FACTORS INFLUENCING SKILL RETENTION IN MULTI-SKILLED
AIR FORCE AIRCRAFT MAINTAINERS

THESIS

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Abstract

The 2013 National Defense Authorization Act allows the Air Force Air Logistics Complexes (ALCs) to promote workers proficient in more than one trade by one pay grade. Multi-skilling is the term used to describe workers trained in more than one job. The United States Air Force wants to utilize multi-skilling at these ALCS, but the effects of implementation are still unknown. This research focuses on the identification of skill retention influences to better understand this multi-skilling through the use of a human subjects experiment at two Air Force bases. We examine the retention of aircraft mechanics' skill to evaluate the feasibility and consequences of initiating multi-skilling at the ALCS along with any traits correlating to higher levels of skill retentions.

Dedication

To Technical Sergeant John Knowles; the only person that worked harder on this research than I did. It was an adventure.

Jessica A. Salgado

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FACTORS INFLUENCING SKILL RETENTION IN MULTI-SKILLED AIR FORCE AIRCRAFT MAINTAINERS

I. Introduction

Background

The United States Air Force wants to utilize multi-skilling at the Air Logistics Complexes (ALC), but the effects of implementation are still unknown. The 2013 National Defense Authorization Act allows Navy, Air Force, and Army depots to promote aircraft maintenance workers proficient in more than one trade by one pay grade (Congress, 2013). Multi-skilling, or cross utilization, is the term used to describe workers being trained in more than one job type. Skill retention for individuals with more than one skill is the focus of my research. The National Defense Authorization Act enables multi-skilled personnel to be promoted; therefore our research focus is on the side effects of this decision in specific regards to skill retention rates in multi-skilled workers and identifying factors that influence skill retention.

Captain Wesley Sheppard in 2014 conducted research exploring Air Force Specialty Codes (AFSCs) that could be combined at F-22 depot maintenance to enable time and money savings for the Air Force. He recommended six AFSCs for combination for a potential savings of over 1 million dollars in overtime prevention. These six skills account for 97 percent of all maintenance requirements performed on the aircraft. One key assumption in this study was the workforce would maintain 100 percent proficiency in both specialty skill sets. However, once the simulation concluded, it found multi-

skilled workers could possess up to 5% skill degradation without losing the overtime savings (Sheppard, Johnson, & Miller, 2014). Our research examines this assumption and conclusion of skill proficiencies of the multi-skilled workforce. We are examining the tradeoffs of this decision.

The cost savings and time saving potential discovered by Captain Sheppard are exciting to Air Force Materiel Command, but the potential side effects should be examined. In this research, we examine the retention of aircraft mechanics' skill to evaluate the feasibility of multi-skilling at the ALCs along with any traits correlating to higher levels of skill retention. We will be searching for factors that influence skill retention. Knowing these factors enables Air Force Materiel Command and the Air Force to foresee some of the potential side effects of multi-skilling their depot maintenance workforce.

Problem Statement

Understanding skill retention rates in workers is vital to mission success. Knowing the output of a workforce enables managers to make better decisions in regards to manpower and scheduling. The dynamic of this workforce has just shifted based off the 2013 National Defense Authorization Act and now must be studied to see how this new workforce will perform. This is a perfect opportunity to evaluate the influential factors for skill retention with this change. Aircraft maintenance depot level workers are allowed to be promoted one pay grade if multi-skilled in an effort to optimize their workforce. This research focuses on the identification of skill retention influences to help improve workforce management decisions.

Research Objectives and Questions

There are two ways of measuring skill retention: recall and recognition (Stothard & Nicholson, 2001). We examine both recall and recognition when it comes to our research subjects and see if there are any other background characteristics that might influence skill retention levels. The Learning Curve (or its inverse, the Forgetting Curve) applies depending on how much or how little knowledge is retained depending on experience levels. This Learning Curve differs depending on the task type. We seek to explore the Learning Curve using specific maintenance tasks in the results of our research.

Research Question 1: Is skill retention a function of the time that has passed since a person has last accomplished the task?

Research Question 2: Is skill retention influenced by whether a person possesses one skill or is multi-skilled?

Research Question 3: Is skill retention influenced by task repetition?

Research Question 4: What personal background characteristics lead to higher retention rates in personnel?

Research Focus

Our research focus is to identify various factors that influence skill retention in aircraft maintenance personnel. We narrowed our research to one set of AFSCs Captain Wesley Sheppard's thesis recommended for combination at the F-22 depot: low observable and sheet metal aircraft maintenance technicians. Select Air Force active duty personnel are multi-skilled (proficient in both low observable and sheet metal), while the

majority are not. The goal of our research is to compare performance with factors that may influence skill retention. The factors we explored include:

- The amount of time that has passed since the task was last accomplished
- Armed Services Vocational Aptitude Battery (ASVAB) scores
- Single or multi-skilled status
- Demographical information (age and gender)
- Grades from technical training school
- The number of times this task has been performed in the past year
- The amount of experience (months and years) in that career field

Methodology

We designed and conducted a human subjects experiment to test skill retention in the low observables, sheet metal, and multi-skilled technicians in an attempt to identify influential factors of skill retention in depot maintenance technicians. We conducted the experiment at the 388th Equipment Maintenance Squadron at Hill Air Force Base, Utah and the 33rd Maintenance Squadron at Eglin Air Force Base, Florida. Both bases support the F-35 Joint Strike Fighter aircraft. Eglin possesses 27 Air Force F-35s while Hill received their first two Air Force F-35s five days prior to the start of the experiment. The differing level of operational capacity of the F-35 units was intentional on the part of the researcher since it helped the sample size mirror the career field. Eglin Air Force Base was the first operational unit for the F-35 and Hill Air Force Base was not yet operational when the experiment started.

The human subjects experiment was quantitative in nature. The Career Field Education and Training Plan outlines every task qualified low observable and sheet metal technicians accomplish. The critical tasks, commonly referred to as core tasks, were identified and selected from both career fields to evaluate in a human subjects experiment. Each experiment subject was assigned a core task in their specific AFSC. They were timed and their finished product was graded on a Likert scale from 1-10 for quality. Multi-skilled technicians were given both the low observable and sheet metal tasks and were timed and graded upon completion. The data was then compared to measure proficiency in multi-skilled versus single-skilled aircraft maintenance technicians.

Assumptions/Limitations

The assumptions of this research are that all information provided by the experiment subjects is accurate and that the tasks at technical training are all taught to the same degree to all subjects in the experiment. We also assumed to have gathered the correct data that would influence skill retention.

The current limitations are the sample size and their demographical information. Any variance from the population will be included in the data analysis.

Implications

This research is an effort to better understand skill retention influences and is one of the first to explore these factors using a multi-skilled populace. It will aid workforce optimization decisions for the aircraft maintenance workforce. This will be another

analysis of the effects certain factors personnel can have on a workplace environment that affects productivity. Industry will be able to understand how numerous skill sets affect an employee and the expected levels of productivity and efficiency.

II. Literature Review

Chapter Overview

The review of literature for this study included a background of multi-skilling, technical training, retention, possible variables for retention, and past analytical work in retention studies. This review will begin with a description of multi-skilling and the reasons for its Air Force focus. It will then cover the common background of technical training for all experiment subjects. Finally, retention and retention variables will be discussed with an examination of prior research in this field.

Background on Multi-skilling

Multi-skilling is the practice of employing a worker who possesses more than one trade in the workplace (Congress, 2013). Training or promotions can achieve a multi-skilled workforce internally, while hiring multi-skilled employees achieves a multi-skilled workforce externally. The intent of multi-skilling is to increase the flexibility of the workforce while eliminating downtime and decreasing overtime. Employees with more than one skill may have higher utilization.

The different types of multi-skilling provided by Horbury & Wright (2001) include:

- Vertical multi-skilling: supervisor tasks are learned by individuals

- Horizontal multi-skilling: skills from another discipline are learned

- Depth multi-skilling: more complex, specific skills within a trade are acquired

The types of multi-skilling (vertical, horizontal, or depth) examined in this study were horizontal and depth multi-skilling. Some technicians will go from low observable to acquire sheet metal or vice versa. This is an example of the horizontal multi-skilling, while they are still advancing through their certifications for both the primary and secondary skill- which is the depth multi-skilling. The multi-skilled personnel evaluated acquired an additional skill (horizontal) but also gained a deeper understanding of each of their career fields in doing so (depth).

Past Work on Multi-skilling

The area of multi-skilling has been examined for potential cost savings and increased workforce utilization. In 2014, Captain Wesley Sheppard examined the potential Air Force career fields to be combined for the Ogden Air Logistics Complex (ALC). He conducted a computer simulation to examine the benefits of multi-skilling the aircraft maintenance workforce at the F-22 Raptor depot speedline. The simulation resulted in the recommendation to combine the low observable career field with sheet metal, the aircraft general (crew chiefs) career field with electricians, and fuels technicians with avionics career field (Sheppard, Johnson, & Miller, 2014). Our study focused on the first career field combination recommended of low observable technicians and sheet metal technicians. Captain Joshua Isom (2015) stated efficiency can drop as low as 5 percent in a multi-skilled environment and still outperform overtime policies. This research focuses on whether that 95 percent job proficiency can be maintained by multi-skilled personnel.

Technical Training

A vital aspect of multi-skilling is the acquisition of a skill. A member of the United States Air Force completes technical training and graduates as an apprentice (3-level) in their respective career fields prior to heading to their first duty station. In technical training, these future low observable and sheet metal technicians learn core tasks necessary for job accomplishment.

The low observable career field (2A7X5) members attend training consisting of 608 instructional training hours in 76 days at Naval Air Station Pensacola, Florida. The research population that attended this training learned composite repairs, fabrication, corrosion control, and low observables (aircraft coatings on stealth aircraft). They also successfully passed an academic examination and physical project as a graduation requirement (Svendsen, 2015).

The sheet metal career field (2A7X3) members complete a 560-hour course in 70 days at Naval Air Station Pensacola, Florida. Sheet metal technicians design, repair, fabricate, and aircraft, metal, composite, plastic advanced composite, low observables, and bonded structural components (Svendsen, 2015). Students also passed an academic assessment and physical project to ensure competency and to fulfill graduation requirements.

Technical training will be the common baseline for all personnel studied. The training will provide the tasks to be assigned and completed during the experiment. This baseline of technical training is a fundamental component in the analysis, because it aids in determining retention levels (Stothard & Nicholson, 2001). The tasks will include parts of the project each maintenance technician completed during technical training.

Skill Retention

Once a skill is learned, the passage of time results in skill degradation (Stothard & Nicholson, 2001). Retention is the ability to continue possessing the cognitive capability to accomplish a task. The learning curve (or "power law of learning"), shown in Figure 1, is the graphical representation of a human's ability to learn and the amount of experience necessary to retain that information. The forgetting curve, shown in Figure 2, applies to this skill acquisition and decay but in an inverse format of the learning curve.

Figure 1: The Learning Curve (Fletcher, 2013)
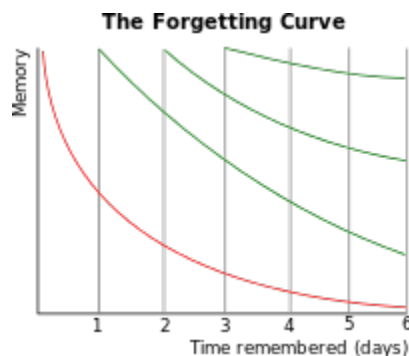
Figure 2: The Forgetting Curve (Wikipedia, 2007)

Numerous studies have been conducted on skill retention and decay. The Forgetting Curve highlights the decay of skills. It shows that the amount of information lost initially is quicker than the amount lost over the long run (Wisher, Sabol, Ellis, & Ellis, 1999).

An example of this is the common "brain dump" after an exam. Students have memorized the information for the test and then quickly forget what they memorized. In aircraft maintenance, there are tasks performed very frequently (daily) and some infrequent tasks (annually or never). The study focused on discrete, procedural tasks accomplished frequently and infrequently to judge skill retention levels. Discrete skills involve tasks with specified beginnings and ends to tasks. This is the case in almost all aircraft maintenance activities: they are discrete and procedural tasks. Studies have shown considerable skill decay in as little as a few weeks or months in these procedural tasks (Wisher, Sabol, Ellis, & Ellis, 1999). Task factors classified by the U.S. Army Research Institute for Behavioural and Social Sciences that affect retention are (Wisher, Sabol, Ellis, & Ellis, 1999):

1. Complexity (the number of steps in a task)

2. Significance of ordering (do the sequence of steps matter)

3. The nature of steps (are cognitive or motor skills required)

4. Feedback (is feedback present)

5. Presence of job or memory aids

Skill retention is measured in two ways; recall and recognition. All of the above factors will be judged based on recall and recognition (Wisher, Sabol, Ellis, & Ellis, 1999). Recall is an open-ended question given when the respondent must rely on their ability to remember. Recognition is like a multiple choice question, when the respondent can actually see the answer to prompt memory. The participant will display recognition when the task is given, and the right task must be referenced in the technical orders.

Recognition will also be utilized when the steps in the technical orders' step-by-step instructions are to be interpreted and completed by the technicians.

Skill Retention Variables

Skill decay is thought to be affected by time (Wisher, Sabol, Ellis, & Ellis, 1999), level of training (Boet et al., 2011) (Schendel & Hagman, 1980), and infrequency of task (Meyer et al., 2014). A more comprehensive list categorizing four broad areas thought to affect skill retention (Bryant & Angel, 2000) is:

1. Task

2. Training

3. Retention interval

4. Individual

The task involves task type (procedural), as well as the list provided by Wisher, Sabol, Ellis, & Ellis (1999) earlier, which includes task complexity, significance of ordering, the nature of steps, feedback, and the presence of memory aids. Training begins at technical training school, where the acquisition of skill is attained and practiced. Training can also take on several forms, such as annual refresher classes, simulation time, physical evaluations, or be less structured such as on-the-job training (OJT), advice from co-workers, or learning by doing. Retention intervals address the frequency of tasks. Finally, every individual is unique and may have different desired learning levels for certain tasks as well as cognitive abilities (Stothard & Nicholson, 2001).

Past Experiments

In preparation for the human subjects experiment, we accomplished an in-depth look for prior work in the field of assessing retention beginning with overtraining as a way to ensure skill retention. Certain military studies evaluated retention in soldiers and concluded that maintaining skills at a Minimum Readiness Proficiency required overtraining (Stothard & Nicholson, 2001). Overtraining soldiers is achieved when learning goes beyond one successful performance of the skill (Schendel & Hageman, 1980, cited in Stothard & Nicholson, 2001). By overtraining, the soldiers get an opportunity to store the skill in long-term memory, which encourages task automation (Stothard & Nicholson, 2001).

Both the military and civilian sector conducted studies to find way to enhance skill retention in workers. A meta-analysis conducted by Driskell, Willis, & Copper (1992) on overtraining, concluded that for overtraining to be effective, at least 50 percent overtraining was needed. Wisher, Sabol, Ellis, & Ellis (1999) focused on soldiers' retention levels and ways to reduce skill decay. They optimized refresher training, maximized original learning (training), testing during training, used task-oriented training, and encouraged peer tutoring for tasks (Wisher, Sabol, Ellis, & Ellis, 1999). The U.S. Army even developed a *User's Manual for Predicting Military Task Retention* to gauge degradation gaps in the workforce (Rose, Radtke, Shettel, & Hagman, 1985). Both military studies focused on training to minimize skill decay.

Studies in the civilian sector have attempted to overcome these skill degradations as well. The medical field conducted numerous studies in an effort to understand retention rates and the variables affecting them. An experiment was conducted to

determine if anatomical knowledge was retained at higher rates before or after clinical

work (Meyer et al., 2014). This experiment concluded that the teaching and application

of anatomy increased students' understanding.

Further skill retention studies focused on training intervals to see if annual

training requirements actually aided skill retention in workers. One study attempted to

determine the necessity of annual training requirements on emergency procedure

knowledge. This experiment involved team training in comparison to individual training,

lecture versus simulation training, and time lengths as variables. The researchers

discovered no significant difference based on training type or time on retention levels

(Crofts et al., 2013). However, Boet et al. (2011) concluded that simulation training

increased retention interval length in a study of anesthetists. An analysis of workplace

safety in multi-skilled environments concluded that training and assessments for multi-

skilling must be consistent for both skills to ascertain retention (Horbury & Wright,

2001).

Armed Services Vocational Aptitude Battery

All enlisted service members prior to admittance into the military take the Armed

Services Vocational Aptitude Battery (ASVAB) examination. This examination was first

introduced in 1968 and measures abilities and potential for future occupational success

(ASVAB Testing Program). The test has four categories: general, mechanical, electrical,

and administrative. Since this test is used to recruit and enlist military service members,

we used this as one of the potential factors to influence skill retention. The low

observable and sheet metal aircraft maintenance technicians took this examination and

based off their mechanical category scores were allowed to enlist in the structural maintenance career field.

Pertinent Factors

Based off this literature review, we have concluded the factors relevant to our skill retention analysis would include the amount of time that has passed since the task was last accomplished, age, gender, whether the individual was single or multi-skilled, their ASVAB scores, technical training scores, the number of times this task has been performed by the individual in the past year, and the amount of experience the individual has in that specific career field. All of these factors could be acquired through the execution of the experiment. All data was gathered through these means with the focus on these eight specific factors.

Hypothesis 1: Skill retention is a function of the time that has passed since a person last accomplished the task.

Hypothesis 2: Skill retention is influenced if an individual is single or multi-skilled.

Hypothesis 3: Skill retention is influenced by task repetition in a person.

Hypothesis 4: There will be personal background characteristics that lead to higher retention rates in multi-skilled personnel.

Conclusion

The literature reviewed for this research included a background of what multi-skilling is and how it might be utilized, the role technical training plays in developing low observable and sheet metal technicians, a description of retention, the variables currently

thought to affect retention rates, and some examples of related work pertaining to

individuals' skill retention whether it was in the military or civilian sector.

III. Methodology

Overview

The goal of this research is to compare skill retention rates of single (low observable or sheet metal technicians) or multi-skilled workers to help leaders determine workforce improvements. The first section of this chapter will explain experiment selection methodology, site selection, and subject selection while the second section addresses the methods of collecting and analyzing the data collected.

Experiment Decision

For the scope of this research, we decided on a human subjects experiment. This was necessary to gather the completion times and quality levels performance data. This data would be better gathered in a controlled experiment environment rather than after the fact. Secondly, an experiment would require both evaluator and subjects to take an active role in the study. This would demand the complete attention of the subject and would reduce the likelihood of the task being interrupted, subject getting distracted, or the task being low in priority. This would make our data less biased. Finally, an experiment was necessary to compare data from one career field to another because it ascertained all subjects underwent the same experiment process and environment to reduce the variability and confounding factors. This human subjects experiment is vital to the success of this research because it is one of the first experiments that include multi-skilled personnel with single skilled personnel to evaluate multi-skilling as a potential factor influencing skill retention. Please refer to Appendix A and B for the Internal Review Board (IRB) exemption memorandum and approval.

Career Fields Selected

Since this research is based off the work conducted by Captain Wesley Sheppard, his thesis recommendations were utilized as a starting point for which specific career fields to target for skill retention factors. His thesis recommended six career fields to be combined. They are as follows: aircraft mechanic (crew chief) and electricians, sheet metal and low observable technicians, and fuel and avionics technicians. The career fields of sheet metal and low observable technicians used to actually be combined and with more stealth (low observable-required aircraft), both career fields are growing. This ensured we had a sample size whereas the other recommended combinations have not been combined previously. Therefore, the experiment would be focused only on these two career fields.

Site Selection

Our focus is the low observable and sheet metal career fields so we searched for the bases supporting these two career fields simultaneously. Sheet metal aircraft maintenance technicians are located at any base with aircraft regardless of aircraft platform. However, low observable aircraft maintenance technicians are only present at bases with very specific aircraft platforms. These maintainers only work on stealth aircraft and the US Air Force has three aircraft platforms requiring low observable technicians. We selected one aircraft platform- the F-35 Joint Strike Fighter- and sought bases supporting this fighter jet. Hill Air Force Base readily agreed to participate in this experiment and Eglin Air Force Base swiftly followed.

The low observable and sheet metal sections fall under Fabrication Flight in the Maintenance Squadron. These two Fabrication Flights are ideal for data collection due to their mission. The Joint Strike Fighter Program is in its infancy at Hill Air Force Base;

therefore, it has gathered a myriad of personnel working all aircraft frames from all different bases and pooled them in one location to help establish maintenance capabilities. The experience levels will be quite representative of the population. Eglin Air Force Base has possessed F-35A aircraft for over a year and represents the more experienced F-35A demographic, since it has had time to establish a work routine and personnel to garner experience. Therefore, these two bases were selected as the sample populations and consented to a human subjects experiment during the month of September 2015. The researcher traveled to both bases while the evaluator was stationed at Hill Air Force Base and then traveled to Eglin Air Force Base with the researcher.

Site 1: Hill Air Force Base, Utah

The experiment took place at Hill Air Force Base 9-18 September 2015. Two F-35 aircraft had arrived two days prior; however, the aircraft maintainers had not yet started doing day-to-day maintenance on the aircraft and were still supporting the F-16 Fighting Falcon operations. The operations tempo was not heavy due to the buildup of manpower in anticipation of the F-35, but a lack of aircraft maintenance was occurring. In fact, management was eager for the experiment to take place due to the lack of job activities for their workforce. There were a higher number of sheet metal personnel than low observable personnel at this site.

Site 2: Eglin Air Force Base, Florida

Eglin Air Force Base differs greatly from Hill Air Force Base. This unit possesses 27 F-35 aircraft that have been meeting daily flying operations for over two years. Eglin was the first operational F-35 fighter wing and trains F-35 pilots. Another unique aspect of Eglin

Air Force Base is the joint environment. This is not only the training grounds for the Air Force F-35 pilots, but the Marines, Navy, and foreign military partners also have their F-35s on the same flightline with the Air Force. The Fabrication Flight possesses more low observable technicians than sheet metal due to the mission requirements placed on that section.

Low Observable Task Selection

The low observable task selected for the human subjects experiment at both Hill and Eglin Air Force Bases was an F-35 tape repair. This task was selected due to its frequency. It is a very common type of task on the aircraft and could be performed daily, but there are various types, places, and methods for tape repairs depending on the location of the damage on the aircraft. Both bases possessed aircraft training panels. These are flat surfaced panels used for training purposes that mimic the structure of panels on the F-35. Figure 3 is a picture of the training panel used during the experiment.
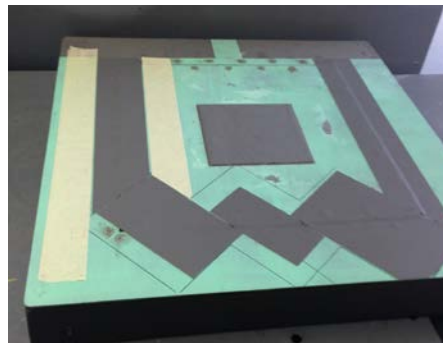
Figure 3: Training Panel

Sheet Metal Task Selection

The task selection for the sheet metal technicians differed greatly from the low observable task selection. Senior subject matter experts in the sheet metal career field

recommended this task. A scab patch is required when there is a hole in an aircraft that must be covered to ensure safety of flight. The task in its entirety is not done frequently. However, a sheet metal technician conducts the individual steps-riveting, measuring, and cutting metal-on a daily basis. This task offers some variability within its repair much like the low observable task, size of hole, damage, metal type, rivet type, and location. We selected this task due to its combination of daily tasks and variability mimicking the low observable task. The low observable section at Hill Air Force Base built a simulated aircraft structure (SAS) to be used during the experiment. All participants tasked with the sheet metal assignment conducted their scab patch on this SAS. A picture of the SAS is featured in Figure 4.

Figure 4. Simulated Aircraft Structure (SAS)

Evaluation Criteria

Performance was measured using completion time and quality. The planning and execution of the experiment shifted, based on past studies from Horbury & Wright (2001). This experiment concluded that training and assessments must be consistent for both skills in order to successfully implement a multi-skilled workforce. Treating both skills as equals assumes retention rates will be equivalent. The inclusion of prior experiences, as well as consistent evaluators for the maintenance tasks, is now an integral

part of the experiment. Based off this information, a task the low observable and sheet metal maintainers have conducted prior to the experiment is necessary.

The dependent measures were the objectives to achieve and those are task completion time and quality. Task completion time is the amount of time it takes for a subject to complete the task assigned. The time began after the individual was told what task they were going to complete and then stopped when the same individual finished that task. To measure quality, we developed a grading scale for each task. Technical Sergeant John Knowles developed our quality measure. He is a structural maintainer with over 12 years of experience. He was a technical training instructor for the structural maintenance course at NAS Pensacola. Grading uses a Likert scale ranging from 0-10. These requirements were taken directly from technical orders for each specific task. Table 1 and Table 2 show the grading criteria for each task.

Table 1. Quality Criteria for Low Observable Task

Quality of Tape Bond
Flushness over Panel Seam
Flushness over Fastener
Tape gap width/evenness
Planform Alignment
Appearance of Final Product

Table 2. Quality Criteria for Sheet Metal Task

Quality of Edge Distance
Quality of Rivet Spacing
Quality of Manufactured Heads
Quality of Shop Heads
Quality of External Skin
Quality of Internal Skin
Flushness of Patch

The independent data we collected are all factors we thought would influence skill retention in our sample population. The independent data are gathered administratively prior to the individual receiving their task assignment. The subjects answered a demographic questionnaire (Appendix D), which inquired about the following factors:

- Experience levels per individual

- Task frequency per individual

- Demographics per individual (age, gender, multi-skilled)

Along with the questionnaire from the experiment, the other potential factors were analyzed from technical training reports from the subjects' respective technical training schools and their Armed Services Vocational Aptitude Battery (ASVAB) scores. A sample of a technical training report with ASVAB scores is located in Appendix E. Each data record was per individual, as well as the experimental data gathered from the evaluator and researcher. The ASVAB scores from personnel records, and the training reports, came directly from the registrar at Sheppard Air Force Base, Texas.

Subject Selection

The selection of the sample population was vital to the success of the experiment. It needed to possess both low observable and sheet metal aircraft maintenance technicians. Subjects participated based off availability and mission requirements. Management really encouraged participation of their members and participated in the study themselves. The only individuals that did not participate were either on the flightline

working real world maintenance tasks or individuals that refused to participate (two in this category). The current populations of the career fields, and the experiment subjects from the 388th Equipment Maintenance Squadron and 33d Maintenance Squadron Fabrication Flights, are compared in the Table 3 below (Cannon, 2015).

Table 3. Populations and Sample Size of Aircraft Structural Maintenance Career Fields

Career Field	Air Force Population:	Experiment Population:
Sheet metal (2A7X3)	2,063	20
Low observables (2A7X5)	832	14

Experiment Procedures

The experiment occurred at Hill Air Force Base, Utah and Eglin Air Force Base, Florida between 9 September and 30 September 2015. It involved the sample size undergoing the treatment (tasks). There were three categories of workers: strictly low observable, strictly sheet metal, and multi-skilled. There were two procedural tasks: low observable and sheet metal. If the subject was multi-skilled, they were assigned both tasks to complete.

Technician   **Procedure**

Low observable technician→low observable-specific task

   Multi-skilled technician→low observable-specific task→sheet metal-specific task

    Sheet metal technician→sheet metal-specific task

The experiment took place in the same room per base with the same layout of all equipment necessary to perform the tasks (composite tool kits, materials, technical orders). The evaluator and researcher welcomed the subject and read a script with instructions to the subject. See Appendix E for experiment verbiage. Once the instructions were read, the participant received three documents to fill out and sign. The first document was the informed consent form (Appendix C). This informed consent mentioned that all risks are normal work procedures. The second document was the demographic questionnaire (Appendix D). This questionnaire asked for the individual's background, experience levels, age, gender, how many times in the past year the individual had performed a scab patch or tape insertion, and then when was the last time they had performed said tasks. The final document was a technical training records release form. The participant agreed for the Office of the Registrar at Sheppard Air Force Base, Texas to release their technical training records. A sample of this form can be found in Appendix F. Once all documentation was completed, the evaluator told the subject what task(s) to accomplish. At this time, the evaluator asked for questions. The individual had to locate the task in the technical orders and then performed that task to technical order specifications. Figure 5 depicts the experiment layout. The evaluator recorded how long it took the subject to perform that task. Once completed, the evaluator graded the completed task based off the grading criteria presented earlier in this chapter. The average amount of time for the low observable task was 3.55 hours and the sheet metal task average completion time was 1.5 hours.

Figure 5. Experiment Layout

Statistical Methodology

In order to test our hypotheses, multiple statistical analyses are necessary. We first used Microsoft Excel to create correlation tables for both low observable and sheet metal tasks. We then created stepwise multivariate models utilizing JMP. Once complete, we created statistical models using multivariate discriminate analysis.

H1: The more amount of time that has passed since a person last accomplished the task will negatively influence the quality of the task and will increase the individual's task completion time.

H2: If an individual is multi-skilled, they will have an increase in their task completion time and a lower quality.

H3: As task repetition increases in a person, task completion time will decrease while the quality will increase.

H4: As ASVAB scores increase, quality will increase and task completion time will decrease.

H5: As age increases, quality will increase and task completion time will decrease.

H6: As technical training scores increase, quality will increase and task completion time will decrease.

H7: As job experience increases, quality will increase and task completion time will decrease.

Conclusion

This study of skill retention rates and understanding the relationship between independent factors and skill retention can help leaders make informed decisions about how to improve their work force. This chapter explains the logic behind experiment design, decisions, and execution. It covers why the sites, tasks, and subjects were selected. Finally, the dependent and independent measures were identified along with the experiment procedures to gather all of the data. The data collection and analysis began the journey toward interpretation and experiment results.

IV. Results

The results of this human subjects experiment showed statistical significance between certain factors thought to influence skill retention and the dependent variables of task completion time and quality. We collected the data from the two sites (Hill Air Force Base and Eglin Air Force Base), statistically evaluated this data using analysis of variance and multivariate stepwise regression, and summarized the results from this data. Finally, we present a summary of experiment findings.

Data Collection

Data gathered at the time of the experiment included answers from the demographic questionnaire as well as the task completion time and quality per experiment subject. All experiment participants received a number designator to protect their identity once all information was received from their technical training reports. This ensured not only personal protection, but also reduced bias on the part of the researcher. Table 4 is a sample of the data present on the data collection; refer to Appendix G for full data sheet.

Table 4. Classification of Experiment Subjects according to Job Type

Designator	Background	Experience	Age	Gender	Completion Time (sec)	Grade
1	LO	5 years	28	M	10542.00	9.66

Using this data, we began analysis in Microsoft Excel and then transferred the data into JMP for further statistical analysis. Excel and JMP were used intermittently depending on the statistical analysis being processed once the initial comparison was

complete. The only data gathered post experiment was technical training scores. All other data was gathered on site during the experiment.

Subject Participation

A total of 34 low observable and sheet metal aircraft maintenance technicians participated in our experiment. Hill Air Force Base housed 23 of these experiment subjects and Eglin Air Force Base provided the other 11. Table 5 is a breakdown of the number of aircraft maintenance technicians that were low observable, sheet metal, or a combination of both who participated in the experiment:

Table 5. Sample Population per base

Maintainer Type	Hill Air Force Base, UT	Eglin Air Force Base, FL
Low Observable Only	8	5
Sheet Metal Only	9	0
Multi-skilled	6	6

Demographics

Our experiment population varied greatly demographically. Figure 6 provides the age breakout from the sample population. Five females and 29 males participated in this experiment. This is consistent with the career fields since aircraft maintenance is mainly male-dominated. The experience levels varied greatly amongst the sample. Figure 7 and 8 display the number of years in that particular trade each participant possessed.
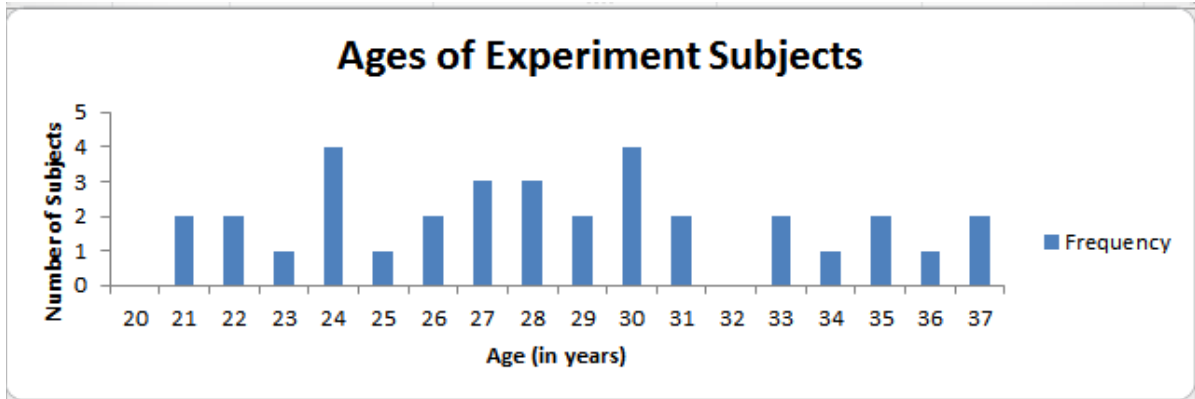
Figure 6. Age Breakdown of Experiment Subjects
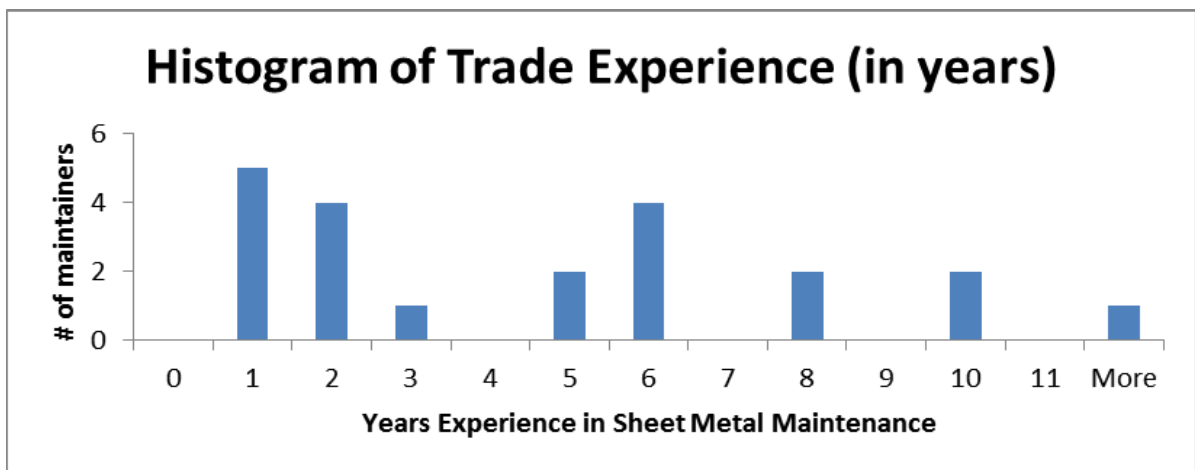
Figure 7. Experience Breakdown of Low Observable Mechanics

Figure 8. Experience Breakdown of Sheet Metal Mechanics

Results

   Our statistical results revealed statistically significant correlations between some

of our dependent variables (time and quality) against our independent variables (single or

multi-skilled, age, experience levels, task frequency, time since task was last

accomplished, technical training scores, and ASVAB scores) for both the low observable

and sheet metal tasks. We first created a correlation table in Microsoft Excel to see if

there were any potential correlations between factors. Table 6 is the correlation table.

Table 6. Correlation Table

	Background	LO Experience	Age	Gender	Frequency	Last Time	General	Admin	Mech	Elec	TS Grade	Block 1
LO Quality	-0.08	0.29	0.07	-0.33	0.44	-0.44	-0.2	-0.2	0.05	0.08	0.12	0.04
LO Time	-0.25	-0.41	-0.15	0.008	-0.23	0.16	0.07	0.08	0.13	0.15	0.08	0.23
SM Quality	-0.05	0.43	0.43	0.28	0.05	0.18	0.2	0.09	0.11	0.13	0.07	-0.15
SM Time	0.45	-0.1	0.21	-0.05	-0.15	0.25	-0.27	-0.1	-0.25	-0.31	-0.38	-0.12

Key:	
LO Time	Low Observable task completion time
LO Quality	Low Observable task grade
SM Time	Sheet Metal task completion time
SM Quality	Sheet Metal task grade
Last Time	Time since task was last accomplished
General	
Admin	ASVAB Sections
Mech	
Elec	
TS Grade	Overall grade from technical training
Block 1	Test grade from the first block of technical training

Stepwise Multivariate Regression Analysis Overview

   For the low observable tape repair task, we created a stepwise regression analysis

model using all the independent factors against task completion time and quality

(dependent variables). First, we conducted the stepwise function with a parameter to

enter or exit the system being 0.25. Once the variables that met these parameters were

identified, we made a model to identify the p-values. We sought a p-value under 0.05.

We also saved the Cook's D and made an overlay plot to discover any overly influential factors that might skew our data results. Variance Inflation Factors (VIF) was also found and nothing over 2 was allowed to stay in the model. If any data points or factors showed high Cook's D or a high VIF score, they were excluded from the model. In the figures, if the p-value is greater than 0.01 but less than 0.05, it will be labeled in red. If the p-value is less than 0.01, it will be labeled in orange.

Low Observable Multivariate Regression Model

The first dependent variable we used to develop our first statistical model was quality. The R2 of this model is 0.57. This means this model explains approximately 57% of the variability within these dependent variables. The model has a p-value in aggregate of <0.01 and the significant factors influencing quality are time since the task was last accomplished, the individual's block 1 score in technical training school, the age of the individual, and the number of times the individual has performed the task in the past year. Table 7 is the stepwise regression model showing all statistically significant relationships. This can be interpreted as:

- As time since task was last accomplished increases, quality decreases
- As scores for block 1 of tech school increase, quality increases
- As age increases, quality increases
- As number of times task was performed in the past year increases, quality increases

Table 7. Regression Model for Low Observable Task with Quality (y)

Summary of Fit

RSquare	0.56581
RSquare Adj	0.469323
Root Mean Square Error	0.89427
Mean of Response	7.997304
Observations (or Sum Wgts)	23

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	18.758590	4.68965	5.8641
Error	18	14.394932	0.79972	Prob > F
C. Total	22	33.153523		0.0033*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	-5.07344	4.480964	-1.13	0.2724	.
Time Since	-0.185334	0.066506	-2.79	0.0122*	1.178836
Block1	0.0702955	0.032635	2.15	0.0450*	1.5142119
Age	0.2140377	0.065859	3.25	0.0044*	1.9624526
Past yr	0.0240897	0.006773	3.56	0.0023*	1.6806199

We then used our other dependent variable of task completion time to generate another regression model. This model had time since the task was last accomplished and the number years of low observable experience as significant factors. The R2 of this model is 0.42 which means this two-variable model explains approximately 42% of the dependent variable's observed variability. This model also possesses a p-value of <0.01. Table 8 is the regression model.

- As time since the task was last accomplished increases, completion time increases
- As years in the career field (experience) increases, completion time decreases

It is important to note that task completion time is recorded using seconds as a measurement. So the relationship between the amount of time passed since the task was last accomplished increases by one year, the time for task completion increases by approximately 276 seconds equating to 4.6 minutes. The interpretation for experience levels is similar. As experience levels increase by one unit (one year), task completion time is reduced by around 418 seconds which is approximately 7 minutes (6.96 minutes).

Table 8. Regression Model for Low Observable Task with Completion Time (y)

Summary of Fit

RSquare	0.423235
RSquare Adj	0.362523
Root Mean Square Error	1451.47
Mean of Response	12621.23
Observations (or Sum Wgts)	22

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	29373323	14686661	6.9712
Error	19	40028557	2106766.2	Prob > F
C. Total	21	69401880		0.0054*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	13990.317	572.1734	24.45	<.0001*	.
Time Since	276.11147	107.8808	2.56	0.0192*	1.1796337
Experience	-418.2626	119.4357	-3.50	0.0024*	1.1796337

Sheet Metal Multivariate Regression Model

The first dependent variable we used to develop our first sheet metal statistical model was quality. The variability explained within these dependent variables is approximately 35%. It has a p-value in aggregate of 0.03 and the factors influencing

quality are the age of the individual and if the individual is single or multi-skilled. Table 9 is the stepwise regression model showing all statistically significant relationships.

This can be interpreted as:

- As age increases, quality increases
- As skill level increases (multi-skilled), quality decreases

For the first relationship, as the aircraft maintainer increased in age by one year, their quality score improve by .15 on the 0-10 Likert Scale. Meaning it improves by 15% as the participants aged one year.

The statistically significant relationship between quality and skill level has an estimate of -1.67 meaning that as an individual goes from being single to multi-skilled, their quality grade decreases approximately 1.67 points. The grading criterion was on a 0-10 Likert scale. Therefore if the expectation is a 7 for a single skilled worker, the expected quality level of a multi-skilled individual would be a 5.33. This can be viewed as a significant decrease in quality, but it depends on the acceptable quality levels of the maintenance workplace.

Table 9. Regression Model for Sheet Metal Task for Quality (y)

Summary of Fit

RSquare	0.348699
RSquare Adj	0.267287
Root Mean Square Error	1.352065
Mean of Response	7.681632
Observations (or Sum Wgts)	19

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	15.659761	7.82988	4.2831
Error	16	29.249291	1.82808	Prob > F
C. Total	18	44.909052		0.0324*

Lack Of Fit

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	3.9680786	1.848629	2.15	0.0475*	.
Age	0.1583274	0.065532	2.42	0.0280*	1.1760699
Skill	-1.674772	0.681318	-2.46	0.0257*	1.1760699

We next used task completion time to find a statistically significant regression model. It has an R2 of 0.83 with a p-value of <0.001 for the entire model. The R2 is the amount of variability explained by the dependent factors. This means 83% of the variability is explained in this multivariate model, making it our strongest model. The factors influential to task completion time are the individual's mechanical scores from the ASVAB, the individual's overall technical training grade, the individual's grade from block 1 of technical training school, and what base the individual works. Table 10 is the regression model. The interpretation of results is:

- As mechanical ASVAB score increases, time decreases
- As the overall grade from technical training increases, time decreases
- As the grade from Block 1 increases, completion time increases
- As the base changed from Hill to Eglin, task completion time increases

The increasing mechanical ASVAB score decreased task completion time. As the mechanical scores increased by 1 point (on a 100-point scale), task completion time fell by over 1 minute (68 seconds). A one percent increase in the overall technical training grade had the same influence on task completion time by allowing it to fall by 227 seconds (3.45 minutes) overall. However, the individual's block 1 grade from technical training had the opposite effect. As the block 1 test grades increased by one percent, the task completion time increased by 189 seconds (a little over 3 minutes). This was a startling realization. A correlation was conducted between the overall grade received in technical training and the block 1 test grade and had a correlation of 0.6. Finally, the relationship between the individual's location (base) and task completion times was the most significant relationship. As the base changed from Hill Air Force Base to Eglin Air Force Base the task completion times changed drastically. As the base switches from Hill Air Force Base to Eglin Air Force Base, aircraft maintainers performed the sheet metal task approximately 76 minutes longer (4589 seconds).

Table 10. Regression Model for Sheet Metal Task with Completion Time (y)

Summary of Fit

RSquare	0.830788
RSquare Adj	0.782441
Root Mean Square Error	1310.045
Mean of Response	5361.789
Observations (or Sum Wgts)	19

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	117966610	29491652	17.1841
Error	14	24027058	1716218.4	Prob > F
C. Total	18	141993667		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	7371.3091	6160.433	1.20	0.2514
Mech	-68.37611	21.61214	-3.16	0.0069*
TechSchoolGrade	-227.2289	69.51365	-3.27	0.0056*
Block 1	189.23961	50.04021	3.78	0.0020*
Base	4589.4122	719.6018	6.38	<.0001*

Once this model was developed, we then removed the base factor to see what influence other factors might have possibly had without the base. The stepwise multivariate regression model found the only influential factor with base excluded as an independent variable was whether the sheet metal technicians were single or multi-skilled. If they were multi-skilled their time increased by approximately 48 minutes. Table 11 is the regression model for the sheet metal task with completion time with the base factor omitted. However, the R2 was very low (only .20) so the prior model is much stronger and the variability within the factors is only explained 20% of the time.

Table 11. Regression Model for Sheet Metal Task with Completion Time (y)
without Base Factor

Summary of Fit

RSquare	0.203559
RSquare Adj	0.161641
Root Mean Square Error	2561.31
Mean of Response	5621
Observations (or Sum Wgts)	21

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	31857778	31857778	4.8561
Error	19	124645898	6560304	Prob > F
C. Total	20	156503676		0.0401*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	4198.7778	853.7701	4.92	<.0001*	.
Skill	2488.8889	1129.432	2.20	0.0401*	1

We finally performed multivariate discriminate analysis on our aggregate data to see if we could correctly classify worker performance as multi-skilled or single-skilled based on their quality of performance and completion time. We found that we were only able to correctly discriminate between the two groups with 62% accuracy which is only 10% above our roughly 52% prior probabilities. This analysis further strengthens our

claim that our study cannot reject that multi-skilled workers retain 95% proficiency within the selected career fields.

Summary of Analysis

Out of all potential factors influencing skill retention in these aircraft maintainers, there were certain factors correlating with our dependent measures of time and quality. There are apparent correlations between any given factor and completion time or quality for low observable and sheet metal maintenance experiment populace. Our stepwise multivariate regression analysis showed numerous statistically significant relationships between the independent and dependent factors for both the sheet metal and low observable task. However, the only factor common applicable to both sheet metal and low observable was quality's relationship with the experiment subjects' age. The other influential factors are listed in Table 12.

Table 12. Influential Factors

Low Observable Tape Repair Task	
Quality	**Time**
Time Since	Time Since
Block 1	Experience
Age	
Frequency	

Sheet Metal Scab Patch Task	
Quality	**Time**
Age	Mechanical ASVAB score
Skill level	Tech School Grade
	Block 1 Grade
	Base

Key:	
Time Since	Time since task was last accomplished
Block 1	Test grade from the first block of technical training
Age	Age of participant
Frequency	How often the participant executed the task in the last year
Experience	Participant's years in career field
Skill level	Single or multi-skilled participant

Summary of Findings

        The results of this experiment conclude that there are certain statistically significant relationships between each dependent factor, but the only factor common to both sheet metal and low observable tasks is that age influences quality. As the aircraft mechanic's age increases, so does their quality. Below are the answered hypotheses.

H1: The more amount of time that has passed since a person last accomplished the task will negatively influence the quality of the task and will increase the individual's task completion time.

Time since the task was last accomplished did influence both the quality and task completion time for the low observable tape repair task. It did not influence the sheet metal task.

H2: If an individual is multi-skilled, they will have an increase in their task completion time and a lower quality.

The only time being multi-skilled was influential, was for the sheet metal quality regression model. As skill level increased (or a person went from being single skilled to multi-skilled), their quality decreased. This was only true for this model. There was no influence on the low observable task or the task completion time for sheet metal.

H3: As task repetition increases in a person, task completion time will decrease while the quality will increase.

Task completion time was not influenced by task repetition for any of the tasks. Quality was influenced in the low observable model based off task repetition and quality did increase as task repetition increased. It was not influential in any other analysis.

H4: As ASVAB scores increase, quality will increase and task completion time will decrease.

Quality was not influenced by ASVAB scores in any of the tasks or variables. The only increasing ASVAB score that had a statistically significant relationship was within the sheet metal task completion time model. As the mechanical section of the ASVAB score increased, task completion time did decrease.

H5: As age increases, quality will increase and task completion time will decrease.

Quality did increase as age increased for both the sheet metal and low observable tasks. However, completion time was not influenced by age for either task.

H6: As technical training scores increase, quality will increase and task completion time will decrease.

The overall technical training score was influenced in sheet metal task for task completion time. It was not influential in any other model or task. However, the technical training scores for Block 1 were influential in the low observable quality model. As Block 1 scores increased, the quality increased. The score from Block 1 was also significant in the sheet metal task completion time. As the score from Block 1 increased, the completion time also increased. This is the opposite relationship from the low observable quality model.

H7: As job experience increases, quality will increase and task completion time will decrease.

The amount of job experience (in years) an individual possessed influenced the low observable task completion time decreases. This was the only model in which experience was significant.

<center>**V. Discussion**</center>

The effect of multi-skilling at the ALCs is the focus of our research. The ALCs will have their multi-skilled workforce maintain the 95% skill proficiency Sheppard said was needed to maintain cost savings. Our recommendation is that the depots continue incorporating multi-skilled aircraft maintenance technicians into their workforce, but with certain expectations of these multi-skilled technicians.

Research Questions Answered

Research Question 1: Is skill retention a function of the time that has passed since a person has last accomplished the task?

The last time a person accomplished the task does have a statistically significant relationship with our dependent measure of task completion time and quality for the low observable tape repair task but did not influence the sheet metal task. Wisher, Sabol, Ellis, & Ellis (1999) say that the amount of information lost initially is quicker than the amount over the long run. Past studies show considerable skill decay in a short amount of time (weeks or months) for procedural tasks according to Wisher, Sabol, Ellis, & Ellis (1999). As the low observable participants' times since the task was last accomplished increased by a year their task completion time increased by approximately 4.5 minutes and the quality decreased by .18. This is notable since it was only for the low observable technicians. The sheet metal technicians did not have any statistically significant relationship on their procedural task. These mixed results for skill retention being a function of time lead to further research opportunities.

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Our results differ greatly between the different task types as well as the literature. The swift loss of skill retention presented by Wisher, Sabol, Ellis, & Ellis (1999) is not mimicked by our data due to a variety of reasons. The first reason being there was a vast difference between the amounts of time that has passed since the task was last accomplished between our two groups (sheet metal task against the low observable task). The relatively small amount of time that passed for the low observable technicians did have a statistically significant relationship which agrees with Wisher, Sabol, Ellis, & Ellis (1999) suggesting there should and is a relationship present within a couple of weeks or months for procedural tasks. Too much time may have passed for the relationship to be present for sheet metal, but this information may not be completely accurate. However, our sheet metal data agrees with Crofts et al.'s (2013) experiment that concluded there to be no significant statistical difference for workers based on the length of time before performing a task again.

We conclude, based on our research, skill retention is influenced by the amount of time since the last was last accomplished for low observable. Yet, skill retention rates do not drop as swiftly as other studies suggest for procedural tasks within sheet metal aircraft maintainers according to our research. This could be due to the nature of the sheet metal tasks, the sample size, and/or the wording of the question asked on the demographic questionnaire regarding when the task was last accomplished. The acceptable quality and time levels must be decided in order to better manage these changes wrought by introducing multi-skilled technicians into the workforce. However, our data suggests that managers can expect a slight increase (4.5 more minutes in a 3.5-hour long task) in completion time and a slight decrease in the quality.

Research Question 2: Is skill retention influenced by whether a person possesses one skill or is multi-skilled?

According to our research, skill retention appears not to be significantly influenced by whether the individual was single or multi-skilled. We found one statistical relationship between skill retention and if an individual possessed one or multiple skills. This was in the sheet metal scab patch task which showed that as workers went from being single to multi-skilled their quality levels decreased by almost .17 on a 0-10 scale. There were no other statistically significant models with skill level as an influential factor. Sheppard (2014) assumed multi-skilled aircraft maintainers would retain 100% of skill proficiency but found in a sensitivity analysis that 95% of skill retention in the multi-skilled depot workforce would allow AFMC to realize the overtime prevention savings. His work stated that efficiency in these multi-skilled workers could drop as much as 5% and still outperform overtime policies. According to our experiment of aircraft maintainers, we still support these assumptions. Even with the relationship between skill level and sheet metal quality, the acceptable level of quality is very subjective and can still be achieved even with the quality degradation we found in our model.

Research Question 3: Is skill retention influenced by task repetition in a person?

According to our analysis, skill retention does not appear to be greatly influenced by task repetition in a person. Skill retention does not have a very influential relationship based off task repetition. The number of times a participant completed the task in the

past year was only influential in the low observable tape repair task with quality as the dependent variable. Even with this statistically significant relationship, the impact of increasing the number of times an aircraft maintainer completes the task in the past year by one, the quality only improves by .02 or .002 of a point if graded on a 0-10 Likert Scale. Past literature suggests skill decay is affected by infrequency of task (Meyer et al., 2014). Our data does not fall into line with this possibly due to the small sample size, wording of the demographic questionnaire, or the selection of tasks specifically for sheet metal. Low observable technicians had a statistically significant correlation, but there was an abundantly clear lack of relationship for the sheet metal technicians. The nature of these different career fields might have also played a role in the mixed results.

Research Question 4: Are there any personal background characteristics that lead to higher retention rates in personnel?

Certain personal background characteristics had statistically relevant relationships to higher retention rates. Age was a statistically significant factor for both sheet metal and low observable tasks with quality as the dependent variable. The scores from block 1 of technical training school also were statistically significant. These scores influenced the quality of the low observable task and the task completion time for sheet metal. The sheet metal task completion time was also influenced by the overall technical training score an individual achieved, their mechanical score from the ASVAB, and finally, was greatly influenced by the location (Hill Air Force Base or Eglin Air Force Base) of the individual. Finally, the experience levels (in years) of an aircraft maintenance technician

had a statistically significant relationship with the task completion time of the low observable tape repair.

Stothard & Nicholson (2001) emphasized that every individual is unique and may have different desired learning levels for certain tasks as well as different cognitive abilities. We attempted to identify some of the characteristics to see if there were cohorts of individuals possessing certain traits but were unable to identify different groupings of individual characteristics that might lead to higher skill retention levels apart from age. Age, gender, technical training grades, ASVAB scores, background, and experience levels were all compared to see if there was a potential correlation between these factors and the amount of time it took a test subject to complete a task and the quality of the product. These findings just reinforce Stothard & Nicholson (2001) with their idea that all individuals vary. Personal background characteristics might lead to higher retention rates in certain people, but attempting to group these individuals allowed for certain factors to be significant, but it was not standardized throughout all dependent variables for both tasks.

Lessons Learned

Upon the conclusion of this experiment, certain decisions could have been changed or adjusted slightly to improve not only the experiment, but the results as well. The first of these decisions being selection criteria-the researcher was recently involved in the F-35 program so there was some selection bias based off the researcher's experience. It would have been interesting to evaluate different low observable and sheet metal data from different aircraft platforms. Another lesson learned is the importance of

our work compared to the perceived importance the hosting units put on said work. We were at the mercy of the units and had unpredictable participation based on the real world mission requirements. This greatly influenced the number of participants in the experiment as well as the time spent waiting for the next experiment subject. Different locations behaved differently as well based once again on these perceptions of importance. Hill Air Force Base was very accommodating and eager, while Eglin Air Force Base seemed almost hesitant. A different unit behaved differently and this might have confounded the data. Finally, the data was collected by asking the individual test subjects the last time they had accomplished a scab patch for the sheet metal task. The scab patch is not a task generally done in aggregate, but the steps of a scab patch are conducted frequently. This data might not be completely accurate; a better question should have broken down the parts of the scab patch procedure to receive more accurate data.

Recommendations for Future Research

The research in the area of skill retention is still pertinent and here are some research opportunities for future skill retention studies. Attempting to improve the workforce and increase output levels is important, and the experiment tried to find these skill retention factors. A major shortfall of this research is the very narrow scope examined. A longer experiment, particularly a time-based series, would have been way more helpful. A time-based experiment would allow each participant to set their own baseline and then compare their future results against their past while manipulating certain variables. An organizational behavior study would also be beneficial in not only

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the field of skill retention, but in multi-skilling as well. There is a large amount of variability present in these groups and a study of culture might prove beneficial. This would have been a significantly greater controlled experiment and would most likely yield better results. We also selected certain factors thought to influence skill retention based off the literature review but they did not yield any statistically significant results. These may not have been the factors to select. There may be more influential factors for skill retention.

There is only a small amount of experimental studies in the field of multi-skilling focusing on skill retention so there is plenty of follow on research that could be accomplished. We recommend further experiments to evaluate output levels of populations possessing these multi-skilled individuals. However, a larger sample size, more variability within the sample size, and higher control of the experiment environment will yield greater controlled data and hopefully better results. Multi-skilling is a large academic area, but there is virtually no experimentation accomplished on multi-skilled aircraft maintenance technicians, so this is an area that needs further exploration by academia in order to greater understand the implications of multi-skilling.

Recommendation

Through the National Defense Act of 2013, multi-skilling has begun implementation at the ALCs. This dynamic workforce needs to be better understood. In our research we sought to improve understanding of these aircraft maintainers. We conclude that different factors influence certain output levels in career fields. The only factor influencing both sheet metal and low observable tasks was age. If an individual was single or multi-skilled did not influence their task completion time or quality levels.

The 95% skill proficiency rating to enable Sheppard's ALC cost savings should be achievable with care.

Appendix A: IRB Exemption Approval

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (AETC)

11 August 2015
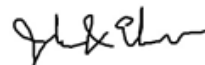
MEMORANDUM FOR DR. KENNETH L. SCHULTZ

FROM: John J. Elshaw, Ph.D.
            AFIT IRB Research Reviewer
            2950 Hobson Way
            Wright-Patterson AFB, OH 45433-7765

SUBJECT: Approval for exemption request from human experimentation requirements (32 CFR 219, DoDD 3216.2 and AFI 40-402) for Research Project Skill Retention Study of Aircraft Maintenance Technicians.

1.   Your request was based on the Code of Federal Regulations, title 32, part 219, section 101, paragraph (b) (2) Research activities that involve the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior unless: (i) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) Any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

2.   Your study qualifies for this exemption because you are not collecting sensitive data, which could reasonably damage the subjects' financial standing, employability, or reputation. Further, the demographic data you are utilizing and the way that you plan to report it cannot realistically be expected to map a given response to a specific subject.

3.   This determination pertains only to the Federal, Department of Defense, and Air Force regulations that govern the use of human subjects in research. Further, if a subject's future response reasonably places them at risk of criminal or civil liability or is damaging to their financial standing, employability, or reputation, you are required to file an adverse event report with this office immediately.

Invalid signature

X _____

JOHN J. ELSHAW, PH.D.
AFIT Exempt Determination Official

Appendix B: IRB Exemption Request Memorandum

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (AETC)

10 August 2015

MEMORANDUM FOR AFIT EXEMPT DETERMINATION OFFICIAL

FROM: AFIT/ENS
2950 Hobson Way
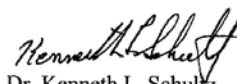Wright Patterson AFB OH 45433-7765

SUBJECT: Request for exemption from human experimentation requirements (32 CFR 219, DoDD 3216.2 and AFI 40-402) for a skill retention study of aircraft maintenance technicians.

1. The purpose of this study is to examine skill retention rates for aircraft maintenance technicians based off technical experience as either single-skilled or multi-skilled. These results will be based on completion times and quality levels of common maintenance tasks. This is a thesis project focused on skill retention rates. The results of this study will be presented in a formal thesis format.

2. This request is based on the Code of Federal Regulations, title 32, part 219, section 101, paragraph (b) (2) Research activities that involve the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior unless: (i) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) Any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

3. The following information is provided to show cause for such an exemption:

   a) Equipment and facilities: The study will take place in the participants' current place of employment. The buildings have been built and maintained to facilitate these activities. All equipment used will be in working order and cause no additional risk than the current maintenance activities performed daily by the subjects.

   b) Subjects: The subjects for this experiment are current Low Observable and Sheet Metal aircraft maintenance technicians in the United States Air Force. All subjects have undergone technical training and are fully qualified to accomplish these maintenance tasks. The source of subjects will be personnel from the 388th Equipment Maintenance Squadron's Fabrication Flight at Hill Air Force Base and the 33d Maintenance Squadron's Fabrication Flight at Eglin Air Force Base. In total, there are 120 subjects from the Low Observable and Sheet Metal career fields. The subjects' ages range from

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18-35 years of age and include both genders. All subjects will have performed the maintenance tasks in the study before and the tasks are very common for their career fields.

c) Timeframe: The experiment will be conducted September 7, 2015 to September 30, 2015. Subjects will not participate in the experiment longer than two hours.

d) Data collected: Information to be gathered through this experiment include age, gender, work history, technical training scores, Armed Services Vocational Aptitude Battery (ASVAB) scores, and task frequency for given tasks. Subjects will answer these questions prior to starting the maintenance task (See Attachment 1 for the data collection questions). The main variable to be examined will be the completion time for specific maintenance tasks. They will either be completing an aircraft skin repair (tape insertion) on a training aircraft panel or repairing a defect on metal (scab patch). The times will be recorded and the final product will be evaluated for quality.

e) Risks to subjects: Subjects will not meet any additional risks uncommon to their daily maintenance tasks. The environment will be well kept and dry. Industrial safety standards will be maintained. The disclosure of personal identifiable information will be the main risk and will be mitigated through the exclusion of names, ranks, and social security numbers in the collection of data. No PII will be collected or stored in the databases. If a subject's future response reasonably places them at risk of criminal or civil liability or is damaging to their financial standing, employability, or reputation, I understand that I am required to immediately file an adverse event report with the IRB office.

f) Informed consent: All subjects must be willing participants of this study. All subjects are self-selected to volunteer to participate in the interview. No adverse action is taken against those who choose not to participate. Subjects are made aware of the nature and purpose of the research, sponsors of the research, and disposition of the survey results. A copy of the Privacy Act Statement of 1974 is presented for their review.

4. If you have any questions about this request, please contact Dr. Kenneth Schultz at 785-3636, ext. 4725 or via email at kenneth.schultz@afit.edu.

Dr. Kenneth L. Schultz
Principal Investigator

Attachments:
1. Interview questions

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Appendix C: Informed Consent Form

INFORMATION PROTECTED BY THE PRIVACY ACT OF 1974

Informed Consent Document
For
Skill Retention Study of Low Observable and Sheet Metal Technicians

Principal Investigator: Dr. Kenneth Schultz, DSN 255-6565
                                   Air Force Institute of Technology, ENS
                                   Kenneth.Schultz@afit.edu

Associate Investigators: Captain Jessica A. Turner, DSN 255-6565
                                   Air Force Institute of Technology, ENS
                                   Jessica.Turner@afit.edu

1. **Nature and purpose:** You have been offered the opportunity to participate in the "Skill Retention Study of Low Observable and Sheet Metal Technicians" research study. Your participation will occur at 7362 Wardleigh Rd, Bldg 20, Hill AFB, 84056 or 1352 Nomad Way, Eglin AFB 32541. The purpose of this research is to evaluate retention rates among Low Observable and Sheet Metal technicians. The time requirement for each volunteer is anticipated to be a total of one visit of approximately 2 hours each. A total of approximately 120 subjects will be enrolled in this study.

2. **Experimental procedures:** If you decide to participate, you will be given maintenance tasks (a maximum of two) to complete in which you will be timed.

3. **Discomfort and risks:** Discomforts may consist of normal risks associated with current job performance such as fatigue and minor stress.

4. **Benefits:** You are not expected to benefit directly from participation in this research study.

5. **Compensation:** Active duty military will receive normal pay.

6. **Alternatives:** Your alternative is to choose not to participate in this study. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. Notify one of the investigators of this study to discontinue.

7. **Entitlements and confidentiality:**

  a. Records of your participation in this study will be protected according to federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations and the Health Insurance Portability and Accountability Act (HIPAA), and its implementing regulations, when applicable, and the Freedom of Information Act, 5 U.S.C. Sec 552, and its implementing regulations when applicable. Any information provided will be transferred to a

system that masks your personal identifiable information. All data collected will be gathered and given a unique designator that will in no way be linked back to you. All PII will be returned to you at the conclusion of your participation. It is intended that the only people having access to your information will be the researchers named above, the AFRL Wright Site IRB, the Air Force Surgeon General's Research Compliance office, the Director of Defense Research and Engineering office or any other IRB involved in the review and approval of this protocol. When no longer needed for research purposes your information will be destroyed in a secure manner through electronic means.

b. Your entitlements to medical and dental care and/or compensation in the event of injury are governed by federal laws and regulations, and that if you desire further information you may contact the base legal office at 75 ABW/JA at (801) 777-6756 for Hill AFB or 96 TW/JA at (850) 882-4611 for Eglin AFB.

c. The decision to participate in this research is completely voluntary on your part. No one may coerce or intimidate you into participating in this program. Participate only if you want to. If you have any further questions, Captain Jessica Turner can be reached at (270) 307-2244. Captain Jessica Turner or an associate will be available to answer any questions concerning procedures throughout this study. If significant new findings develop during the course of this research, which may relate to your decision to continue participate or may affect the risk involved, you will be informed. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled. Notify one of the investigators of this study to discontinue. Additionally, the investigator of this study may terminate your participation in this study if she or he feels this to be in your best interest. If you have any questions or concerns about your participation in this study or your rights as a research subject, please contact Kim London at (937) 656 – 5688 or kim.london.1@us.af.mil.

d. Your participation in this study may be photographed, filmed or audio/videotaped. The purpose of these recordings is to validate the data collected.

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. YOUR SIGNATURE INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PROVIDED ABOVE.

SUBJECTS MUST SIGN **PRIOR** TO PARTICIPATION.

Volunteer Signature_____**Date**_____

Volunteer Name (printed)_____

Privacy Act
Statement

Authority: We are requesting disclosure of personal information. Researchers are authorized to collect personal information on research subjects under The Privacy Act-5 USC 552a, 10 USC 55, 10 USC 8013, 32 CFR 219, 45
CFR Part 46, and EO 9397, November 1943.

Purpose: It is possible that latent risks or injuries inherent in this experiment will not be discovered until some time in the future. The purpose of collecting this information is to aid researchers in locating you at a future date if further disclosures are appropriate.

Routine Uses: Information may be furnished to Federal, State and local agencies for any uses published by the Air Force in the Federal Register, 52 FR 16431, to include, furtherance of the research involved with this study and to provide medical care.

Disclosure: Disclosure of the requested information is voluntary. No adverse action whatsoever will be taken against you, and no privilege will be denied you based on the fact you do not disclose this information. However, your participation in this study may be impacted by a refusal to provide this information.

Appendix D: Demographic Questionnaire

Questionnaire

1. What is your background?
   ☐ Low Observable
   ☐ Sheet Metal
   ☐ Low Observable/Sheet Metal
2. How many years of experience do you have?
   Low Observable_____
   Sheet Metal_____
3. What is your current age?
4. What is your gender?
   ☐ Male
   ☐ Female
5. When did you graduate technical training?
   _____/_____(Month/Year)
6. How many times in the **past year** have you performed the following tasks?
   Scab Patch_____
   Tape Insertion_____
7. When was the last time you performed the following tasks?
   Scab Patch_____
   Tape Insertion_____
8. Write your ASVAB scores below
   General_____
   Administrative_____
   Mechanical_____
   Electrical_____

9. Did you study these tasks prior to beginning this experiment?
   ☐ Yes
   ☐ No

10. Did you have prior knowledge of this study?

Appendix E: Experiment Verbiage

Experiment Verbiage

"Welcome, today you are being asked to participate in an experiment to evaluate skill retention in Low Observable and Sheet Metal technicians. This experiment is for research purposes only and will have no influence on your job or position here. This will be a 100% academic environment. You will be asked to conduct a series of tasks from your Career Field and Education Training Plan, CFETP. There will be an evaluator, myself, and a recorder (points to Capt Turner) present in the room to assist with any initial questions, but once the initial phase is over, we can offer no additional help. Today's experiment is completely voluntary. All personal identifiable information will be kept completely confidential and destroyed upon the completion of this study. Would you be willing to participate in this experiment today?"

RECEIVE VERBAL INFORMED CONSENT. ONCE COMPLETE.

"Thank you for agreeing to participate in this experiment. Today we are looking at how much of your specific AFSC is retained through the years. First, there is an informed consent form I need you to read and fill out in its entirety. I also have a (copy of your) demographic questionnaire; will you please review it and ensure it is accurate? This is a way for us to find out more about you and your history. There is also a sheet under your demographic form to release your technical training records. Please fill that out as well. Again, all of your personally identifiable information will be protected and will have no influence on your job or performance. This is all for academic use only. The areas of the form for you to fill out are highlighted. Please do not hesitate to ask me any questions regarding these forms."

FILL OUT TECHNICAL TRAINING FORM REQUEST. ONCE COMPLETE,

"Once again, thank you for agreeing to participate in this study. You will start all tasks at the tape line on the floor. Please head to this line. In this room are all items required to accomplish the maintenance tasks I assign. I will give you a task and then when I say 'begin' we will start recording your time. Do not cross the line on the floor until I say to begin. We will be timing you as you do these tasks. I cannot assist you any further once you start the tasks. Do you have any questions thus far?"

QUESTION TIME

FOR LO-SPECIFIC:

"You will be conducting a tape repair on the panel in front of you. Do you have any questions before we begin? Begin."

END OF LO-SPECIFIC PORTION

FOR SM-SPECIFIC:

"You will be conducting a scab patch on the material in front of you. Do you have any questions before we begin? Begin."

END OF SM-SPECIFIC PORTION

FOR MULTI-SKILLED WORKERS:

"You will begin by conducting a tape repair on the panel in front of you. Do you have any questions before we begin? Begin."

UPON COMPLETION

"Please head back to the tape line. Your next task will be a scab patch on the panel behind you. Do you have any questions? Begin."

UPON COMPLETION

"Thank you for your time and participation. We are willing to share any conclusions of this study once completed if you are interested. Do not talk about or share this experiment experience with any of your coworkers until the experiment is concluded. We will debrief the flight upon completion of the study. However, it is imperative that you wait until after the debrief before sharing any information. Your discretion is appreciated. Have a great rest of your day."

Appendix F: Sample Technical Training Report

ACADEMIC VALIDATION (Name)	VALIDATION DATE / TIME 20130913 16:45:52	VALIDATION TYPE PRE

STUDENT TRAINING REPORT

Student: ▆▆▆▆▆▆▆▆

Course Number: JCABP2A733 048B   Class ID: 08022   Training Squadron: 361TRS

Course Title: Aircraft Structural Maintenance Apprentice

Course Chart Hours: 648

Total Student Hours: 573

Average Grade: 78   Final Grade: 78   w/Honors:

Reason For Elim: Elimination Date:

Original Class Start: 20080909   Current Class Start: 20080909

Graduation Date: 20090114   Sex: ▆   Curr-Gd: 33   Travel Status: 9   Command/OGA: AJ10

Current PAS: SQ0JFLSK   Projected PAS: EL0RFBBR   Course DSN:

Guaranteed AFSC:

Aptitude Scores: ADMIN: 59   MECH: 54   GEN: 55   ELECT: 56   AFQT: 56   EDUCATION: F   ADP APT:

PART 1

Date	Title	Instructor	Status	Hours CC	Hours Student	Grade PC/Test	Grade Block
20080919	Block 1, Unit 9, Test a	GROVE, RICHARD L	TEST PASS			80	
20080919	Block I - Fundamentals of Aircraft Structural Maintenance	GROVE, RICHARD L	PASS	61	61		80
20081001	Block 2, Unit 5, Test a	MITCHELL, DENNIS E	TEST PASS			75	
20081001	Block II - Fabrication of Aircraft Parts	MITCHELL, DENNIS E	PASS	64	64		75
20081016	Block 3, Unit 4, Test a	MITCHELL, DENNIS E	TEST PASS			70	
20081016	Block III - Preparation for Structural Assembly	MITCHELL, DENNIS E	PASS	83	83		70

NOTE: Sample ONLY. All Personally Identifiable Information (PII) has been removed.

Appendix G: Experiment Data

Designator	Background	LO Experience (in years)	Age	Gender	Tech School Graduate	Task in Past year Tape	Last Time Tape (in years)	General	Admin	Mech	Elec	Seconds	Grade	TS Grade	Block 1
1	LO	5	28	M	Jul-10	10	0.33	87	85	87	87	10542.00	9.66	93	100
4	LO/SM	8	27	M	Dec-06	100	0.25	70	74	86	88	10580.00	9.33	90	100
5	LO	0	30	M	May-15	0	0.08	68	67	72	74	13893.00	7	88	90
6	LO	11	31	M	Sep-04	100	0.58	40	45	68	53	12532.00	9.166	88	80
9	LO	1.5	24	M	Dec-13	75	0.25	40	49	66	40	13706.00	9.166	98	100
10	LO/SM	8	30	M	Apr-04	0	11.00	49	47	73	62	13901.00	5.833	93	90
11	LO/SM	4	28	M	Sep-11	1	0.25	83	76	76	81	15293.00	6.67	84	100
13	LO/SM	5	33	F	Jun-03	0	2.00	68	50	62	76	11802.00	8.833	97	95
16	LO	2	22	M	Sep-13	50	0.25	82	82	83	87	15748.00	7.33	88	90
17	LO	6.5	28	M	Mar-09	50	0.41	66	69	61	84	10137.00	9.5	93	95
18	LO	3.5	24	M	Mar-12	40	0.58	74	60	82	87	17614.00	8.5	90	100
19	LO/SM	5	33	F	Dec-01	0	11.00	57	84	47	61	14450.00	6.33	87	95
20	LO/SM	6.5	26	M	Dec-09	100	0.33	55	59	54	56	9799.00	8.66	78	80
22	LO	0.16	31	M	May-15	1	0.50	55	59	85	84	15666.00	8.83	99	95
24	LO	1.5	30	M	Dec-13	5	0.16	49	56	47	59	13964.00	8.33	98	100
25	LO/SM	8	37	M	Mar-98	0	3.00	70	35	87	84	11323.00	8.33	89	90
26	LO/SM	7	37	M	May-98	2	0.08	24	25	58	24	11640.00	8.66	83.1	75
27	LO	2	29	F	Feb-13	2	0.66	78	69	66	60	12351.00	5.66	93	90
28	LO	2	23	M	Apr-13	20	0.01	62	67	65	64	13212.00	7.5	83	80
29	LO	0.5	24	M	Jun-15	3	0.00	80	78	86	93	11669.00	7.66	97	100
30	LO	2.5	29	M	Feb-13	0	1.00	80	74	87	72	11826.00	6.5	91	100
31	LO/SM	9	34	M	Nov-01	0	4.00	74	84	65	70	12282.00	8.16	90	90
32	LO/SM	7	30	M	Sep-05	2	1.00	47	69	52	55	13473.00	9	89	95
34	LO/SM	5	24	M	Dec-10	40	0.02	42	59	51	43	10410.00	6.83	93	90

Experiment Data for the Low Observable Tape Repair Task

Designator	Background	SM Experience (in years)	Age	Gender	Tech School Graduate	Past yr Scab	Last Time Scab (in years)	General	Admin	Mech	Elec	Seconds	Grade	TS Grade	Block 1
2	SM	18	36	M	Mar-97	0	8	40	49	58	35	3179.00	9.21	88	80
3	SM	2	21	M	Aug-13	1	0.66	62	69	57	76	3621.00	9.214	100	100
4	LO/SM	0.25	27	M	Dec-06	0	9	70	74	86	88	4094	6	90	100
7	SM	6	27	M	May-09	5	0.08	72	69	74	70	2697.00	7.714	93	90
8	SM	6	27	M	Aug-09	4	1	95	96	97	99	7340.00	7.28	97	95
10	LO/SM	2	30	M	Apr-04	0	10	49	47	73	62	1021	5.833	93	90
11	LO/SM	0.5	28	M	Sep-11	0	4	83	76	76	81	6206	6.571	84	100
12	SM	2	22	M	Apr-13	0	2	68	69	71	80	4487.00	0	93	100
13	LO/SM	8	33	F	Jun-03	0	10	68	50	62	76	3692	9.428	97	95
14	SM	8	35	M	Sep-08	0	3	93	96	97	94	2958.00	9.285	94	90
15	SM	5.5	25	F	Jun-10	0	5	94	92	89	93	4164.00	9.428	91	95
19	LO/SM	2	33	F	Dec-01	0	14	57	84	47	61	8162	8.928	87	95
20	LO/SM	0.5	26	M	Dec-09	0	6	55	59	54	56	4548	5.214	78	80
21	SM	1	21	F	Oct-14	2	0.5	78	69	68	64	5421.00	6.28	93	100
23	SM	5	26	M	Jan-11	1	0.33	49	56	47	59	3922.00	7.857	94	85
25	LO/SM	10	37	M	Mar-98	0	3	70	35	87	84	6799	8.71	89	90
26	LO/SM	10	37	M	May-98	0	7.5	24	25	58	24	8929	5.14	83.1	75
31	LO/SM	5	34	M	Nov-01	0	6	74	84	65	70	6530	7.71	90	90
32	LO/SM	3	30	M	Sep-05	0	8	47	69	52	55	13064	7.28	89	95
33	LO/SM	6	35	M	Jan-00	0	11	57	37	76	56	8827	9.57	78	75
34	LO/SM	0.5	24	M	Dec-10	0	5	42	59	51	43	8380	5.14	93	90

Experiment Data for the Sheet Metal Scab Patch Task

Appendix H: Technical Orders (Directions) for Experiment Tasks

Low Observable Tape Repair Task- FOR REFERENCE USE ONLY

Tape (Elastomeric (Insertion)) - Repair (Splice)

F35-AAA-A5182010000-660A-A   **Verified**
UNCLASSIFIED

Preliminary Requirements

Required Conditions
Required Condition Data Module / Technical Publication
 Make aircraft exterior safe for maintenance. Aircraft Exterior Safe for Maintenance
 Position protective pad set, if required. Protective Pad Set - Position

Required Personnel
Skill Category Number Required
 APG 1

Support Equipment
Nomenclature Identification No. Qty
 SE1. Platform, Maintenance, B-1 S0500002 1
 SE2. Ladder, Aircraft, 2 Step S0500012 1
 SE3. Tool Set, LO Dispatch Box S0500144 1
 SE4. Tool Set, LO/Composite Repair S0500145 1
 SE5. Enclosure, Localized S5100004 1
 SE6. Control Unit, Environmental S5100005 1
 SE7. Tool, Hot Air S5130027 1

Supplies, Consumables and Personal Protective Equipment
Nomenclature Identification No. Qty
 SU1. Alcohol, Isopropyl, Technical TT-I-735GRADE A AR
 SU2. Cloth, Wiping, Lint Free AMS3819BCL1GRAX207X12IN AR
 SU3. Covers, Shoe Covers, Shoe 1 Pair
 SU4. Glasses, Safety With Side Shields Glasses, Safety W/ Side Shields 1
Set
 SU5. Gloves, Nitrile Gloves, Nitrile AR
 SU6. Marker, Overhead, Fine Point SAN16001 1
 SU7. Marker, Permanent, Fine Point SAN30001 1
 SU8. Pad, Abrasive, Ultra Fine 7448 AR
 SU9. Pencil, Carpenter's, No. 2 Lead CPB-12 1
 SU10. Blade, Razor, Single Edge GG-R-60 AR
 SU11. Film, Mylar, 4-Mil Double Matte 7924D24A AR
 SU12. Tape, Application Conform 4075-RLA AR
 SU13. Tape, Double Coated, 1 Inch 70-0064-3615-1 AR
 SU14. Tape, Elastomeric, Form 3, Class A (2 Inch) 2ZZZ00014F3/2.0 AR
 SU15. Tape, Elastomeric, Form 3, Class B (2.5 Inch) 2ZZZ00014F3/2.50 AR
 SU16. Tape, Elastomeric, Form 3, Class C (3 Inch) 2ZZZ00014F3/3.00 AR
 SU17. Tape, Elastomeric, Form 3, Class D (3.6 Inch) 2ZZZ00014F3/3.60 AR
 SU18. Tape, Elastomeric, Form 3, Class E (18 Inch) 2ZZZ00014F3/18.0 AR
 SU19. Tape, Elastomeric, Form 3, Class F (5.35 Inch) 2ZZZ00014F3/5.35 AR
 SU20. Tape, Elastomeric, Form 3, Class G (12 Inch) 2ZZZ00014F3/12.0 AR
 SU21. Tape, Masking 1.88 inch 3M 234 70-0067-3376-3 AR
 SU22. Tape, Mylar, 1 Inch 70-0061-2738-8 AR
 SU23. Tape, Mylar, 2 Inch 70-0061-2739-6 AR

Safety Conditions

WARNING

Cleaning solvents are flammable and are hazardous to skin and eyes. Make sure there is sufficient ventilation. Keep ignition sources away. Prevent skin and eye contact. Failure to comply can result in injury or illness to personnel.

WARNING

Compounds are irritants to skin and eyes. Prevent skin and eye contact. Failure to comply can result in injury or illness to personnel.

WARNING

Personnel can fall while working on top of aircraft. Maintenance stand(s) must be put near aircraft where personnel are working. Failure to comply can result in injury to personnel.

CAUTION

Composite substrate can be cut during applied material removal/restoration. Applied material must be cut into carefully. Failure to comply can result in damage to aircraft.

CAUTION

Aircraft substrate materials can be removed during tape and surface material removal. Tapes and surface materials must be removed carefully. Failure to comply can result in damage to aircraft.

CAUTION

Leakage of solvents out of repair area can cause tape disbonds. Minimum quantity of solvent must be used in repair area. Failure to comply can result in damage to aircraft.

CAUTION

Heating tool can damage aircraft surface. If using heating tool to remove material, nozzle must be minimum of 3 inches from aircraft surface. Nozzle exhaust must be in constant side-to-side or circular motion. Failure to comply can result in damage to aircraft.

CAUTION

Aircraft performance can be affected by dents, scratches, or abrasions on aircraft surface. Protective cover must be used on walk areas during high volume traffic. Protective shoe coverings must be used at all other times. Sharp-edged tools must not be put on external surfaces. Failure to comply can result in damage to aircraft.

Procedure
Additional Information
Figure 1, Edge Seal Type II Top of Aircraft General Locator
Figure 2, Edge Seal Type III Top of Aircraft General Locator
Figure 3, Edge Seal Type II Bottom of Aircraft General Locator
Figure 4, Edge Seal Type III Bottom of Aircraft General Locator
Figure 5, Type 2 Seam (General Production Configuration) Intermediate
Locator
Figure 6, Type 2/3 Seam (Cover to Skin) Intermediate Locator
Figure 7, Type 2/3 Seam (Cover to Cover) Intermediate Locator
Figure 8, Type 2/3 Seam (Tape-to-Boot Transition) Intermediate Locator
Figure 9, Blade Seal (Taped) Intermediate Locator
Low Observable Material Identification (LOMI) - Description
NOTE
Environmental conditions should be maintained to prepare and apply Low Observable (LO) materials during repair.

1Inspect environmental conditions.
1.1 Inspect environmental temperature conditions in area of LO material repair with thermohygrometer. Make sure environmental temperature requirements are met for each LO material. Refer to LO Material Repair Cure

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Parameters - Description

1.2 Inspect relative humidity in area of LO material repair with thermohygrometer. Make sure relative humidity requirements are met for each LO material. Refer to LO Material Repair Cure Parameters - Description

1.3 Install localized enclosure and environmental control unit, if required.

1.4 Assemble maintainer fabricated enclosure, if required. Refer to Enclosure (Maintainer Fabricated) - Assemble

NOTE

Gloves must be worn to clean, prepare, and apply materials during repair. Clean gloves must be worn to touch clean surfaces. Surface must be cleaned again if surface becomes contaminated.

2 Prepare repair surface area.

2.1 If repair surface area has been prepared, go to Step 3. If repair surface area has not been prepared, go to Step

2.2 .NOTE Mylar tape is used to stop adjacent surface contamination.

2.2 Apply two-inch Mylar tape (1, Figure 10) to perimeter of repair surface area (2).NOTE when possible, splices should be made in material between fasteners. If fasteners cannot be avoided, splices should be made through center of fastener. Splice points should be aligned with nearest planform.

2.3 Layout splice points (1, Figure 11 Figure 12) on elastomeric tape with marker and protractor on repair surface area (2), if required. NOTE Factory elastomeric tape should be scored along edges to prevent damage to adjacent coatings in a rolling die cut method. Factory elastomeric tape should be cut from points of saw tooth inward to prevent damage to elastomeric coatings. 2.4 Score edge (2, Figure 13) of filled elastomeric coating adjacent to edge of elastomeric tape (1) with blunt rotary knife and ruler.

2.5 Adjust cutting depth on depth controlled cutter with small standard screwdriver. NOTE Depth controlled cutter should be adjusted to cut through scrim layer but not past adhesive layer or into backing material of scrap piece of elastomeric tape.

2.6 Make test cut on scrap of elastomeric tape on off-aircraft surface with depth controlled cutter to make sure correct depth of cut. NOTE Elastomeric tape should not be trimmed after installation using sharp blade and slice method, without depth control, as damage to substrate materials will result. If elastomeric tape requires final trim after installation, us depth-controlled cutter, blunt chisel blade, or blunt rotary knife in die cut or rolling die cut method.

2.7 Cut required splices into elastomeric tape (1, Figure 14) with depth-controlled cutter, blunt rotary knife, or blunt chisel blade and straightedge. WARNING Heat generating tools that output temperatures of more than 400 deg F are source of ignition in flammable environments. Heat generating tools must not be used in flammable environments. Failure to comply can result in injury or death to personnel and/or damage to aircraft and/or equipment.

WARNING

Fuel spills and leaks are hazardous. If fuel spill or leak occurs, all maintenance and/or servicing must stop and local procedures must be followed. Failure to comply can result in injury or death to personnel and/or damage to aircraft and/or equipment.

CAUTION

Heating tool can damage aircraft surface. If using heating tool to remove material, nozzle must be minimum of 3 inches from aircraft surface. Nozzle exhaust must be in constant side-to-side or circular motion. Failure to comply can result in damage to aircraft.

NOTE

When removing material, substrate materials can be easily damaged. Use care to ensure no additional damage occurs. Plastic or nonmetallic scraper should be used carefully to stop damage of underlying fillers and substrate materials. Elastomeric tape should be removed by lifting one edge or corner with a non-metallic or plastic scraper while peeling elastomeric tape back against itself, parallel to surface of access panel. Hot air tool may be used to assist removal.

2.8 Remove elastomeric tape (1) with nonmetallic or plastic scraper. Peel elastomeric tape (1) in rear direction against itself parallel to surface

(2). NOTE

Hot air tool may be used to assist removal. 2.9 Remove edge paste (2, Figure 15) with plastic or nonmetallic scraper, if applicable. NOTE Frayed or loose edges of fabric scrim layer of elastomeric tape should be removed or cut away. Elastomeric tape should not be trimmed after installation using sharp blade and slice method, without depth control, as damage to substrate materials will result. If elastomeric tape requires final trim after installation, use depth controlled cutter, blunt chisel blade, or blunt rotary knife in die cut or rolling die cut method.

2.10 Clean elastomeric tape adhesive and paste residues from surface with plastic or nonmetallic scraper and ultra fine abrasive pad moistened with isopropyl alcohol.

2.11 Inspect gap filler (3) for voids, loose, missing material, or other damage. Rework as necessary. Refer to one of two options: Perform non-conductive gap filler repair. Refer to Gap Filler, Non-Conductive Polythioether – Repair Perform conductive gap filler repair. Refer to Gap Filler (Conductive Polythioether) – Repair

2.12 Inspect fastener head filler (4) on fastener heads (6) and fastener head recesses (1) for voids, loose or missing material, or other damage on repair surface area. Rework as necessary. Refer to Fastener Filler (Hot Melt) - Repair (Hot Melt)

NOTE

Application of waterborne primer to nonconductive gap filler is optional.

2.13 Inspect waterborne epoxy primer (5) for voids, loose or missing material, or other damage on repair surface area. Rework as necessary. Refer to Coating (Waterborne Epoxy Primer) - Repair (Touchup)NOTE Flexible primer should be applied to conductive gap filler only. Flexible primer should not be applied to non-conductive gap filler.

2.14 Inspect flexible primer (4) for defects, dirt, lint or other damage. Rework as necessary. Refer to Coating (Flexible Primer) - Repair (Touchup)

2.15 Clean surface with wiping cloth moistened with isopropyl alcohol.

2.16 Wipe surface with clean dry wiping cloth. NOTE Elastomeric tape installation should reduce, as much as possible, the number of paste gaps. 3Apply elastomeric tape. NOTE Correct width roll stock of elastomeric tape should be selected to meet butt and edge gaps. Application tape or general purpose masking tape may be used in place of Mylar film and double coated tape.

3.1 Apply Mylar film (1, Figure 16) on repair surface (3) with double-coated tape (2).NOTE

Firm pressure should be applied on carpenter's pencil at bottom of step formed by adjacent material to trace elastomeric tape template pattern. Mylar film, application tape, or general purpose masking tape template will be used to cut elastomeric tape template pattern from elastomeric tape.

3.2 Make elastomeric tape template pattern (3) on Mylar film (1), application tape, or general purpose masking tape. NOTE Elastomeric tape form 2 should be replaced with elastomeric tape form 3 for insertion repair.

3.3 Apply template pattern (1, Figure 17) on elastomeric tape (2) with double-coated tape (3), if required. NOTE Straightedge should be placed on elastomeric tape stock and cut on unwanted side. Inner angles should be cut starting from inner angle and continue in outward direction.

3.4 Cut through center of elastomeric tape template pattern (1) on an off-aircraft surface with razor knife and straightedge.

3.5 Remove template material from elastomeric tape (2), if required.

3.6 Pre-fit elastomeric tape (4, Figure 18) on repair surface area (2).

3.7 Make sure elastomeric tape (4) butt and edge gaps (3) are 0.030 to 0.080 inch.

3.8 Make sure elastomeric tape (4) has peel-off backing material (5).

3.9 Apply elastomeric tape (4) on repair surface area (2) and hold in position with one-inch Mylar tape (1) on one end.

NOTE

Wrinkling and air entrapment of material should be avoided during elastomeric tape installation.

3.10 Lift opposite end of elastomeric tape (4).

3.11 Peel-off approximately two inches of backing material (5).

3.12 Fold backing material (5) below opposite end of elastomeric tape (4).

3.13 Install section of elastomeric tape (4) on repair surface area (2).

3.14 Remove one-inch Mylar tape (1) from secured section of repair surface area (2).

3.15 Peel-away remaining backing material (5).

3.16 Apply remaining elastomeric tape (4) on repair surface (2) with light hand pressure while maintaining even butt and edge gaps.

3.17 Make sure elastomeric tape area butt and edge gap (3) widths remain 0.030 to 0.080 inch.

NOTE

Minimum of two passes with roller or squeegee must be applied.

3.18 Apply flat, full, and firm pressure on elastomeric tape (4) with rubber roller or squeegee. NOTE Entrapped air must be removed during first 10 minutes of elastomeric tape installation. Rework of elastomeric tape installation will be required if elastomeric tape surface has bubbling greater than five percent of total repair area.

3.19 Inspect installed elastomeric tape (4) for air entrapment, wrinkles, creases, voids, and gouges.

3.20 Pierce bubbles with air release tool. Remove entrapped air with finger pressure or squeegee.

3.21 Cure elastomeric tape (4). Refer to LO Material Repair Cure Parameters – Description

NOTE

Repair paste can be applied before elastomeric tape is fully cured.

3.22 Apply repair paste compound into butt and edge gaps (1, Figure 19). Refer to Compound (Paste) - Repair (Paste) 4Apply flexible primer layer to repair paste surfaces, if required. Refer to Coating (Flexible Primer) - Repair (Touchup) 5Apply topcoat layer to repair paste surfaces, if required. Refer to Topcoat (Polyurethane) - Repair (Touchup) 6Remove localized enclosure and environmental control unit, if required.7Disassemble maintainer fabricated enclosure, if required. Refer to Enclosure (Maintainer Fabricated) - Disassemble8Record LO material repair area physical characteristics in Low Observable Defect Entry Module (LODEM). Refer to Low Observable Defect Entry Module (LODEM) Repair - Check

Follow-on Maintenance

Required Condition Data Module / Technical Publication
Remove protective pad set, if required. Protective Pad Set - Remove

End of Data Module

NOTES:

1. Remove crack damage, maintaining minimum radius of 0.09 inch.
2. Repair parts shall be the same type material and one gauge thicker than the original part; however, for material substitution, refer to Material Substitution (1.12.4) (51-02-04).
3. Standard fastener spacing shall be used when installing fasteners in areas where fasteners were not originally installed. Refer to Rivet Edge Distance and Spacing (1.13.6.1) (51-03-01) for spacing and edge distance requirements.
4. Before assembly, all bare metal surfaces shall be treated for corrosion protection in accordance with TO 1F-16( )-23.
5. If damaged part is in a fuel or pressurized area, the repair shall be sealed and tested for leaks. Refer to AIRFRAME SEALING (1.11) (51-01-00) or SECTION 3 (51-20-00).

a. Remove damaged area of part and, if required, replace with a filler of the same shape and material or the equivalent of built-up angles/plates.

b. Determine minimum number of fasteners required in each element of damaged part on each side of damage as follows:

(1) Determine gauge and type material of damaged part.
(2) Determine size and type of original fasteners installed. Replace removed fasteners with next larger size fastener, if practical. Refer to Fastener Requirements (1.13.4) (51-03-00).
(3) Determine number of fasteners required on each side of damage per cross-sectional inch of damaged part. Refer to Fastener Requirements (1.13.4) (51-03-00).
(4) Determine width of each element of damaged part to which repair part(s) is being attached.
(5) To determine minimum number of desired type and size fasteners required per element of damaged part on each side of damage, multiply each dimension obtained in 4.1.13 Step b(4) by number of fasteners obtained in 4.1.13 Step b(3).

c. Determine repair angle gauge(s) and fabricate repair angle(s) to requirements of 4.1.13 Step a and 4.1.13 Step b.
d. Assemble and clamp repair parts in position.
e. Lay out and drill fastener hole pattern to meet spacing and edge distance requirements. Refer to Rivet Edge Distance and Spacing (1.13.6.1) (51-03-01). Use existing fastener pattern when one exists.
f. Comply with all notes and limitations and install repair parts.

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14. ABSTRACT

The 2013 National Defense Authorization Act allows the Air Force Air Logistics Complexes (ALCs) to promote workers proficient in more than one trade by one pay grade. Multi-skilling is the term used to describe workers trained in more than one job. The United States Air Force wants to utilize multi-skilling at these ALCS, but the effects of implementation are still unknown. This research focuses on the identification of skill retention influences to better understand this multi-skilling through the conduction of a human subjects experiment at two Air Force bases. We examine the retention of aircraft mechanics' skill to evaluate the feasibility and consequences of initiating multi-skilling at the ALCS along with any traits correlating to higher levels of skill retentions.

15. SUBJECT TERMS

Multi-skilling, cross utilization, skill retention

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