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Noise and Time Pressure Effects on Situation Awareness and Aviation Maintenance Tasks

Syaza R. M. Haris
Embry-Riddle Aeronautical University, mohamads@my.erau.edu

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Syaza Raehah Mohamad Haris

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Syaza Raehah Mohamad Haris

This thesis was prepared under the direction of the candidate's Thesis Committee Chair, Dr. Andrew R Dattel, and has been approved by the members of the thesis committee. It was submitted to the College of Aviation and was accepted in partial fulfillment of the requirements for the Degree of Master of Science in Aeronautics.

Andy Dattel Digitally signed by Andy Dattel Date: 2021.12.06 16:31:50 -05'00'

Andrew R. Dattel, Ph.D.
Committee Chair

Mitchell A. Geraci Digitally signed by Mitchell A. Geraci Date: 2021.12.07 09:10:35 -05'00'

Mitchell A. Geraci, M.S.
Committee Member

Steven Hampton Digitally signed by Steven Hampton Date: 2021.12.09 11:16:35 -05'00'

Steven Hampton, Ed.D.
Associate Dean, School of Graduate Studies, College of Aviation

Donald S. Metscher Digitally signed by Donald S. Metscher Date: 2021.12.07 09:22:01 -05'00'

Donald S. Metscher, D.B.A.
Master of Science in Aeronautics Program Coordinator

Alan Stolzer Digitally signed by Alan Stolzer Date: 2021.12.09 14:03:32 -05'00'

Alan J. Stolzer, Ph.D.
Dean, College of Aviation

Christopher Grant Digitally signed by Christopher Grant Date: 2021.12.10 14:19:17 -05'00'

Christopher D. Grant, Ph.D.
Associate Provost of Academic Support

Signature Page Date

Abstract

Researcher: Syaza Raehah Mohamad Haris

Title: Noise and Time Pressure Effects on Situation Awareness and Aviation Maintenance Tasks

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Aircraft maintenance technicians (AMTs) working in a line maintenance work setting are very susceptible to the deafening occupational noise from the airport vicinity or the maintenance machinery itself. Compared to a base maintenance working period, a line maintenance job requires AMTs to complete a task within a short time frame. The current study's objective is to determine if different noise levels and time pressure influence AMTs' performance and situation awareness (SA). Sixteen Embry-Riddle Aeronautical University students majoring in Aviation Maintenance Science participated in a within-subject experimental design. Each participant's performance, SA level, and perceived workload were measured during maintenance tasks in four different environments. The results show that time pressure significantly affects AMTs' performance, SA, and perceived workload. However, the performance, SA, and perceived workload were not significantly affected by the noise levels.

Keywords: Aircraft Maintenance Technician, Situation Awareness, Performance, Workload, Time Pressure

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Chapter I: Introduction

Aircraft maintenance technicians (AMTs) play an essential role in the aviation field to ensure aircraft airworthiness. The safety of the aircraft operation crucially depends on AMTs' ability to perform work safely and correctly. Despite stringent rules and regulations in aircraft maintenance operation systems, aircraft accident and incident rates remain high in general aviation. The International Air Transport Association Safety Report (ICAO [International Civil Aviation Organization], 2020) reported that maintenance errors caused 9,572 aircraft accidents and incidents between 2013 and 2018**.**

The aviation maintenance work environment is generally divided into two settings: line and base maintenance. Unlike base maintenance, where structured activities are planned in advance, and the aircraft is not on duty for a specific period, line maintenance activities typically occur outside the hangar maintaining aircraft on an active flying cycle (Code of Federal Regulation, n.d.). Although both work settings expose AMTs to environmental and occupational noise, line maintenance technicians are also susceptible to constant time pressure to complete the tasks. Line maintenance activities involve aircraft maintenance work during turnaround periods, which is the time right after an aircraft touches the ground and before it takes off. During a typical aircraft turnaround, airplanes are powered by the auxiliary power unit (APU) or ground power unit (GPU) and surrounded by various ground service vehicles that produce uncomfortable noise. Apart from the compulsory pre- and post-flight inspections, AMTs must rectify any minor discrepancy logged in the Aircraft Journey Log (AJL) within the ground time before Return to Service is signed off. Aircraft ground time is also subject to other factors such as air traffic and weather, resulting in shorter turnaround times for any line maintenance work. Therefore, time constraints are deemed as a factor that influences aircraft maintenance technicians to commit errors (Wang & Chuang, 2014).

Apart from performance, the work environment may also impact AMTs' situation awareness (SA). SA is having consciousness of what is happening around by comprehending environment cues to project one's future status (Endsley & Robertson, 2000). Maintaining a high level of SA is indispensable to AMTs in performing a maintenance task, especially in line maintenance, where AMTs must carry out the job within a specific time frame. The complexity of the aircraft system requires maintenance personnel to understand the job they are working on and, at the same time, be aware of the surroundings that may affect the task completion.

Statement of the Problem

Line AMTs' working environment can be anywhere within the airport vicinity, on the apron, or in the hangar. Their working environments are susceptible to a variety of noise exposure from the aircraft itself and surrounding vehicles. A typical APU produces noise between 100 – 120 dB, and noise from all the ground support vehicles can increase distraction (Siebel et al., 2018). According to Issad et al. (2021) and Couth (2020), prolonged exposure to loud noise is found to be harmful physiologically and psychologically.

Line maintenance work requires AMTs to execute failures with high accuracy within a limited time frame, especially during aircraft ground time. During a typical turnaround, line maintenance tasks often involve routine in-service inspections, troubleshooting and rectification, and daily check action. Even though the routine tasks can be straightforward, a certain in-flight discrepancy may occur that requires rectification during turnaround, such as tire replacement and autopilot system malfunction. Aircraft ground time is the time period between the aircraft landing and before it takes off. Cahyo et al. (2020) claimed that having critical thinking skills and problem-solving ability is crucial in carrying out aircraft maintenance tasks. The effect of time pressure may be compounded when the intensity of background noise is high, thus affecting AMTs' performance and SA.

Purpose Statement

Studies on factors affecting human error, especially in the line maintenance setting, are sparsely explored. This study aims to fill the gap by assessing the effect of different noise levels and time pressure on performance and SA in performing aircraft maintenance tasks. The severity of noise and time pressure interaction is also observed to understand better the contributing factors that increase human error risks.

Significance of the Study

Line maintenance AMTs are not only responsible for troubleshooting malfunction and executing the problems but also demand to return aircraft to their original state within a specific time frame. This study explores if technicians experience changes in performance and SA levels in different background noise and time pressure intensity. Discovering environmental thresholds may alleviate human factor risks through safety regulations and improve maintenance scheduling.

Research Question and Hypotheses

The current study observed the factors that affecting aircraft maintenance tasks in different environmental conditions. The research question and hypotheses are as follows:

RQ

Is there a significant effect of noise and time pressure on performance, SA, and perceived workload when performing maintenance tasks?

H_1

There is no significant effect on AMTs' performance under different levels of noise environments.

H_2

There is no significant effect on AMTs' performance under different levels of time pressure.

H_3

There is no significant interaction effect between noise and time pressure in terms of performance.

H_4

There is no significant effect on AMTs' SA under different levels of noise environments.

H_5

There is no significant effect on AMTs' SA under different levels of time pressure.

H_6

There is no significant interaction effect between noise and time pressure in terms of SA.

H_7

There is no significant effect on AMTs' workload under different levels of noise environments.

H_8

There is no significant effect on AMTs' workload under different levels of time pressure.

H_9

There is no significant interaction effect between noise and time pressure in terms of workload.

H_{10}

There is no significant interaction effect between workload, noise levels, and time pressure.

Delimitations

This research study aimed to assess the effect of noise and time pressure on aircraft line AMTs' performance and SA. However, due to airlines' safety and security, the selection of participants was delimited to students attending Embry-Riddle Aeronautical University (ERAU), majoring in Aviation Maintenance Science. Participant eligibility was limited to a student who has completed Federal Aviation Administration (FAA) AMT General modules to ensure they were familiar with handling tools and following maintenance manual instructions.

Limitations and Assumptions

The research confined the study to ERAU students; thus, their knowledge and skill levels would not be expected to be as high as the experienced AMTs. There were a limited number of qualified participants that could have been selected from the Aircraft Maintenance Science (AMS) students to participate in this experiment. The tasks were limited to AMS lab facilities that may not represent actual aircraft components and locations on an aircraft. Moreover, the experiment was limited to using equipment altered for educational purposes, and the difficulty level may not replicate the actual situation. The presence of an evaluator/observer during the experiment may alter the participants' actual performance and SA. Participants' high technical English proficiency was assumed to understand the purpose and procedures of this experiment. It was assumed that participants had adequate comprehension of the Aircraft Maintenance Manual (AMM) instructions.

Summary

Understanding different environmental factors and their interaction effects towards line maintenance technicians are paramount for future aircraft maintenance management improvement. This research aimed to examine the implication of varying noise levels and time pressure on AMTs' work performance and SA in a line maintenance work setting. The outcomes of this research can be used as a guide in improving future aircraft maintenance management systems and mitigating human error risks.

The literature review in Chapter 2 elucidated the theoretical framework and expounds on relevant research outcomes to understand the importance of this study to aviation in general and specifically the aircraft maintenance domain. In Chapter 3, the methodology of the proposed research experiment is outlined. Chapter 4 presented the statistical findings, and the conclusions are described in Chapter 5.

List of Acronyms

AJL	Aircraft Journey Log
AMS	Aircraft Maintenance Science
AMM	Aircraft Maintenance Manual
AMT	Aircraft Maintenance Technician
ANOVA	Analysis of Variance
APU	Auxiliary Power Unit
EASA	European Union Aviation Safety Agency
ERAU	Embry-Riddle Aeronautical University
FAA	Federal Aviation Administration
GPU	Ground Power Unit
ICAO	International Civil Aviation Organization
IATA	International Air Transport Association
IRB	Institutional Review Board
LRU	Line Replacement Unit
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
SPAM	Situation Present Awareness Method

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Chapter II: Review of the Relevant Literature

Aircraft maintenance is an intricate activity in which individuals perform various complex tasks in challenging workplace conditions. AMTs are responsible for inspecting aircraft systems, diagnosing malfunctions, performing repair and modification tasks, and maintaining the overall aircraft's airworthiness while ensuring compliance with aviation safety rules and regulations. Multiplex and high-demand operations are vulnerable to various occupational cognitive failures (Allahyari et al., 2014). Depending on the situation, the environmental effect can ameliorate or hinder employees' work performance and elevate the propensity of poor SA. Numerous studies have shown that the workplace environment significantly impacts employee performance level (Carlisle et al., 2019; Guillaume et al., 2017; Maula et al., 2016). In addition to technical skill competency, line maintenance work environments require the technician to execute problems within a limited time frame. Studies have determined that an increase in time pressure is directly proportional to a decrease in job performance (De Paola & Gioia, 2016; Ryari &Wieseke, 2021). AMTs working in a line maintenance environment are highly exposed to the occupational noise environment. Studies have ascertained that aircraft noise affects the psychological and physiological as well as performance levels among aviation workers and people around the airport vicinity (Basner et al., 2019; Baudin et al., 2019).

This chapter presented the overview of AMTs' profession in a line maintenance setting, followed by the analysis of occupational noise and time-constrained sources in line maintenance work setting. The literature reviews also explored the theories of noise and time pressure and their impact on performance, SA, and workload. In general, this chapter presented the significance of the current study and the notable research studies on occupational noise, time pressure, as well as the connection to human performance, SA, and workload, especially towards AMTs.

Gaps in the Literature

Japan Airlines Flight 123 changed the landscape of aviation safety, especially in the aircraft maintenance sector. The incident that claimed 520 lives in 1985 demonstrated the importance of discerning human errors and their contributing factors in aircraft maintenance operations (Hood, 2012). Human factors in aircraft maintenance have become a crucial aspect in maintaining reliable and airworthy aircraft.

The FAA includes SA as a part of 12 common causes of human factors errors called The Dirty Dozen (Panger, 2015). Endsley (1988) defined SA as perceiving a stimulus, comprehending what it means, and accurately predicting how future situations may change. A high level of SA means AMTs are in the present state of mind and in a complete understanding of what they are doing at the moment. The AMTs must have the good judgment to identify a system's condition and distinguish abnormalities for further rectification. Competent AMTs are expected not only to have the ability to project the system forward but also to predict the previous status of the system to determine what event may have led to a current state of the system (Endsley & Robertson, 1997). For example, in troubleshooting autopilot system malfunction, AMTs must have the ability to identify the faulty sub-systems with an adequate diagnosis.

Hobbs and Williamson (2003) emphasize that aircraft maintenance errors could not be generalized by the contributing factor individually; therefore, this study intended to assess if the combination of noise and time constraints affects individuals' performance and SA. Even though the effect of occupational noise and time pressure on individual performance is widely explored (Sonnentag et al., 2014; Teixeira et al., 2019), the interaction of these two factors on line maintenance technicians is practically unavailable.

Theoretical Framework

Overview of Line Maintenance Work

According to European Union Aviation Safety Agency (EASA, 2015) Part145, AMC 145.A.10; line maintenance is any task that is carried out before flight to ensure the aircraft fits for the intended flight. Line maintenance activities can be carried out in the hangar (overnight maintenance) or on the apron, especially during turnaround, while the aircraft remains in its operating state. The task may include troubleshooting, defect rectification, daily check actions, component replacement, Line Replaceable Units (LRUs), routine in-service inspection, and minor repairs and modifications (Papakostas et al., 2010). Even though line maintenance tasks are done according to the airline's maintenance programs, some events may occur where AMTs are required to perform "unscheduled maintenance" based on the aircraft's performance prior to the next flight. Unscheduled maintenance is on-condition maintenance that must be addressed immediately to ensure aircraft is safe to fly and airworthy (Gerdes et al., 2016). Discrepancies that fall under unscheduled maintenance are often discovered during routine checks. Because of line maintenance complexity and demanding work nature, the AMTs require good SA when performing tasks. The typical line maintenance nature of work is highly susceptible to occupational noise and time pressure.

Occupational Noise

Along with advanced development, occupational noise pollution is becoming more widespread and directly impacting human life (Bolm-Audorff et al., 2021; Nelson et al., 2005; Si et al., 2020; Thai et al., 2021). Depending on noise level and exposure duration, unwanted noise at the workplace significantly influences the quality of work, productivity, and performance (Korica & Popović, 2017; Lakhal et al., 2021). A pleasant sound can become noise when exposed continuously and interfere with normal human activities or conversations. Occupational Safety and Health Administration (OSHA, n.d) classified noise permissible exposure limit (PEL) based on the sound level as shown in Table 1.

Table 1

Noise Permissible Exposure Limit

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1 ½	102
1	105
½	110
¼ or less	115

Note. When daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. Adapted from *"Noise Permissible Exposure Limit"* by OSHA.

Effects on Physical and Psychological. Prolonged exposure to loud noise significantly contributes to hearing loss among industrial workers, and environmental noise stress negatively affects specific cognitive functions (Daiber et al., 2019; Jennings & Shaw, 2018). Wright et al. (2014) evaluated the relation between noise stress on attention, memory, executive function, working memory, and mental flexibility response and concluded environmental noise exerts a negative effect on an individual's psychological well-being. Even though individual responses may have various effects on noise stress, studies show an undeniable impact on the human psychological and physiological state (Daiber et al., 2018; Stansfeld & Matheson, 2003). Picard et al. (2008) found noise-induced hearing loss contributes a significant consequence on work-related accidents.

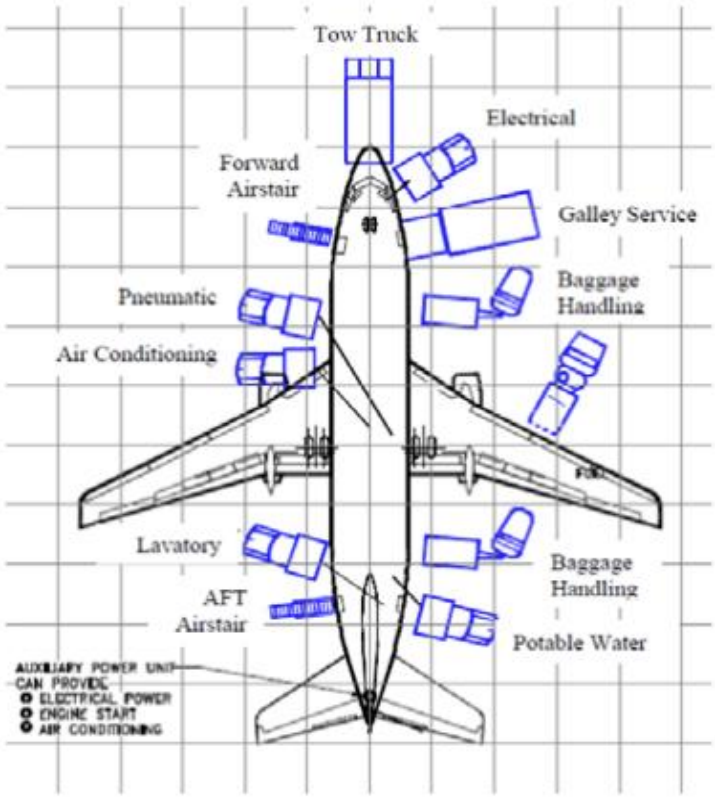
Basner et al. (2015), in a study of biological effects of noise, found occupational setting and transport has the most influential noise sources that affect health with 18% of occupation-related hearing loss among workers aged 18-65. Noise generated from aircraft take-off and landing activities at night significantly influences sleep disturbance, including increased awakenings and motility (Perron et al., 2012). In an office setting, noise appears to affect working performance in different ways. Individuals working with tasks involving semantic information recall decreased performance in a high noise office environment (Jahncke & Halin, 2012). Employees working in a loud office reported to be more tired, less motivated, and had higher perceived workload (Jahncke et al., 2011; Jahncke & Halin, 2012). Seo et al. (2012) found a significant effect of background noise on performance even in low cognitive load activities. In the aviation field, noise was found to be a hindrance to pilots, and the air traffic controller's performance and hearing ability are important in maintaining pilot safety (Casto & Casali, 2013). Studies have found that prolonged aircraft interior noise exposure have significant effects on pilot operation and navigations performance, and their well-being (Ivošević, 2018; Lindvall & Västfjäll, 2013).

Effective communication is crucial when the work done involves various parties. Line maintenance AMTs are expected to communicate effectively with supervisors, fellow AMTs, and other ground service operators and crews onboard. One of the practical communications skills is speech predictability, which is affected by the presence of surrounding sound. However, a difficult listening environment can hinder communication (Marrufo-Pérez et al., 2019). Interdependent workplaces tend to cause miscommunication to occur, and the presence of multiple sources of noise increases the likelihood of it occurring.

Line AMT Occupational Noise Source. Employees in technical industries, including aircraft maintenance technicians, generally work in an inevitably noisy environment (Smagowska, 2013). A maintenance job done at an aircraft bay area is exposed to a noisy environment from various sources such as neighboring aircraft's movement and aircraft take-off or landing sound. During a ground operation, aircraft are typically powered by the (Auxiliary Power Unit) APU and (Ground Power Units) GPUs which produce significantly loud noise (Tam et al., 2013). A typical APU produces between 20 and 300 Hz low-frequency broadband noise (Siebel, 2018). Typical aircraft turnaround ground operation involves several ground service vehicles, including fuel trucks, cabin service vehicles, and baggage handling trucks, as shown in Figure 1. The presence of these vehicles adds to the increase in environmental noise. Madbuli and Mohamed (2013) found a significant effect of noise exposure duration on hearing loss among civilian aircraft maintenance workers. Workers with more prolonged exposure to noise level ≥85 dBA showed significant hearing impairment compared to non-exposed employees. Long noise exposure is an influential source of stress and is reported to cause physiological and psychological stress reactions (Barbaresco et al., 2019; Sajeda et al., 2018).

Figure 1

Ground Operation Layout at Aircraft Bay



Note: Adapted from Fitouri-Trabelsi et al., (2014). Managing uncertainty at airports ground handling.

Time Pressure

Effects on Performance. Time pressure has been a significant factor in a workplace environment that affects the quality of decision making, mental judgment, human behavior, and stress levels (Payne et al.,1996; Plessas, 2019; Tinghög et al., 2016). Constrained work duration can be a source of stress in performing tasks and significantly affects work performance, decision-making, and creativity (Phillips-Wren & Adya, 2020). In a challenge-hindrance study, although short-term time pressure can benefit employee performance, it reduces their work engagement when exposed to repeated time pressure for a long duration (Baethge et al., 2018). There are numerous studies on the impact of noise on concentration, behavior, and physical health but very little on SA, especially towards aircraft maintenance technicians (Banbury & Berry, 2005; Muzet, 2007).

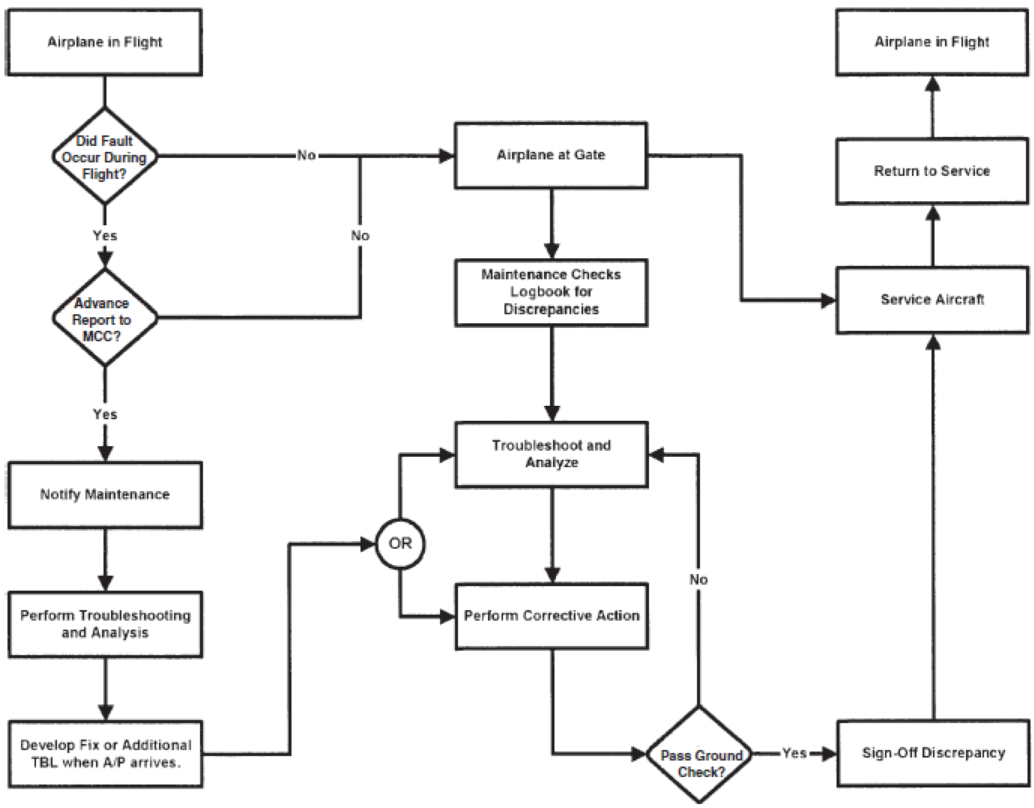
Time Pressure in Line Maintenance. The plane is not making any money while it is on the ground is a well-known quote in the aviation industry. Exorbitant fuel prices and escalating airport charges influence airlines' concern on minimizing turnaround time as the number of flights can be maximized, especially in short-haul flight cycles (More & Sharma 2014). Turnaround time or aircraft ground time is also vital in airline scheduling and network operation (Asadi et al., 2020; Postorino et al., 2020; Zografos et al., 2017). Unavoidable factors such as air traffic and weather can affect aircraft turnaround time, reducing the time for maintenance personnel to complete their task. Aircraft turnaround operations are the activities conducted between arrival and departure at the airport to prepare an inbound aircraft for the following outbound flight. According to the FAA (2018a) in the Advisory Circular AC 43-9C Maintenance Records, airplanes are subject to Return to Service approval, which tells whether or not the aircraft is airworthy and ready to fly. A line maintenance operation is a fast-paced maintenance environment due to aircraft turnaround time and must be done without disturbing the flight schedule (Kinnison & Siddiqui, 2013). In other words, line maintenance AMTs must rectify any unexpected discrepancies within a short time frame.

Gate-to-gate ground handling involves various activities; while some activities can take place independently, some take place in sequence (Abd Allah Makhloof et al., 2014). Pujangkoro et al. (2019) found that the allocated 150 minutes of cabin standard checks for Airbus A330 is impossible to accomplish in a cabin line maintenance service.

It is difficult for AMTs to perform cabin checks, including aircraft entrance door, cockpit interior, lavatory, passenger seats, and galley within this time frame. Figure 2 shows a typical line maintenance operation process during a turnaround. AMT will be notified regarding any fault that occurred during a flight and the rest of the process, as shown in the figure.

Figure 2

Line Maintenance Operation during Turnaround



Note. Adapted from Kinnison & Siddiqui (2013). Aircraft Maintenance Management.

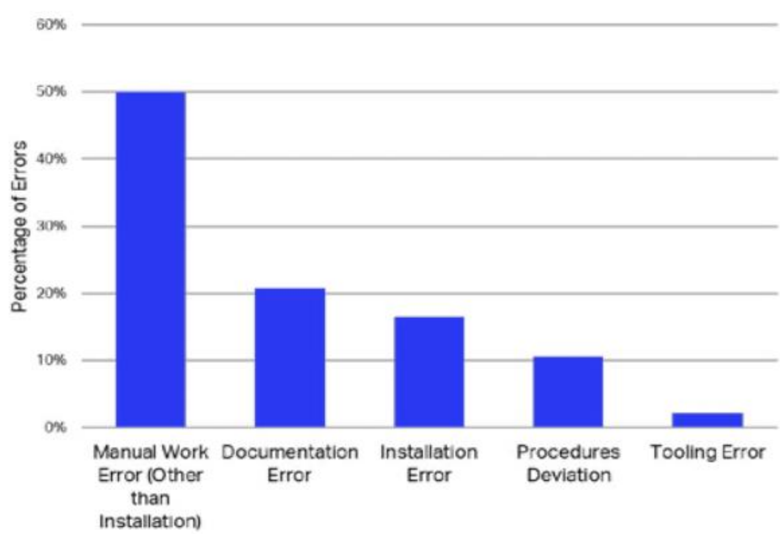
Human Factors in Aircraft Maintenance

Even though the aircraft system has evolved immensely over the years, for better failure detection and rectification, many external factors may influence human judgment in performing work, leading to aircraft accidents and incidents. The International Air

Transport Association (IATA) (2020) Safety Report grouped maintenance errors into five categories: manual work, documentation error, installation error, procedures deviation, and tooling error. The report also shows maintenance operations were cited in 67% of accidents between 2015 to 2019. Figure 3 shows the maintenance error classifications by the IATA. As seen in the graph in Figure 3, maintenance personnel committed the highest number of errors in manual work, which according to IATA, covers errors such as equipment left in the aircraft, panels/plugs open or removed, task/check not appropriately accomplished, incorrect placarding, and aircraft damaged during maintenance/task/check. It manifests the importance of AMTs to have a conducive working environment that helps concentration and reduce making errors.

Figure 3

Maintenance Error Classification



Note. Adapted from "Safety Report 2019" by the International Air Transport Association (IATA).

Many contributing factors influence maintenance personnel to commit mistakes. Often, aircraft maintenance mistakes are not visible and have the potential to remain latent, which jeopardizes aircraft safety (FAA, 2018b). The dynamic aircraft systems require AMT high attentiveness and safety consciousness in performing maintenance tasks. Aircraft maintenance work demands the AMT work in an environment with time pressure, uncomfortable conditions, tight space, and odd working hours often become the cause of committing an error. Significant numbers of reported maintenance-related accidents and incidents are predominantly caused by human error (Latorella & Prabhu, 2000).

Pettersen and Aase (2008) emphasized that line maintenance safe work practices can be achieved not only by having skilled and competent AMTs but also by creating a healthy maintenance timeframe simultaneously. Unexpected work roster changes in order to prioritize aircraft availability were found to be the factor in a fatigue-related error in aircraft maintenance (Signal et al., 2019). Chang and Wang (2010) identified several environmental risk factors that influence maintenance performance: climate and temperature, noise, lighting, ventilation, motion and vibration, and toxic materials and fumes. Necessary preventive and proper corrective measures of human errors related to aircraft maintenance can be developed by identifying the contributing factors (Rybalkina & Enikeev, 2021).

Research Model

The current research study utilized a within-subjects experimental research design to examine aircraft AMTs' performance, SA, and perceived workload when performing two maintenance tasks. AMTs normally perform maintenance tasks with time constraints and noisy working environments. It is evident that performing a complex task with the presence of noise and time pressure may affect work performance, SA, and perceived workload among manufacturing workers (Mahdiniah et al., 2021 Mapuranga et al., 2020). However, it remains unknown how time pressure and noise could affect performance, SA, and workload on AMTs specifically. The current study simulated four working conditions with different combinations of levels of noise and time pressure. The tasks chosen for the experiment were safety wire locking and fan blade removal, which are the common tasks performed in a line maintenance workforce (Hinsch, 2019). The two tasks require AMTs to follow instructions, be aware of their surroundings, and test their decision-making ability. Therefore, their performance, SA, and workload were measured to examine the effects of noise and time pressure.

Participants' performance was assessed on their total task completion. Two assessments were used to measure participants' SA— the time they took to answer the questions and if they answered the questions correctly. Response-time measurement is widely used as a research methodology in measuring human attitude (Kong et al., 2007; Mulligan et al., 2003; Townsend & Eidels, 2011). Cunningham et al. (2015) implemented an online probe question and measured the pilots' responses to indicate their SA level. NASA-TLX was used to assess participants' perceived workload during the experiment.

Hypotheses and Support

This study aims to determine whether a high level of noise and time constraint environment affects aircraft maintenance technician's performance and SA, especially in line maintenance settings. Studies have shown that an individual's work performance is influenced by occupational noise (Golmohammadi et al., 2020; Zou et al., 2021). Based on the literature review, it is hypothesized that loud noise and time pressured conditions would negatively affect AMT's performance and decrease SA.

Summary

The literature review shows occupational noise and time pressure affect the performance and SA of individuals. Aircraft line maintenance work demands AMTs' high accuracy and reliability in performing maintenance tasks. AMTs working environments are frequently at the mercy of deafening noise and time pressure. Thus, performing maintenance tasks in such conditions can alter AMTs' performance and SA, consequently contributing to human error. Although there are countless studies on the effects of a workplace environment and circumstances on individuals' performance, its effects on line maintenance AMTs are insufficiently investigated. As the turnaround time at the airport becomes a significant factor in managing airline operational cost, this study proposes specific research on its influence on AMTs working in a line maintenance setting.

The aircraft maintenance personnel's performance and level of SA caused by noise have not been fully explored, particularly in the line maintenance setting (Endsley & Robertson, 2000). Therefore, it is necessary to highlight this subject matter to strengthen aviation maintenance safety by identifying existing contributing factors and planning mitigating action in a safety program. It is crucial to train AMTs to have a high SA level to improve the quality of work and prevent any mishaps. The improvement can be achieved by identifying factors affecting SA, especially in a line maintenance setting. Although there have been various research studies on environmental impact and its contributing factors in human error, the combination of noise levels and time pressure that affect line maintenance technician's performance and SA has not been addressed.

Chapter III: Methodology

The purpose of the study was to investigate the effects of noise and time pressure on the level of performance and SA of individuals working on aircraft maintenance tasks in a line maintenance setting. This chapter will expound on the details of the experiment, including participants, apparatus, research design, and procedures. In evaluating AMTs' performance, SA level, and perceived workload, a research experiment was conducted in a maintenance lab by simulating several line maintenance environments.

Research Method Selection

This study used a factorial research design to assess objective and subjective measurement to determine the differences in performance, SA, and workload of AMTs working under four different working conditions. A two-way within-subjects design was conducted to observe the two independent variables: two levels of noise and two levels of time constraints. A three-way within-subjects design also was conducted by adding the six levels of the NASA-TLX to the noise levels and time constraints. Experimental research was conducted to measure the cause-effect relationship by manipulating noise level and time pressure constraint to finish a task. The level of performance, SA, and perceived workload are the three dependent variables observed in this study to determine the relations of noise level and time pressure on AMTs performing maintenance tasks.

Population/Sample

The study aimed to assess the interrelations of environmental adversity on aircraft technicians' level of performance and SA in a line maintenance setting. Although certified aircraft maintenance technicians are the most relevant population, due to unavoidable constraints, the targeted sample was drawn from ERAU students currently enrolled in Aviation Maintenance Science program.

Population and Sampling Frame

Participation was offered to students from the College of Aviation enrolled in Aircraft Maintenance Science. The prerequisite for participation eligibility in the study is they must have completed the FAA General modules. The participants were expected to know basic maintenance knowledge and skills including, sufficient knowledge of safety wire locking procedures, tools handling, and act in accordance with the AMM. Therefore, the sample was limited to students in their third and fourth year of a Bachelor's degree.

Sample Size

Sixteen participants were recruited for this research based on power analysis conducted using G*Power sampling tools (Faul et al., 2019). For a counterbalancing purpose, the sample size must be divisible by the experiment set, which is four for this research study.

Sampling Strategy

Participants were recruited from the targeted population via email from the AMS program. Advertising flyers were posted around the ERAU campus. Participants were randomly assigned to the experiment sequences.

Data Collection Process

All 16 participants performed two types of maintenance tasks in four different environmental settings. The researcher, subject matter expert (SME), and student assistant were in the same laboratory to record the experiment data. Each participant was required to answer a NASA-TLX questionnaire after each condition. The experiment utilized both objective and subjective measurements during the experiment to measure overall performance, their level of SA, and perceived workload.

Design and Procedures

A factorial within-subjects experimental design was conducted using a two-way and three-way Analysis of Variance (ANOVA) to determine the effects of noise level, time pressure, and perceived workload on AMTs performing maintenance tasks. The dependent variables were AMTs' performance, SA, and workload. The independent variables were noise level and time allotted to perform the tasks to simulate the time-pressure effect. The background noise level is denoted by Low (≤ 60dB) and High (>85dB) and controlled using a sound meter from a mobile application. Mixed audio consisted of music, and aircraft take-off sound were used as a background sound. The time pressure effect was simulated by varying the time allotted to perform the tasks. In the high-pressure environment, participants were asked to perform the task in 10 minutes. In a low-pressure environment, participants were asked to perform tasks at their own pace; however, the researcher stopped this condition at 15 minutes. As shown in Table 2, the four conditions were 10Low (high time pressure + low noise), 10High (high time pressure + high noise), 15Low (low time pressure + low noise), and 15High (low time pressure + high noise).

Table 2

Noise Levels and Time Pressure Conditions

Time	Noise	
	Low	High
10	10Low	10High
15	15Low	15High

Note. Low noise condition is ≤60 dB while high noise condition is >85 dB. 10 indicates high time pressure and 15 is low time pressure.

The tasks chosen for the experiment were safety wire locking and engine fan blade removal. Safety wire locking is one of the FAA A&P technical knowledge skill requirements in becoming a Certified Aircraft Mechanic (FAA, 2021a). The task requires a mechanic to make a proper technical judgment based on the location and bolts type to be safely locked. Engine fan blade removal is a routine maintenance task that attests to AMTs' ability to follow instructions and technical know-how. Two different tasks with the same level of difficulty were administered for counter-balancing purposes; each participant performed two different tasks twice in four conditions. In Condition 1, participants were asked to re-do a safety wire locking to a band clamp and two sets of bolts on the APU section. In Condition 2, participants performed the safety wire of a band clamp and two sets of bolts on the CFM[1] engine (see Appendix C1 and C2). In Condition 3 and 4, participants removed engine fan blade numbers 3 and 10, respectively (see Appendix C3). Each condition utilized different aircraft positions and task goals to maintain task engagement. Different combinations of noise levels and time pressure were assigned to each condition, and participants were randomly selected for each condition.

[1] CFM is not an acronym but the name of the engine.

Table 3 shows the condition sequence for each task. The four experimental conditions with two levels of noise and time pressure effect were tested.

Table 3

Experiment Conditions

Participant	Safety wire locking		Fan Blade Removal	
	Sim 1	Sim 2	Sim 3	Sim 4
1-4	10 Low	15 High	10 High	15 Low
5-8	15 Low	10 High	15 High	10 Low
9-12	10 High	15 Low	10 Low	15 High
13-16	15 High	10 Low	15 Low	10 High

Note. Sim 1 = Safety wire on APU. Sim 2 = Safety wire on CFM engine. Sim 3 = Blade #3 removal. Sim 4 = Blade #10 removal.

A prerecorded audio of SA questions was constructed based on the Situation Present Assessment Method (SPAM) approach (Durso & Dattel, 2004). The recorded audio used a computerized female voice and mixed it with the background sound of each condition. A series of SA questions were delivered through a headset, and participants were required to answer verbally. Therefore, participants were required to wear a headset at all times during all four conditions.

Prerecorded SA questions automatically played during the task performance at 2-minute, 4-minute, 6-minute, and 8-minute marks of the tasks. There was a one-second beep sound before each recorded question appeared to indicate the question would be played within a second. The beep is played so that participants will know to expect the upcoming question. All four conditions utilized a distinct set of questions for counter-balancing purposes and ensured that participants could not expect the same questions. There is no fixed answer for question number four in Condition 2 and question number one in Condition 4 because it depends on participants' progress with the task. However, answer correctness is observed through the audio and video recordings. The questions set for each condition and the answers (in bold) are as follows:

Condition 1:

1. What is the line with blue and red placard label? **(Pneumatic line)**
2. What wrench size would be needed to tighten the band clamp? **(7/16")**
3. Is it possible to do 2-bolt locking instead of 3? **(No)**
4. How many bolts are you tying together? **(Two)**

Condition 2:

1. What is the name of the green component below the band clamp are you working on? **(Heat Exchanger Oil/Fuel)**
2. What is the safety wire size diameter? **(0.032”)**
3. Is it possible to do 2-bolt locking instead of 3? **(Yes)**
4. Which direction is your twisting?

Condition 3:

1. What socket size are you using? **(¼")**
2. Is it a right or left turn bolt? **(Right)**
3. Do you see any FOD? **(No)**
4. Does the pin have the correct part number? **(No)**

Condition 4:

1. What part are you removing now?
2. What blade number are you removing? **(#10)**
3. How many bolts are securing the panel to the fan cowl **(10)**
4. Does the fan blade have the correct part number? **(Yes)**

Performance measurement was collected based on a performance checklist constructed based on the items required and the usage of correct maintenance tools to complete the task (see Appendix B1). The SA question form was created for data collection (see Appendix B2). Participants could obtain a maximum of 10 points for each task based on the performance evaluation. NASA-TLX questionnaire was used to measure the participants' perceived workload (see Appendix B3). Participants' consent was received before the experiments were conducted. A copy of the consent form is attached in Appendix B4.

Apparatus and Materials

Audacity® 3.0.4. Audacity ® is a digital audio editor and recording application software. The software is used to play the background noise and record the participants' answers to get accurate response time to avoid obtrusive and inconsistent use of a stopwatch. Music and aircraft sounds were recorded simultaneously in two different noise levels. Computerized audio of SA questions was added to the background sound at a certain time. The background sound stopped momentarily when the questions were played. This application was also used to record participants' voices answering the questions.

Logitech Headset. A headset with a built-in microphone was used to induce four different noise backgrounds and record the participant's verbal answers. It was a lightweight headset with a long cable to reduce distraction while performing the experiment. The headset was connected to the laptop equipped with Audacity ® application.

Maintenance Tools. Basic maintenance tools were provided such as long-nose plier, duckbill plier, 1/4" ratcheting driver, 1/4" – 9/16” socket set, 1/4" universal adapter, side cutter, 1/4" fixed driver, 6" extension driver, and 1/4" – 9/16” combination wrench set. Non-related tools were also provided to observe participants' performance in using the correct tools. See Figure 4.

Figure 4

Maintenance Tools Used in the Experiment

Wires and Safety Wire Twister. The type of wires that were used in the experiment is the general safety wire - Inconel and Monel wire with 0.032" diameter. A safety wire twister is a specialized tool used for wire locking jobs that grips the two-safety wire loose ends in order to twist the safety wire.

GoPro Video Recorder. Participants' performance was observed through video recording for accuracy.

NASA Task Load Index (NASA-TLX). This multidimensional rating-scale questionnaire is widely used to measure the dependent variable of this experiment:

perceived workload. There are six sub-scales, mental demand, physical demand, temporal demand, performance, effort, and frustration. Participants were briefed on the questionnaires so they could understand the purpose and its scaling and would be able to answer the questions precisely.

Sources of the Data

Three primary data sources were involved in the experiment: participants' SA, performance, and workload. SA was measured by the participant's response time (in seconds) and the accuracy of answering the questions delivered. One point is given for each question answered correctly, for a total of four points per task. For the questions that were answered incorrectly, response time for that question was not collected. Performance was measured based on the participants' overall procedure completion evaluation done by the SME. A 10-point evaluation was given when the participants used the correct tools and for each sub-task performed during each task. Performance was scored by reviewing videos taken during each condition. The six-subscales NASA-TLX was used to assess the perceived mental workload for each task performed.

Ethical Consideration

Each experiment set lasts for 10 – 15 minutes which is lower than the permissible 8 hours for 85dB noise exposure. Hence, the risk of participating in this study was minimal. Informed consents were signed to confirm participants' willingness to participate in this research study. Participants also agreed to be recorded during the experiment. Experiment procedures followed the Institutional Review Board (IRB) requirements and guidelines. The IRB approved letter is included in Appendix A.

Data Analysis Approach

Data collected from the experiment were analyzed using the IBM® SPSS. All experiment procedures were strictly followed to avoid data recording conflict and to minimize experimenter bias.

Reliability Assessment Method

An AMM is a formal document that describes how all maintenance tasks shall be accomplished (FAA, 2021b). The checklist used to measure the performance for each task was constructed based on related AMM for each task. SPAM is one method of measuring situational awareness (SA) based on the assumption that SA oftentimes involves present cues to obtain some information rather than remembering that information. SPAM method does not require a memory component and uses response latency as the primary dependent variable and SPAM has been widely used in measuring SA among aviation-related jobs and found to be more predictive to the assessment (Cak & Misirlisoy, 2019; 2020; Fujino et al., 2020)

NASA-TLX has been widely used in various fields of study to measure individual performance (Guru et al., 2015; Yu et al., 2016) and found to be a better predictor compared to the Subjective Workload Analysis Technique (Hunggins & Claudio, 2018). Said et al. (2020) reported high criterion validity where the NASA-TLX questionnaires as a reliable tool for measuring subjective workload. Response-time measurement has been used to assess human physiological response and found to be a precise and reliable method (Bassili & Fletcher, 1991; Jakopin et al., 2017).

Validity Assessment Method

The tasks selected for the experiment were reviewed by the researcher and the SME. The SA questions using the SPAM Approach were developed by the researcher with the guidance of two of ERAU's senior aircraft maintenance professors based on the tasks selected for the experiment. The questions also were reviewed by an expert in SA. The performance score was constructed based on the AMM.

Summary

This chapter explained the conducted methodology section of the study. Sixteen participants performed safety wire locking and engine fan blade removal tasks, in a total of four conditions that lasted between 10 – 15 minutes with 5-minute intervals. The four environmental conditions: high time pressure with low noise background (10Low), high time pressure with high noise background (10High), low time pressure with low noise background (15Low), and low time pressure with high noise background (15High).

A series of four SA questions were asked during all tasks through prerecorded audio, and participants' verbal answers were recorded to measure their response time. The number of correct answers given was used to measure accuracy. A 10-point performance rating measured participants' performance by the SME. A NASA-TLX questionnaire was used to measure participants' perceived workload for each condition. Both objective and subjective measurements were analyzed using a statistical software tool and presented in Chapter IV.

Chapter IV: Results

This chapter presents the statistical findings based on the research methodology comprising demographics results, descriptive statistics, and quantitative data analysis results. The results showed that time pressure and noise levels have varied effects on AMTs' SA, performance, and perceived workload during maintenance task performance.

Demographics Results

A convenience sampling was used to select participants from ERAU's AMS students. A total of 16 male participants were recruited students majoring or minoring in AMS.

Descriptive Statistics

The objective measures of SA and performance and subjective measures of workload were collected in the experiment. Measurement for SA included accuracy and time response score in answering SA questions as shown in Table 4 and Table 5, respectively. Measurement for performance was the SME 10-point performance evaluation scores. Measurement of workload was collected from the NASA-TLX scores (see Table 6).

Table 4

Means and Standard Deviations for SA Question Accuracy

Variable		*M*	*SD*
10 Minute	Low Noise	2.75	1
	High Noise	2.44	.96
15 Minute	Low Noise	2.63	.62
	High Noise	2.38	.62

Table 5

Means and Standard Deviations for SA Question Response Time

Variable		*M*	*SD*
10 Minute	Low Noise	3.95	2.93
	High Noise	3.41	1.91
15 Minute	Low Noise	5.87	10.91
	High Noise	5.32	7.79

Table 6

Means and Standard Deviations of Workload in Different Time Pressure

Variable		*M*	SD
Mental	10-Minute	48.13	19.42
	15-Minute	39.43	17.59
Physical	10-Minute	45.16	22.11
	15-Minute	43.13	23.08
Temporal	10-Minute	73.91	13.81
	15-Minute	45.16	24.64
Performance	10-Minute	42.34	30.20
	15-Minute	52.50	19.45
Effort	10-Minute	62.66	17.31
	15-Minute	48.91	15.44
Frustration	10-Minute	49.22	20.08
	15-Minute	37.50	16.15

Quantitative Data Analysis

Ten hypotheses were tested in this research study. Within-subject factorial ANOVAs were conducted to determine if there were any statistically significant differences in aircraft maintenance technicians' working performance, SA levels, and workload in different noise levels and time pressure conditions.

Hypothesis Testing Results

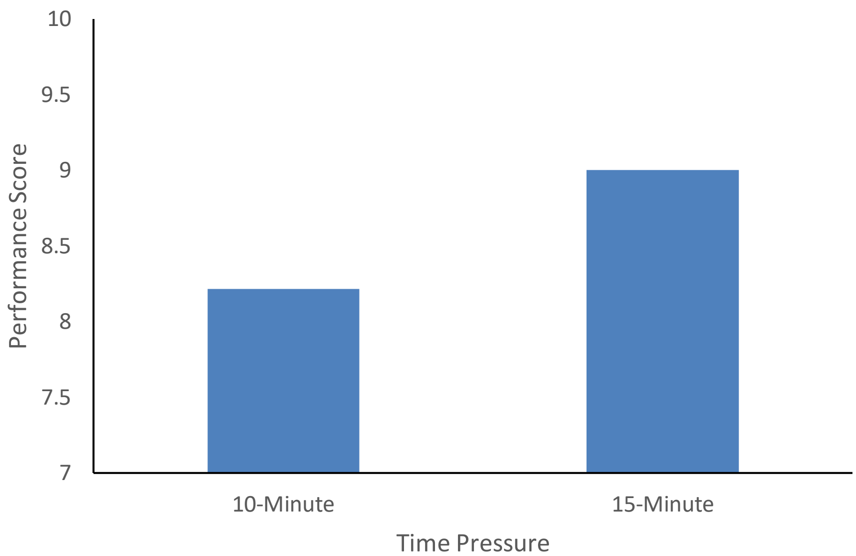
Performance

Performance was objectively measured based on the procedure completion evaluation score done by the SME. There was a 10-point checklist for each task, including the step performed and the correct tools used by the participants. Participants obtained one point for each item performed.

A 2 x 2 factorial ANOVA was conducted to determine the effect of different noise levels and time pressure on participants' performance. The results showed no significant interaction between noise levels and time pressure, $F(1, 15) = .097$, $p = .76$. There was also no significant main effect of noise levels found, $F(1, 15) = .296$, $p = .595$. However, there was significant main effect of time pressure, $F(1, 15) = 5.054$, $p = .04$, $\eta^2 = .252$ (see Figure 5).

Figure 5

Main Effect of Time Pressure on Performance



Therefore, for the hypotheses H_1, there is no significant effect on an AMT's performance under different levels of noise environments; and for H_3, there is no significant interaction effect between noise and time pressure in terms of performance; were retained, however, H_2 was rejected. There was a significant difference in AMTs' performance between the two time pressure conditions.

SA

Four relevant SA questions were asked during task performance in each condition. The accuracy and response time were recorded as SA measurements. The response time was only collected for the questions correctly answered. A 2 x 2 factorial ANOVA was conducted to compare the main effects of noise levels and time pressure effect as well as their interaction effect on the accuracy and response time of answers.

Accuracy. For each correct question answered, a score of 1-point was given for accuracy scores (a total of 4 points for each condition). The main effect of time pressure was not statistically significant, $F(1, 15) = .245$, $p = .628$. The main effect of noise levels was also not statistically significant, $F(1, 15) = 2.537$, $p = .132$. There was also no significant interaction found between noise levels and time pressure, $F(1, 15) = .027$, $p = .872$.

There was a negative skewness in the statistic result for the accuracy. After removing a participant who was two *SD* below the mean, ANOVA was re-run and found there was still no significant difference between two noise level conditions but it approaches significance, $F(1, 14) = 3.415$, $p = .086$.

Response Time. Response time was measured in a unit of milliseconds. The time was measured between the end of the question and the time participants gave a correct answer. A 2 x 2 ANOVA was conducted to determine the effect of noise levels and time pressure on participants' response time and showed no significant results. The main effect of time pressure was not statistically significant, $F(1, 15) = 1.422$, $p = .252$. The main effect of noise levels was also not statistically significant, $F(1, 15) = .097$, $p = .76$. There was no significant interaction found between noise levels and time pressure, $F(1, 15) = .000$, $p = .996$.

Therefore, all three SA hypotheses were retained. For H_4, there was no significant effect on AMTs' SA under different levels of noise environments. For H_5, there is no significant effect on AMTs' SA under different levels of time pressure. For H_6, there is no significant interaction effect between noise and time pressure in terms of SA.

Workload

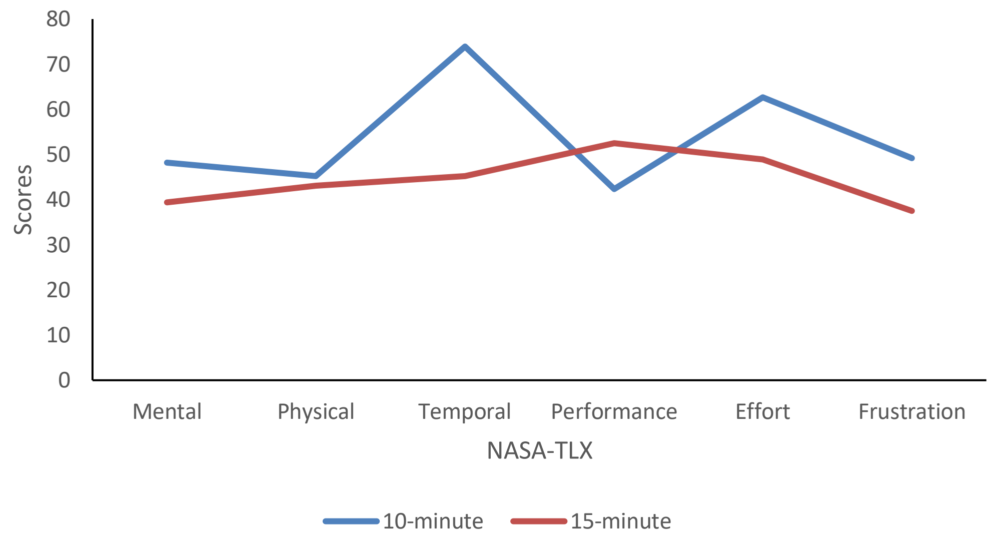
Subjective measurement of NASA-TLX was used to measure participants' perceived workload. After the completion of each condition, participants completed the NASA-TLX form. NASA-TLX has six subjective sub-scales, and each one is based on a 21-mark scale. Each space between two marks represents 5 points. The highest score obtainable is 100 points.

According to Mauchly's test of sphericity, the assumption of sphericity for the three-way interaction was violated, $\chi^2(14) = 24.47$, $p = .043$. Because Mauchly's sphericity test was violated for the workload, $\chi^2(14) = 35.054$, $p = .002$, the Hyunh-Feldt was applied for correction. The results of 2 x 2 x 6 factorial ANOVA showed that the interaction between workload, time pressure, and noise levels were not significant, $F(3.417, 51.252) = 1.988$, $p = .12$. The main effect of time pressure and workload were found to be significant, $F(1, 15) = 16.370$, $p = .001$, $\eta^2 = .522$ and $F(3.191, 47.867) = 2.957$, $p = .039$, $\eta^2 = .165$, respectively.

No significant main effect was found for noise levels, $F(1, 15) = .813$, $p = .381$. The Mauchly's sphericity test was also violated for the interaction between time pressure and workload, $\chi^2(14) = 41.753$, $p < .001$; and the interaction between noise levels and workload, $\chi^2(14) = 49.567$, $p < .001$, thus the Hyunh-Feldt was applied for correction. A significant interaction was found significant between time pressure and workload, $F(2.456, 36.844) = 6.112$, $p = .003$, $\eta^2 = .290$ (see Figure 6). However, the interaction between noise levels and workload was found not to be significant, $F(2.31, 34.657) = 2.307$, $p = .108$. There was also no significant interaction between time and noise levels, $F(1, 15) = 1.086$, $p = .314$.

Figure 6

Interaction between Time Pressure and Workload



A paired-sample *t*-test (see Table 7) was conducted to examine the differences in the effect of time pressure on each NASA-TLX sub-scale. Bonferroni correction was conducted to protect from Type 1 Error. The new *p*-value will be the alpha-value (α = .05) divided by the number of comparison (3): (α = .05/3) = .017. To determine if any of the three correlations were statistically significant, the *p*-value must be $p < .017$. Based on the Bonferroni adjustment, participants reported temporal demand and effort to be higher in the time pressured condition compared to the no time pressure condition.

Table 7

Paired Samples t-Test between Workload and Time Pressure

	t	df	p
Mental Demand	2.621	15	.019
Physical Demand	0.574	15	.574
Temporal Demand	4.721	15	< .001
Performance	-1.378	15	.188
Effort	2.847	15	.012
Frustration	2.180	15	.046

Therefore, for hypothesis H_7, there is no significant effect on AMTs' workload under different levels of noise environments; and for the H_8, there is no significant interaction effect between noise and time pressure in terms of workload; were retained while for H_9, it was rejected. Participants perceived different workloads between time pressure conditions and no time pressure conditions. As for hypothesis H_{10}, it was retained as there was no significant interaction effect between workload, noise levels, and time pressure.

Summary

Two out of 10 hypotheses, H_2 *and* H_8, were rejected based on the statistical findings. There were significant effects on AMTs' performance and workload under greater time pressure. Participants performed poorly in rushed times and were unable to complete the tasks thoroughly and they felt pressured to complete the task in a rush when a time limit was imposed. Even though the tasks had similar difficulty levels, participants perceived increased effort in time-constrained situations. The time pressure effect also urged participants to perform the task in a hurry to get the task done. A discussion of the findings, including the possible recommendation for future research, are presented in the next chapter.

Chapter V: Discussion, Conclusions, and Recommendations

The objective of this study was to assess the effect of noise levels and time pressure on AMTs' performance and SA in a line setting environment. The perceived workload in performing tasks in different conditions was also observed. Based on the statistical findings of the current research, a comprehensive discussion and conclusion, as well as recommendations for future studies, are presented in this chapter.

Discussion

The participants' performance, SA, and workload were differently affected by noise levels and time pressure. While there was no significant effect on noise level, the time pressure significantly affected participants' performance, SA, and perceived workload. Participants tended to omit maintenance steps and used the wrong tools under time pressure. Participants also perceived a higher temporal demand and effort on high time pressure conditions which construe a higher workload. However, participants' answer accuracy scores response time for the SA questions were similar throughout four conditions. Participants also perceived higher temporal demand and applied more effort in high time pressure conditions.

Performance Measure

It is crucial for AMTs to perform maintenance tasks according to the AMM and use the correct tools to avoid aircraft damage. Participants' performance was observed on their overall performance in completing a maintenance task in different environmental conditions. Participants were not affected by the background noise. However, greater time pressure contributed to lower performance. Participants tended to miss maintenance steps and were unable to finish the task in time-constrained conditions. They were also inclined to use the wrong tools. This finding is substantiated by the NASA-TLX scores, where the participants perceived they had performed poorly under higher time pressure.

SA Measures

Three main principles of SA – perception, comprehension, projection – were considered in designing the SA questions. Participants were asked about the overall task they performed that included understanding the tasks they were going to perform, the task progresses, and the decision-making on the proceeding steps. There were two types of maintenance tasks involved in the four conditions. The results showed no significant difference in both response time and answer accuracy. The projected probable cause for the insignificant obtained result may be the tasks designed for this study. Because the procedures of the tasks were relatively straightforward, the participants were able to perform the tasks with high awareness of the situation despite changes in time pressure and noise levels.

Workload Measure

The NASA-TLX self-evaluation outcome showed that participants perceived higher temporal demand and effort, in a time-pressured environment. Time pressure affects participants' perception of workload. They felt the task performed in a shorter time frame than the longer allocated time was temporally demanding and exerting even though they were identical tasks. (Briker et al., 2021). The participants felt urged to complete a task hurriedly and hastily in a shorter allotted time environment. The participants also perceived the need to put more effort when they were rushed to finish a task. They felt more insecure, discouraged, irritated, stressed, and annoyed in a time-pressure environment.

Conclusions

This study imparted valuable findings of the different noise levels and time pressure on AMT students completing tasks in a simulated line maintenance work setting and how they influence participants' performance and SA. The present study is consistent with the results of previous studies regarding a working environment suggesting time pressure effect should be taken into account in analyses contributing factors to aircraft maintenance error. Even though occupational noise and time pressure are unavoidable in the line maintenance work environment, this study's finding provides insight into the conditions that had the most effect on AMTs performance, SA, and workload. This study can be used as a basis for aircraft maintenance training, maintenance planning, AMTs work schedule, and design maintenance facilities. Aircraft maintenance is a complex task and requires high cognitive performance.

Noise levels were found not to have significant differences in effect on performance, SA and perceived workload. This study corroborates with Golmohammadi et al. (2020), where the difference in noise levels does not seem to significantly affect perceived performance levels compared to the type of noise. It may also be caused by constant noise throughout each condition. Even though the noise levels were different, the sound was constant. A recent study found exposure to intermittent noise alters cardiovascular physiological functioning in conscious rats (Hazari et al., 2021). The participants may have acclimated to the constant sound; thus the different sound levels do not alter their performance, SA, or perceived workload.

Theoretical Contributions

Previous studies have evaluated the effect of occupational noise and time pressure and how it affects work performance and individual SA. The current study fills the gap to determine how noise levels and time pressure affect aircraft maintenance technician performance and SA. It can be concluded that time pressure is more likely to increase AMTs' perception of workload and reduce work performance than noise levels.

Practical Contributions

As the global aviation industry is rapidly recovering from the unexpected halt due to the COVID-19 pandemic, an increase in maintenance pressure is anticipated. AMTs shortage paired with high flight demands will increase the risk of work time pressure. Maintenance operators must project and construct an enhanced aircraft maintenance plan to circumvent the time pressure effects on a line maintenance work environment

Limitations of the Findings

Three limitations were found that influence the generalizability of the results. First, the generalizability of the findings may be limited due to a less experienced sample. Second, simulated noise type, sound level, and exposure duration may differ from the actual line maintenance working environment. The last limitation was that the aircraft parts used in the study do not necessarily represent their actual location on the aircraft as they were used for education purposes.

Recommendations

While the current findings imparted the evaluation of noise levels and time pressure on aircraft maintenance technicians' performance and SA, it highlights theory and practical recommendations applicable in the aviation industry and potential follow-up research. It has also proposed a number of interesting suggestions to facilitate future research.

Recommendations for the AMTs

Identifying the effects contributing to AMTs' low SA and performance is vital to diminish human factor error (Rybalkina & Enikeev, 2021). According to the current study's findings, it is recommended a line maintenance operator should develop practical solutions to reduce time pressure on AMTs' work nature. This improvement can be achieved with better maintenance work and shift scheduling, aircraft maintenance planning, and improved maintenance system operations. Operators need to implement periodically structured technical training for AMTs to retain technical knowledge. Training helps AMTs revitalize knowledge and reduce the chance of committing mistakes (Zimmerman, 2011).

Recommendations for Future Research Methodology

Based on the limited findings of the current study, there are several suggestions for new or improved research methods, procedures, and analysis techniques that can be applied for possible future studies. Aircraft maintenance tasks vary in difficulty based on the complexity and location of the aircraft parts that need to be worked on. Different levels of difficulties could be put into consideration in designing future research methods. Furthermore, performing aircraft maintenance tasks at the aircraft part's actual location on the aircraft might have distinct findings.

Recommendations for Future Research

There are innumerable causes of decreased performance and increased workload, especially in line maintenance settings, which are insufficiently explored. Although the recent study outcomes showed low performance and high perceived workload in time pressure conditions, it is unknown if their experience and knowledge level in the technical field influenced the result. The future research sample could acquire a broader sample size with a distinct demographic background to observe the contributing factors. The number of experience in aircraft maintenance and level of skill may have a different response to noise and time pressure. Apart from occupational noise levels, it would be worthwhile to investigate different types of noise and exposure duration when studying noise effects on AMTs' performance and SA.

Due to the small female population of maintenance students in ERAU, the sample selected in the study was all-male participants. Studies found that males and females respond differently in behavior towards conflict and pressure, so gender demographics may contribute to different findings. (McElwain et al., 2005; van der Graaff et al., 2017, 2018). Sex or gender differences in the health effects of environmental noise exposure studies from the year 2000 to 2020 were inconsistent (Rompel et al., 2021). However, a recent study from Gogokhia et al. (2021) found gender differences in anxiety response to high intensity white noise exposure. Future research should consider gender as the factor to assess the effect of noise and time pressure.

Shift work in aircraft line maintenance is a common practice; this can be included as a possible variable in determining the cause-effect in AMTs' performance and SA. Shift work effects on performance and physiology are widely observed (Aslam et al., 2021; Farquhar, 2017; Moreno et al., 2019); however, its effects on AMTs' SA are not extensively explored.

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Appendix A

Permission to Conduct Research

Embry-Riddle Aeronautical University
Application for IRB Approval
EXEMPT Determination Form

Principal Investigator: Syaza Raehah Mohamad Haris

Other Investigators: Dr. Andrew Dattel, Mitchell Geraci

Role: Student **Campus:** Daytona Beach **College:** Aviation/Aeronautics

Project Title: The Effect of Noise and Time Pressure on AMT Performance and Situation Awareness in Line Maintenance

Review Board Use Only

Initial Reviewer: Teri Gabriel **Date:** 09/03/2021 **Approval #:** 22-015

Determination: Exempt

Dr. Beth Blickensderfer
IRB Chair Signature: ____________________

Brief Description:

This study explores if aircraft maintenance technicians (AMTs) experience changes in performance and situation awareness (SA) level in different background noise and time pressure intensity. Discovering environmental thresholds may alleviate human error risks through safety regulations and improve maintenance human resources scheduling. Different noise levels and time pressure on performance and SA will be assessed in performing aircraft maintenance tasks. The severity of noise and time pressure interaction will also be observed to better understand the contributing factors that increase human error risks.

This research falls under the **EXEMPT** category as per 45 CFR 46.104:

☑ (3)(i) Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the following criteria is met: (Applies to Subpart B [Pregnant Women, Human Fetuses and Neonates] and does not apply for Subpart C [Prisoners] except for research aimed at involving a broader subject population that only incidentally includes prisoners.) (Does not apply to Subpart D [Children])

☑ (A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;

☑ (B) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or

☐ (C) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a **Limited IRB review** (use the Limited or Expedited Review form) to make the determination.

Appendix B

Data Collection Device

B1 Task Completion Checklist

B2 SA Question Response Time and Accuracy Form

B3 NASA-TLX Questionnaire

B4 Consent Form

Appendix B1

Task Completion Checklist

Task Completion Checklist

Participant ID: ______________________________

Safety Wire Simulation:		
1	Remove the wire on the band clamp.	
2	Perform safety wire lock on the band clamp.	
3	Make three wire loop.	
4	Remove the wore on the two bolt.	
5	Perform safety wire lock on the two right-turn bolt.	
6	Make a correct twist direction.	
7	Remove the wire on the two bolt.	
8	Perform safety wire lock on one right-turn bolt to the anchor.	
9	Make a correct twist direction.	
10	Use the safety wire twister	

Engine Blade Simulation:		
1	Remove nuts on the front segment.	
2	Remove front segment and safely place it on workstation.	
3	Remove the 14 nuts holding the rear segment.	
4	Carefully slide out the rear segment and place it on the work station.	
5	Remove 10 bolts on the access panel.	
6	Use the pin extraction tool to remove the pin.	
7	Carefully remove the blade and place it on the workstation.	
8	Does the participant use the correct size of tool? (1/4")	
9	Does the participant use universal adapter to remove the rear segment?	
10	Does the participant use extension when necessary?	

Appendix B2

SA Question Response Time and Accuracy Form

SITUATION AWARENESS DATA

Participant ID: ____________________

Simulation 1: APU

	Question	Response time
1.	What is the line with blue & red placard label? **(pneumatic)**	
2.	What wrench size would be need to tighten the band clamp? **(7/16")**	
3.	Is it possible to do 2-bolt locking instead of 3? (YES/**NO**)	
4.	How many bolts are you tying together? **(two)**	

Simulation 2: CFM-56 (Gearbox)

	Question	Response time
1.	What is the name of the green component below the band clamp you are working on? **(Heat Exchanger Oil Fuel)**	
2.	What is the safety wire size diameter? **(0.032)**	
3.	Is it possible to do 2-bolt locking instead of 3? (**YES**/NO)	
4.	Which direction is your twisting? (LEFT/**RIGHT**)	

Simulation 3: Fan Blade #1

	Question	Response time
1.	What socket size are you using? **(¼")**	
2.	Is it a right or left turn bolt? **(RIGHT)**	
3.	Do you see any FOD? (YES/**NO**)	
4.	Does the PIN have the correct part number? (YES/**NO**)	

Simulation 4: Fan Blade #10

	Question	Response time
1.	What part are you removing now?	
2.	What blade number are you removing? **(3)**	
3.	How many bolts securing the panel to fan cowl? **(10)**	
4.	Does the FAN BLADE have the correct part number? (**YES**/NO)	

Appendix B3

NASA-TLX Questionnaire

Figure 8.6

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

Appendix B4

Consent Form

INFORMED CONSENT FORM

Participation on The Effect of Noise and Time Pressure on AMT Performance and Situation Awareness in Line Maintenance Tasks

Purpose of this Research: I am asking you to take part in a research project for the purpose of assessing environmental effects on aircraft maintenance technician (AMT)'s performance and situation awareness (SA). During this study, you will be asked to complete a safety wire locking task in four different noise backgrounds and time limits. A series of questions will be asked during task completion and you will be asked to complete a self-assessment survey upon each set of experiments. The completion of the experiment will take approximately 70 minutes. This experiment will be video recorded using a Gopro.

Risks or discomforts: The experiment involves simulation of loud noise which may cause annoyance and discomfort. You will be asked to wear a ground maintenance headset at all times during the experiment. The noise used in this experiment is lower than the Occupational Safety and Health Administration's permissible eight-hours for 85db exposure. The risk of participating in this study will be minimal.

Benefits: While there are no benefits to you as a participant, your assistance in this research will help alleviate human factor risk through safety regulation improvement and workforce scheduling in aircraft maintenance.

Confidentiality of records: Your individual information will be protected in all data resulting from this study. Your response to this experiment will be confidential. No personal information will be collected. In order to protect the confidentiality of your responses, I will keep your responses and video recording in a password-protected file on a password-protected computer. No one other than the researcher will have access to any of the responses. Information collected as part of this research ***will not be used*** or ***distributed*** for future research studies.

Compensation: You will be paid $25 for completing the experiment. Only those who complete the experiment will be paid.

Contact: If you have any questions or would like additional information about this study, please contact Syaza Haris, mohamads@my.erau.edu, or the faculty member overseeing this project, Dr. Andrew Dattel, dattela@erau.edu. For any concerns or questions as a participant in this research, contact the Institutional Review Board (IRB) at 386-226-7179 or via email teri.gabriel@erau.edu.

Voluntary Participation: Your participation in this study is completely voluntary. You may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Should you wish to discontinue the research at any time, no information collected will be used.

CONSENT. By signing below, I certify that I am a student of Embry-Riddle Aeronautical University, above 18 years old and majoring in Aircraft Maintenance Science; understand the information on this form, and voluntarily agree to participate in the study.

Signature of Participant:________________________________Date: _________________

Printed Name of Participant: _____________________________

VIDEO RECORDING:

- ☐ **I agree** that the video recording can be used in publications or presentations.
- ☐ **I do not agree** that the video recording can be used in publications or presentations.

Appendix C

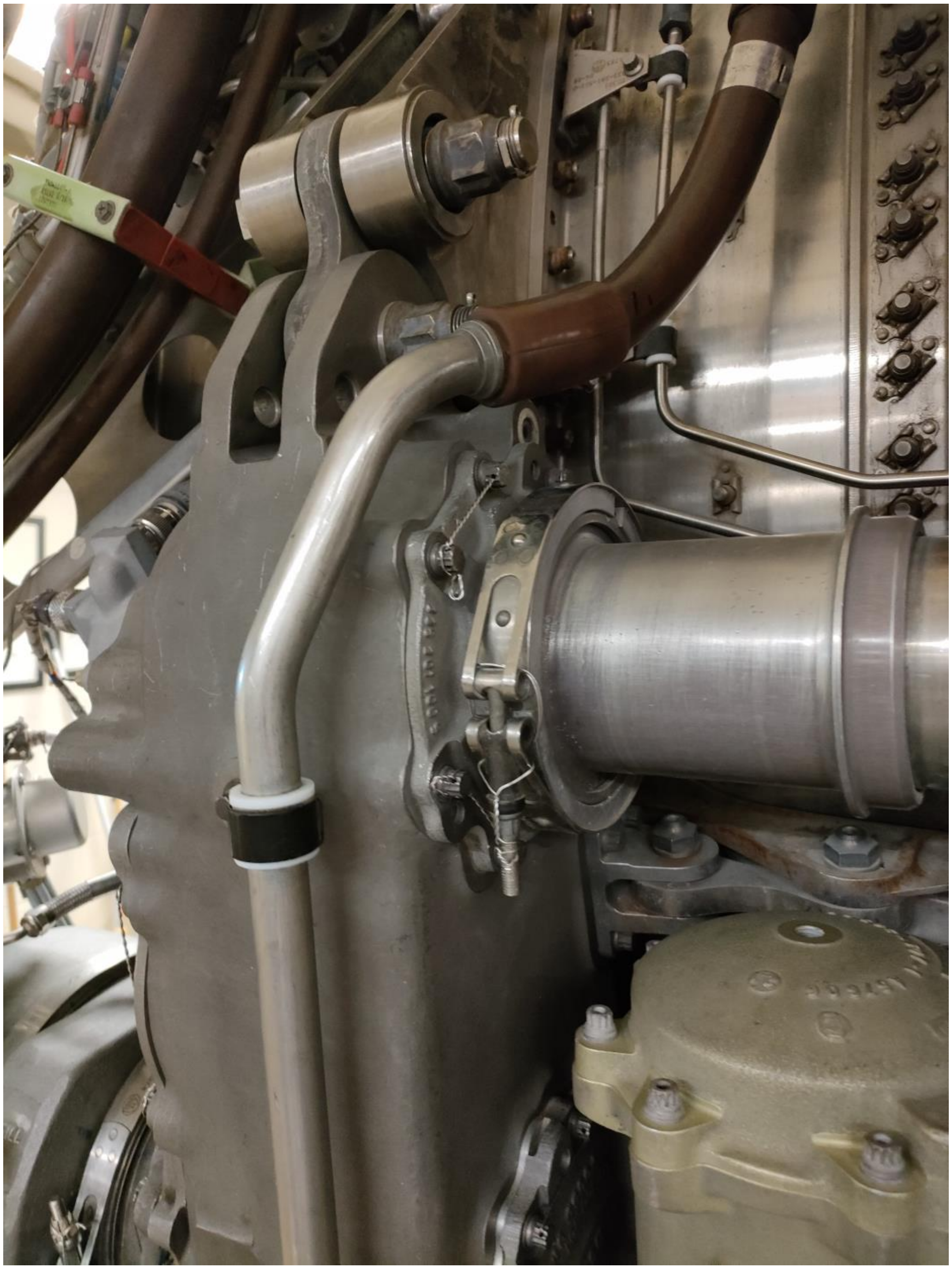
Figures

Appendix C1

APU Safety Wire Lock Task

Appendix C2

CFM Safety Wire Lock Task



Appendix C3

TF-34 Engine Blade Task