>
</tr>
<tr>
<td>5- Remove rotor from body</td>
<td></td>
</tr>
<tr>
<td>6- Remove stator from body</td>
<td></td>
</tr>
<tr>
<td>7- Inspect Diode</td>
<td></td>
</tr>
</tbody>
</table>

**Inspection**

<table>
<thead>
<tr>
<th>Inspection</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8- Test for no continuity between body and terminals 1, 2, and 3*</td>
<td></td>
</tr>
</tbody>
</table>

**Reassembly**

<table>
<thead>
<tr>
<th>Reassembly</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9- Install stator onto body</td>
<td></td>
</tr>
<tr>
<td>10- Place rotor into body</td>
<td></td>
</tr>
<tr>
<td>11- Assemble case to body*</td>
<td></td>
</tr>
<tr>
<td>12- Secure case to body*[25 inch/lbs]</td>
<td></td>
</tr>
<tr>
<td>13- Attach fan and spacers to shaft</td>
<td></td>
</tr>
<tr>
<td>14- Attach pulley to shaft*</td>
<td></td>
</tr>
</tbody>
</table>

I_________________________certify this task as complete.

---

Note: Steps 1-7 on the workcard participant’s received contained initials by the previous shift.
Airworthiness Directive

Effective Date 1-15-2011

AD-37748

Purpose

A manufacturer discrepancy has been filed with the Division of Airworthiness Standards office regarding a change in repair procedures for the Vent Ace Model 100-F Airframe. This aircraft utilizes two different alternator models: Delco-Remy Model 15-D and Delco-Remy Model K5. This airworthiness directive applies to all alternators labeled “Delco-Remy Model K5”. If encountered, all aircraft with a “Delco-Remy Model K5” alternator installed shall be grounded until the “required action” is performed. Failing to comply with this directive will produce an unairworthy condition and legal action will be taken.

Required action

The manufacturer (Delco-Remy) has changed the torque value for the four bolts that join the case to the body of the alternator to 28 inch/lbs.

Required documentation

Notice of completion must be indicated on all workcards. Place the following information next to the technicians initials for the installation step: “AD-37748 Complied”
Appendix D

Task Evaluation Sheet

*Experimenter shall determine participants met the following conditions, after participant completes the task and leaves the lab. An X indicates error has been made. All torque values must be ± 1 inch/lbs*

Check if the Center Nut, Lock Washer, and Pulley are positioned correctly.

Check if fan and spacer are positioned correctly.
- Is the fan installed before the spacer?
- Remove fan and spacer.

Check torque value of case bolts [28 inch/lbs]
- Is each case bolt at correct torque value per airworthiness directive?
- Remove case bolts.

Check if case and body are aligned correctly by locating alignment marks.
- Do both marks match?
- Remove case from body.
- Remove rotor from body.

Check torque value at stator nuts [Hand tight]
- Are stator nuts at correct torque value?
- Remove stator.

Check position of diode (refer to figure below)
- Is diode in correct position according to figure below?

Remove diode and place in the INCORRECT position for experiment reset.

<table>
<thead>
<tr>
<th>Position correct?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Nut</td>
</tr>
<tr>
<td>Pulley</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Position correct?</th>
</tr>
</thead>
<tbody>
<tr>
<td>fan</td>
</tr>
<tr>
<td>spacer</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4 Torque Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>bolt 1</td>
</tr>
<tr>
<td>bolt 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AD complied with?</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Case Aligned?</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3 torque values</th>
</tr>
</thead>
<tbody>
<tr>
<td>nut 1</td>
</tr>
<tr>
<td>nut 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diode position correct?</th>
</tr>
</thead>
</table>

Total Errors_______ Percent
Correct_______
Appendix E

Please answer the following questions honestly and accurately. Your responses will remain completely anonymous.

All questions are answered with a 5-point scale.

1 - strongly disagree, 2 – disagree, 3 – unsure, 4 - agree, 5 - strongly agree

1. I had a good understanding of how to inspect and reassemble the alternator correctly.

2. The previous shift technician provided a clear picture of what work had been done to the alternator.

3. All information required to complete the task was in the documentation.

4. I felt pressured to finish the alternator task quickly.

5. I fully understood each and every step of the task.

6. I am confident that the previous shift technician completed every step correctly.

7. I always look-over someone else's work before I sign-off on a task.

8. I had plenty of time to finish the alternator task.

9. I was aware the alternator had a "due back time" and I tried to finish the task quickly.

10. I was in a hurry to finish the alternator task.
Appendix F

Scripts

Participant Briefing Script

Researcher:

1) Hello and welcome to the study. Please read this consent form carefully and sign and date it.

2) Please, fill out this demographics form.

3) Do you have any questions regarding the consent or demographics form?

4) Demonstrate the use of a clicker-type torque wrench to apply torque to a bolt.

5) Demonstrate the use of a digital multi-meter to find continuity.

6) Ask Participant the following questions:

   Are you familiar with workcards?

   A work card is an ordered number of steps, for instance 1-8, required to complete a task. AMT's use work cards when performing maintenance on aircraft and components. You follow the steps and initial each step as complete once you finish it. Each work card is tailored to the specific task it is used for. AMT's are trained to follow procedures to ensure a job is performed correctly.

   Are you familiar with airworthiness directives?

   Airworthiness directives (AD's) are legal documents, issued by the FAA, that require immediate attention. AMT's are trained to comply with airworthiness directives. They know that if they do not comply with AD's, the consequences could be severe. Noncompliance affects not only for the integrity of the technician, but hundreds of lives that fly in the aircraft.

7) Let me describe what will be happening today. You were just hired as an AMT at a major aircraft repair facility. You work the evening shift and are just coming into your first day of work. Today you will be asked to complete a maintenance task that a mechanic from the day shift did not finish.

8) Randomly assign the participant to a condition.
Manager:

*Say the following in a mild tempered voice.*

1) Hi, welcome to work. Let's get started!

**Walk participant over to workstation**

2) I need you to finish up Jim’s work with that alternator; he left already for the day.

3) He left all the tools out for you. Here’s the paperwork.

**Hand Participant “written documentation packet”**

4) I need that alternator and workcard back in 20 minutes! Dispatch is already screaming at me!

5) I've gotta get back to my desk; gotta a lot of work to do.

6) Get it done quick and make sure it’s done right!

**Return to manager desk. DO NOT RESPOND TO PARTICIPANT QUESTIONS.**

**Start timer when you return to manger desk.**

**Monitor the timer and follow the notification schedule below:**

- **At 5 minutes on the timer,** walk over to participant and say IN A FIRM VOICE
  "Ya doing alright with that?"

- **At 10 minutes on the timer,** walk over to participant and say IN A FIRM VOICE
  "I need that alternator in 10 minutes"

- **At 15 minutes on the timer,** walk over to participant and say IN A FIRM VOICE
  "Ya got 5 minutes to finish that alternator!"

- **At 18 minutes on the timer,** walk over to participant and say IN A FIRM VOICE
  "Hurry up with that alternator, dispatch is losing it!"

**Stop timer when participant returns the work card and alternator to the manager.**

**Record total time.**
Face-To-Face With Time Pressure Manager Script

Manager:

*Say the following in a mild tempered voice.*

1) Hi, welcome to work.

2) I need you to relieve Sam over there; her shift is ending soon.

3) She’s got everything ya need.

*Send participant to actor.*

*Return to manager desk. DO NOT RESPOND TO PARTICIPANT QUESTIONS.*

*Start timer when actor returns to manager desk.*

   Monitor the timer and follow the notification schedule below:

   At 5 minutes on the timer, Walk over to participant and say IN A FIRM VOICE
   "Ya doing alright with that?"

   At 10 minutes on the timer, walk over to participant and say IN A FIRM VOICE
   "I need that alternator in 10 minutes"

   At 15 minutes on the timer, walk over to participant and say IN A FIRM VOICE
   "Ya got 5 minutes to finish that alternator!"

   At 18 minutes on the timer, walk over to participant and say IN A FIRM VOICE
   "Hurry up with that alternator, dispatch is losing it!"

*Stop timer when participant returns the work card and alternator to the manager.*

*Record total time.*
Written Manager Script

Manager:

*Say the following in a mild tempered voice.*

Hi, welcome to work.

I need you to finish up Jim’s work with that alternator; he left already for the day.

He left all the tools out for you. Here’s the paperwork.

*Hand Participant “written documentation packet”*

Face-To-Face Manager Script

Manager:

*Say the following in a mild tempered voice.*

Hi, welcome to work.

I need you to relieve Sam over there; her shift is ending soon.

She’s got everything ya need.

*Send participant to actor.*
1) "Hey, how’s it going? I’m Sam.”

2) "This alternator is due for inspection, so I started working on it.”

3) "Let me show you what I have done so far.”

4) "Here is the workcard & maintenance manual pages I printed out. Follow along while I describe each step I've done”
   - Give participant the maintenance manual pages & workcard.
   - Point to each part of alternator as you describe how you removed it.

5) "I began by removing the center nut and lock washer"

6) "Then I took the pulley off"

7) "Then I removed the fan"

8) "And next came the spacer"

9) "You got all that?”
   - If yes, continue describing steps.
   - If no, make sure participant understands what, how and why you did each step.

10) "Then I separated the case from the body, by removing the four case screws.”

11) “Here’s the Airworthiness Directive for the case bolts.”
   - Point to Airworthiness Directive.

12) "The documentation does not say anything about the alignment marks, but they are very important.”

13) "I then pulled the rotor out of the body.”

14) "Then, to get the stator out, I removed the 2 stator nuts holding it to the transducer"
15) "Got all that?"

- If yes, continue describing steps.
- If no, make sure participant understands what, how and why you did each step.

16) "I removed the two screws holding down the diode, took it out, and tested it."

17) "I was finishing up step 7 when you walked in."

18) "It checked out just fine, so I reinstalled it."

19) “To be honest, I went through this kinda quick. I’m trying to get out of here.”

19) "That’s all I got for ya. Do you have any questions?"

**IMPORTANT**

This participant is NOT in the time pressure condition, say the following just before you leave:

“When you’re finished with the alternator, go and get the boss!”
1) "Hey, how’s it going? I’m Sam.”

2) "This alternator is due for inspection, so I started working on it.”

3) "Let me show you what I have done so far.

4) "Here is the workcard & maintenance manual pages I printed out. Follow along while I describe each step I've done"
   - Give participant the maintenance manual pages & workcard.
   - Point to each part of alternator as you describe how you removed it.

5) "I began by removing the center nut and lock washer"

6) "Then I took the pulley off"

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8) "And next came the spacer"

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10) "Then I separated the case from the body, by removing the four case screws."

11) “Here’s the Airworthiness Directive for the case bolts.”
   - Pont to Airworthiness Directive.

12) "The documentation does not say anything about the alignment marks, but they are very important."

13) "I then pulled the rotor out of the body."

14) "Then, to get the stator out, I removed the 2 stator nuts holding it to the transducer"
15) "Got all that?"

- **If yes, continue describing steps.**
- **If no, make sure participant understands what, how and why you did each step.**

16) "I removed the two screws holding down the diode, took it out, and tested it."

17) "I was finishing up step 7 when you walked in."

18) "It checked out just fine, so I reinstalled it."

19) “To be honest, I went through this kinda quick. I’m trying to get out of here.”

19) "That’s all I got for ya. Do you have any questions?"

**IMPORTANT**

This participant is in the time pressure condition, say the following just before you leave:

“This is an AOG part and the aircraft is waiting to depart. The boss wants the alternator back within the next 20 minutes.”
Appendix G

Debriefing Form

Thank you for participating in this study. This study is examining AMT's completing an unfinished maintenance task that was left over from a previous shift. There is a prominent issue regarding critical information transfer in aviation maintenance shift briefings. Your participation will help determine how maintenance personnel may benefit from shift briefings.

We ask that you do not share your detailed experiences involved in this study with anyone for a period of two months. This will increase confidentiality and prevent learning effects for future participants in the study. Your performance and results in this study will remain anonymous. All data gathered will remain under lock and key in the Human Factors Department. Results will only be reported in group numbers (e.g. means, etc.).

You have the right to request a written copy of the results of this study for your personal records. Results will be mailed to you, via email, after the finalization of this study.

Would you like a copy of the finalized results of this study emailed to you?

    Yes or No

    Email address__________________________